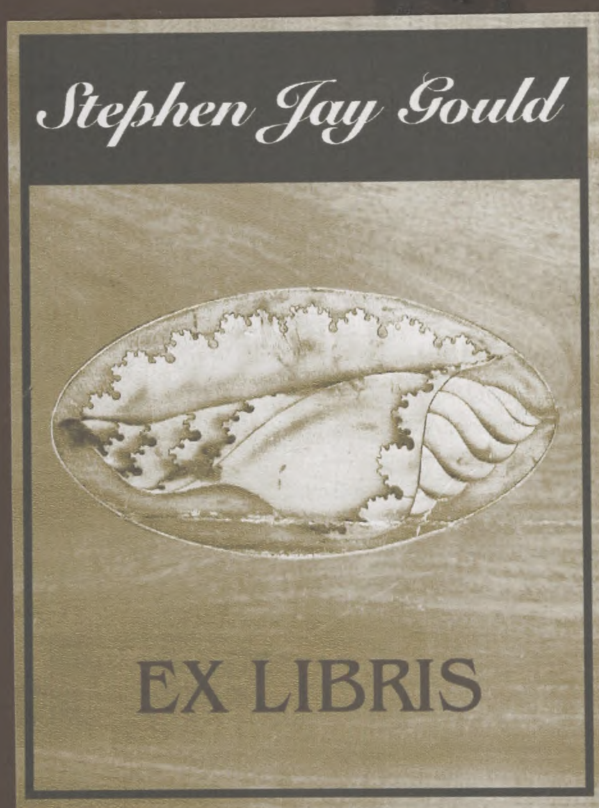
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TYPICAL FORMS

AND

SPECIAL ENDS IN CREATION.

BY

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The principles now fully explained and illustrated in this work were first brought before the public in an article on Typical Forms by Dr. McCosh in the "North British Review" for August, 1851. Mr. Hugh Miller wrote a lengthened notice of that article, describing it as :

"An article at once the most suggestive and ingenious which we have almost ever perused. The typology of Scripture has formed the subject of many a volume and many a discourse. It is one of the most obvious and rudimental truths of the theologian, that he who spoke in parable and allegory when he walked the earth in the flesh, spoke in his previous revelation ere he had yet put on the nature of man, by type and symbol; and that there is thus a palpable unity of style maintained between God in the Old and God in the New Testament. Nay, some of the profounder theologians went further than this; and works such as the "Analogy" of Butler may be regarded in one point of view as critical Essays, written to establish a yet further identity between the style of Deity in Revelation and in Nature. "All things are double one against another," said the wise son of Sirach; and the celebrated "Treatise" of the most philosophic of English bishops may be deemed simply an expansion of the idea. Butler set himself to seek in the natural world the "double" of the revelations of the spiritual one, and to argue from the existence and fitness of the natural type the authenticity and genuineness of the spiritual anti-type. Such, in short, seems to be the principle of his "Analogy." It has, however, been reserved for our own times, and hitherto at least for a class of men not much disposed to conciliate the assertors of the popular theology, whether at home or abroad—in Protestant or in Popish countries — to find in nature analogies which, though they themselves have failed to apply them, seem to reach further than even those of Butler; and which, we can have little doubt, will at no distant date form the staple facts of a department of theology still very meagerly represented in our literature, and intermediate in its place and character between the Natural Theology of the Philosophers and the Dogmatic Theology of the Divines. The article in the "North British" on Typical Forms is a vigorous contribution to this middle department of theology, which, like a central area left unbuilt in a street after the completion of the erections on both sides, seems so necessary to the union of the contiguous fabrics, and to the design of the whole; and all that its perusal leaves us to regret is, that its accomplished author, in whom the reader will, we believe, recognize a most original thinker—a man already well known in the ethical field, both in our own country and America—should not have expanded it into a volume. But in the special field which he has chosen he need not greatly fear a competitor. The subject is one, too, on which thought ripens slowly; for, like the agricultural produce of a new colony, it has all to be raised from the seed; and the deeply interesting, but comparatively brief article of the reviewer, will, we can not doubt, be yet expanded into a separate treatise, which will prove none the less fresh, and all the more solid, from the circumstance that it should have appeared as an article first."

Since the time when the article referred to was written, Dr. McCosh, in conjunction with Dr. Dickie, has been prosecuting the subject, and the two have laid a number of their scientific observations before various learned societies, such as the Botanical Society of Edinburg, the Natural History Society of Belfast, and the British Association for the Promotion of Science at its meetings in 1852 and 1854. Summaries of these have appeared in the Transactions of the Botanical Society of Edinburgh in the Annals of Natural History, in the proceedings of the British Association, and in the Edinburgh New Philosophical Journal. They were referred to by his Grace the Duke of Argyle, the President of the British Association, in his opening address in September last in the following language:

"In physiology, what is the meaning of that great law of adherence to type and pattern, standing behind, as it were, and in reserve, of that other law by which organic structures are specially adapted to special modes of life? What is the relation between these two laws; and can any light be cast upon it derived from the history of extinct forms, or from the conditions to which we find that existing forms are subject? In vegetable physiology do the same or similar laws prevail, or can we trace others, such as these on the relations between structure, form, and color, of which clear indications have already been established in communications lately made to this Association by Dr. McCosh and Dr. Dickie of Belfast."

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BOOK FIRST.

CHAPTER I.

NATURE OF THE ORDER PREVAILING IN THE MATERIAL WORLD.

SECT. I.—PRINCIPLES WHICH SEEM TO RUN THROUGH THE STRUCTURE OF THE COSMOS.

In taking an enlarged view of the constitution of the material universe, so far as it falls under our notice, it may be discovered that attention, at once extensive and minute, is paid to two great principles or methods of procedure. The one is the PRINCIPLE OF ORDER, or a General Plan, Pattern, or Type, to which every given object is made to conform with more or less precision. The other is the PRINCIPLE OF SPECIAL ADAPTATION, or Particular End, by which each object, while constructed after a general model, is, at the same time, accommodated to the situation which it has to occupy, and a purpose which it is intended to serve. These two principles are exhibited in not a few inorganic objects, and they meet in the structure of every plant and every animal.

These two principles are characteristic of intelligence; they must proceed from intelligence, and they are addressed to intelligence. They may both be discovered, though necessarily to a limited extent, in human workmanship. When circumstances admit, man delights to construct the instruments or utensils which are designed to serve a common purpose after a common plan, even when this is by no means essential to the immediate purpose to be served. Each particular piece of dress or article of furniture in a country is commonly fashioned after some general model, so that we are able to guess its use as soon as we cast our eyes upon it. That there is so much of this figure no way fitted to accomplish a special end, is evident from the circumstance that articles serving the same purpose take—in different ages and nations, and according to the fashion of the place or time—somewhat different forms, all of which are equally convenient. The farmer builds up his grain in stacks, which have all a like contour, and the merchant packs his goods in vessels of equal size and similar shape, or disposes of them in bales of equal weight. It is only when his possessions are so arranged that man can be said to have the command of them. Were his property not so disposed, were his grain gathered into heaps of all sizes and shapes, were his merchandise scattered in every corner of the apartment, the possessor would become bewildered in proportion to the profusion and variety of his wealth. When things are formed or arranged on some plan tacitly agreed on, man can recognize every object at a distance by its physiognomy, and determine its nature and its end without seeing it in use or operation.

There are still more frequent and obvious examples in the works of man of the principle of special adaptation. While there is a general regard, so far as it can be done without immediate inconvenience to the principle of order, there is a far more constant attention to the other principle. In some cases, indeed, little respect can be had to the general model; the sole end aimed at is the fitting of the instrument to the purpose which it is meant to serve. In nations low in the scale of civilization, and among persons who have to engage in a hard struggle to procure the necessaries of life, the general order is apt to be neglected in the exclusive regard which must be had to immediate utility. In such circumstances, individuals care little how an article be constructed, provided it serves its practical purpose. But as man's industrial treasures increase, and the number of separate works intended to accomplish similar ends are multiplied, he finds it becoming to institute some systematic arrangement among them, or devise some pattern after which to fashion them.

When hard necessity does not forbid, man feels a pleasure in constructing his works upon a general plan. Human intelligence delights to employ itself in forming such models. They seem to have a beauty to the eye, or rather to the mind, which contemplates them. If it is a basket that is to be woven, there will commonly be a regularity in the succession of the plaits, and an aiming after some ideal form in the shape of the whole. If it is a water-jug that is to be fashioned, there will be a general attention paid to symmetry; not unfrequently there will be graceful and waving lines in the figure which strikes the eye. The dwelling which the individual erects for his own special accommodation, will commonly be found to have a door, or some other prominent object, in the center, with a balancing of pillars, windows, or something else that fixes the attention, on the one side and the other. As man advances in the scale of civilization, and comes to have superfluous wealth and leisure, he pays an increasing attention to symmetry and ornament. In the urns which he makes to receive the ashes of the dead, in the temples erected by him in honor of the God whom he worships, there is a scrupulous regard had to proportion and outline. As wealth accumulates and taste is cultivated, the law of order and ornament comes to be valued for its own sake, and is followed in the construction of every house, and of every article of furniture in that house, in the setting of every jewel, and in the location of every ornament.

In most articles of human workmanship we may discover a greater or less attention to both of the principles to which we have referred. The farmer's stacks are all formed after a general mould, but we may observe a departure from it on either side to suit the quantity or quality of the grain. The merchant's shop seems to be regulated by forms or weights, but there is special form or average weight for every separate article. In some objects we see a greater regard to general plan, and in others to special purposes, and this according as persons wish to give a greater prominence at the time to ornament or to utility.

Now, if this world proceeds from intelligence, and if it is intended to be contemplated by intelligence, it is surely not unreasonable to suppose that there may be traces in it of the same two modes of procedure. In this treatise we hope to be able to show that there are abundant illustrations of both, by an induction reaching over all the kingdoms of nature, and extending even into the kingdoms of grace. Both will be found in the theology of nature to point to the same conclusion ; each furnishes its appropriate proof of the existence and wisdom of a Being who hath constructed every thing on a plan, and made it, at the same time, to serve a purpose. The one, as well as the other, will be found in the dispensations of God, in the kingdom of his Son, and point to a most interesting analogy between nature and revelation. It will be expedient to treat of them as so far different, which they really are, but it will be necessary, at the same time, to show, what is equally true, that the two principles are made to correspond the one to the other, that they meet in a higher unity, and that, after all, they are but two aspects—in many respects different indeed—of one Great Truth.*

In certain sections of this treatise it is proposed to unfold some of the more striking examples of General Plan. In respect of this order of facts, natural theology can now take a step in advance, in consequence of what has been done of late years in the discovery of homologies by the sciences of comparative anatomy and morphological botany. But the recent discoveries in regard to the homology of parts can never set aside the old doctrine of the teleology of parts, which affirms that every organ is adapted to a special end. Every organic object is constructed after a type, (τύπος,) and is, at the same time,

* In order to remove misapprehension, it may be necessary here to estimate how much truth there is in a statement of Professor Owen, who has done so much to illustrate the subject of general order. "By whatever means or instruments man aids or supersedes his natural locomotive organs, such instruments are adapted expressly and immediately to the end proposed. He does not fetter himself by the trammels of any common type of locomotive instrument, and increase his pains by having to adjust the parts and compensate their proportions so as best to perform the end required without deviating from the pattern previously laid down for all. There is no community of plan or structure between the boat and the balloon, between Stephenson's engine and Brunel's tunnelling machinery; a very remote analogy, if any, can be traced between the instruments devised by man to travel in the air and on the sea, through the earth or along its surface." (Owen on the Nature of Limbs, p. 9.) There is truth in the remark here made, but it seems to us to be overstated, and without the necessary corrections. Man does, in many cases, construct the works which are to serve a common end upon a common plan. There is a model structure for the boat, for the steam-engine, for our houses, and our temples, in which elegance is more or less attended to. But still it is to be admitted that the harmonies, the correspondences, the compensations, are far more numerous and beautiful, both in kind and degree, in the works of God than in the works of man. It is certain that the union of the two principles is not so frequently attended to in human as in Divine workmanship. Man is often obliged to sacrifice the one to the other, the symmetry to the convenience, or the utility to the ornament. It is only in the works of Deity that we find the two at all times in harmonious operation.

made to accomplish a final cause, (τέλος.) Throughout the next Book we purpose to exhibit the traces of General Order in one series of sections, and the traces of Special Adaptation in another series of sections, the two being made to run alongside of each other. While both will be illustrated, it will be seen, by our adopting this method, that the two are not contradictory, but coincident; that they do not cross, but run parallel to each other. The general conformity to a pattern will be seen to be all the more curious when contemplated in connection with certain singular deviations; while the special modifications will appear all the more wonderful when exhibited as a departure, and evidently an intentional departure, to effect a particular end, from a model usually attended to, nay, to some extent attended to, it may be, in the very structure which is thus modified. The designed irregularities will thus, by a legitimate reaction, show that the regularities are also designed; the exceptions in this case emphatically prove the rule. The nature of the eccentricities demonstrate that, after all, there is a center round which the revolution is performed; the deviations point to a disturbing influence also under the influence of law—in much the same way as the deviations of an old planet were shown by living astronomers to point to a previously undiscovered planetary body. The nature, the value, and the relation of the two principles, will thus come out to view more strikingly by comparison and contrast when they are placed in juxtaposition.

The arguments and illustrations adduced by British writers for the last age or two in behalf of the Divine existence, have been taken almost exclusively from the indications in nature of special adaptation of parts. Hence, when traces were discovered within the last age of a general pattern, which had no reference to the comfort of the animal or the functions of the particular plant, the discovery was represented by some as overturning the whole doctrine of final cause; not a few viewed the new doctrine with suspicion or alarm, as seemingly adverse to religion, while the great body of scientific men did not know what to make of its religious import. The question is thus started, Have not the writers on the theology of nature been of late most unnecessarily narrowing and restricting the argument? We have found it most interesting to notice that the philosophers of ancient Greece and Rome, and not a few of the earlier writers on the subject in our own country, gave it a much wider range, and reckoned that they had found evidence of the existence of God whenever they detected traces of order and ornament. Let us inquire what instruction we can gather on this subject from some of those great luminaries of the ancient world, which, like stars, send their light down to us through the wide space which intervenes, and serve, like them, to enlarge and rectify our ideas of magnitude, and to keep us from being unduly impressed with the greatness of the near and the present.

Plato, in the Fourth Book of the Laws, makes Clinias of Crete, in proving the existence of God from his works, appeal at once to the order and beauty of the universe, and does not regard it as at all necessary to dwell on minute instances of adaptation. He refers to the earth, the sun, and all the stars, and to the beautiful arrangement of the seasons, divided into months and years, as evidencing that there is a Divine Being.* In the review of the argument in the Twelfth Book, he repeats, that the orderly movements of the stars, and other objects,

* B. x. c. 9, where he also brings in the argument from universal consent.

prove that all things were arranged and adorned, not by matter or necessity, but according to a Divine forethought and will.* According to the sublime philosophy of Plato, all things are formed according to unalterable laws or types, which remain unchanged amidst the flux of individual objects, and that because they proceed from eternal ideas, which had been in or before the Divine mind from all eternity.

A similar style of argument is adopted in Cicero's Treatise on the Nature of the Gods, the most systematic work on natural theology which has been handed down to us from ancient times. The evidence adduced by Balbus the Stoic, the representative of theism in the dialogue by which the argument is conducted, is derived from four sources: first, from the presages of futurity by gifted men and oracles; secondly, from the number of things fit and useful; thirdly, from prodigies; fourthly, and highest of all, from the equable motions of the heavenly bodies, and from the beauty and order of the sun, moon, and stars, of which the very sight is sufficient to convince us that they are not fortuitous.† Throughout his defence, he dwells on the consenting and conspiring motions of the heavenly bodies, on their progressions and other movements, all constant and according to law; he points to the planets, which are regular in their very wanderings; and shews how, in all this, there is an order and a certain likeness to art.‡ When one observes, he says, their defined and equable motions, and all things proceeding in an appointed order, and by a regulated and unchangeable constancy, he is led to understand not only that there is an inhabitant in this celestial and divine dwelling, but a ruler or regulator, and, if we may so

* B. xiii. c. 13.

† Cic. De Nat. Deor., Lib. ii. c. v.

‡ Lib. ii. c. vii.; xx.; xxxii.

speak, architect of so great a work and gift.* He speaks of the harmony arising from dissimilar motions; and after quoting largely from the hymn of Aratus, he says, such order and ornament could not have proceeded from bodies running together hither and thither, and by accident.†

Plutarch derives men's general agreement as to the existence of God, from their observation of the constant order and motion of the stars.‡

In modern times, we have the same line of argument seized by the profound mind of Newton. Referring to the UNIFORMITY IN THE BODIES OF ANIMALS, he says, "It must necessarily be confessed that it has been effected by intelligence and counsel."§ Dr. Samuel Clarke quotes this language, and asks—"In all the greater species of animals, where was the necessity for the conformity we observe in the Number and Likeness of all their principal members?"‖

It is very evident that, down to a comparatively late date, writers on natural theism did not confine their proof to a mere adaptation of parts, but that along with this they introduced other considerations, and in particular, the prevalence of general order. It will not be difficult to defend the legitimacy of the conviction which the order and beauty of the universe have produced in unsophisticated minds in all ages. In this, as in many other instances, the philosopher will find it to be his delightful office, not to set aside the spontaneous beliefs of mankind, but rather to vindicate and illustrate them by the new discoveries which advancing science is ever opening.

* Cic. De Nat. Deor., Lib. ii. c. xxxv.
† Lib. ii. c. xliv.
‡ Plut. De Plac. i. 6.
§ Optics.
‖ Demonstration of Being and Attributes of God.

SECT. II.—ANALYSIS OF THE ORDER IN NATURE—LAWS OF NATURE.

The most careless observer is led to notice, that there is a beautiful regularity running through nature as a whole, and through every individual part of it. This was discovered in very early ages of the world's history, by persons who had no very precise ideas as to its nature, or the means by which it was produced. The Greeks, from the time of Pythagoras, embodied their impressions in the word by which they denoted the visible world, which they called Cosmos, to denote at once its order and its beauty, while the Latins styled the world Mundus, to express their sense of its surpassing loveliness. Ever since the time when the philosophic spirit was first awakened, reflecting minds have been speculating as to the sources of this order, and caught, at a very early age, glimpses of the truth. The philosophers of the Ionian School, which arose between 600 B.C. and 500 B.C., referred it to the power and the varied transformations of certain elements, which they did their best to classify, as air, water, earth, and fire, representing the dry, the moist, the solid, the ethereal. In the speculations of this school, we have vague anticipations of modern chemistry, and in particular, of the doctrine of polar forces, in the balanced strife and friendships of Empedocles, and of that of definite proportions, in the "homoiomera" or equal parts of Anaxagoras. A rival school arose at a little later date, among the Greeks in Italy, and ascribed the order of nature, in a more profound spirit, to the power of Numbers. We have no authentic or connected account of the system of the Pythagoreans, but it is evident, from the scattered notices which have been handed down to us, that they represented numbers, the significance of which is so clearly seen in music, as in some mysterious sense the principia of the universe. Aristotle tells us, that they considered existing things to be a copy of numbers,* and we have extracts preserved from the writings of some of the disciples of the school, describing numbers as being in the Divine Mind prior to the existence of things, as being used as a model (παράδειγμα) in the formation of objects, and as that by which all things were brought together and linked in order. Among the disciples of the same school, and others who arose at a subsequent date, there was supposed to be a deep meaning in forms; and the properties of certain figures, such as the triangle, the square, the parallelogram, the circle, the ellipse, were investigated with great care, giving us the science of geometry as the result. A very special interest gathered round certain numbers, such as seven and ten, and certain figures, such as the circle and triangle, which came in consequence to be regarded as perfect, or as sacred. From a still earlier date, and as a manifestation of the same intellectual propensity, peculiar feelings became associated with certain recurring times and periodical seasons, such as the revolutions of the moon, the signs of the zodiac, and other cycles, which seemed to have a deep significancy in the economy of nature. Democritus, who lived 400 B.C., and the Epicureans, who flourished at a later date, sought for the origin of this order in the formation of all things out of atoms possessed of definite forms. The sublime genius of Plato ascribed it to certain patterns after which all things were fashioned, which patterns he traced back to the eternal ideas of the Divine Mind. Aristotle, while correcting some of the extravagances of his great master, clung resolutely to the doctrine, that forms were as necessary as matter to

* Μίμησιν εἶναι τα ὄντα τῶν ἀριθμῶν.—Metaph. of Aris.

the construction of the universe. The Platonists of the Alexandrian School literally revelled among numbers and forms, till they lost themselves among their intricacies and windings. The Platonizing Jew who wrote the Book of Wisdom, caught for a moment a very clear glimpse of the full truth, when he speaks of God "having arranged all things in measure, number, and weight."*

Early science, like youth, is ardent, is eager, and not having as yet determined either its strength or its weakness, it would attempt every work, and works far beyond its capacity. Like the giants of the early world, it is ambitious, and would heap Ossa on Pelion, and mount to heaven, not by gradual and numerous steps, but by one old bold and presumptuous effort. In following this method of speculation, the sage—as he meditates on the banks of the Euphrates or Nile, along which an early civilisation had sprung up, or in the cities of Miletus, Elea, or Athens, in which the human spirit was sharpened by discussion and the love of enterprise —makes many a shrewd guess; he anticipates not a few truths which later discovery confirms; he awakens a spirit of inquiry which craves for a more accurate mode of procedure; and if he does not settle, he at least starts questions which must sooner or later be settled. But his attempt, though characterized by enlargement of vision and power of vaticination, is, in respect of scientific strictness and certainty of result, a failure, and the favourite dogma of one school is ever disputed by the disciples of another school. It turns out that the work which one man or one school has attempted, needs, in order to its completion, the combined industry of many investigators continued through long successive ages.

* Πάντα μέτρῳ καὶ ἀριθμῶ καὶ αταθμῷ διατάξας.

For just as when society makes progress there is a necessity for the division of manual labour, (as Adam Smith has shewn in the opening chapter of the Wealth of Nations,) so, in order to the advance of science, there is need of a division of intellectual labour. Most important of all, there arises, in the midst of the jealousies of rival schools and the noise of fruitless disputations, a demand for a surer, even though it should be a slower, method of investigation,—a method which will give results, be they many or be they few, which are not of the nature of ingenious speculations, to be set aside by other ingenious speculations, but ascertained truths, fixed for ever, and which all inquirers who come after may use, to help them to add to the accumulating stores of knowledge. It is late in the history of the world before such a plan comes to be systematically unfolded ; and it is to the glory of our country, a glory not exceeded even by that of the land which produced Plato and Aristotle, that the first exposition of it was by Lord Bacon. Since his days, scientific inquirers, according to their tastes, talents, and position, have betaken them each to his own field of investigation, with the view of thoroughly exploring it ; and as the grand result, we have a settled body of truth, to which additions will be made from age to age.

But as the deeply-underlying and prompting cause of all this intellectual activity, there is still the same craving desire to find out the means by which unity and order are given to the great Cosmos. In these days we speak of all things being governed by laws ; we lay it down as a maxim, that the end of all science is the discovery of law. The language may be more correct than that employed by the ancients, but it is far from being definite or incapable of misinterpretation. For the question occurs, What is meant by laws in this application of the term? Every one sees that, as thus used, it does not mean the same thing as when we speak of the laws of a country, of the moral law, or of the law of God. It is a term with which we cannot dispense, but it is far from being unambiguous; it is often used in an unlawful sense, and at times it is turned to the worst of purposes, as when it is supposed, that in referring an event to a law of nature, we have placed it beyond the dominion of God. When we speak of things being arranged in a law, or falling out according to a law, we signify, if we know what we mean, that all phenomena take place in a regular manner, that is, according to a rule.* It is the special office of each science to discover what the nature of the law is in its own department. This is the grand aim, so far as it has a grand aim, of all modern physical investigation,—to determine the rule to which the particular classes of objects under contemplation accommodate themselves. But in very proportion as the sciences have become subdivided and narrowed to particular facts, is there a desire waxing stronger, among minds of larger view, to have the light which they have scattered collected into a focus. As the special sciences advance, the old question, which has been from the beginning, will anew and anew be started,—What is the general meaning of the laws which reign throughout the visible world? A correct and adequate answer to this wide question can be given only by a wide induction, and a combination of the results gained by a vast number of separate sciences, each conducted on its own principles. We live in the expectation of the approach of a time when science—the division of labour having fulfilled its ends—shall seek to combine its individual truths, and to

* See a more minute analysis of the laws of nature in the Method of the Divine Government, Physical and Moral, B. ii. c. 1.

realize the dream of its youth, and, as it were, carry us to a mountain top, whence we may obtain not only a scattered view of the separate parts, but a connected view of the whole, and of the relative bearing and direction of every part. It appears to us that we are approaching the time when an answer may be given to the old question, and that this must be something like the following: —All things in this world are subordinated to law, and this law is just the order established in nature by Him who made nature, and is an order in respect of such qualities as NUMBER, TIME, COLOUR, and FORM. We use the vague languages of such qualities, because science has not arrived at such a stage as to enable it to determine what these qualities are with anything like perfect certainty and precision.*

Every law of nature which can be said to be correctly ascertained is certainly of this description. We shall furnish abundant illustrations in the next Book of this treatise; in this section we are merely to collect a few striking examples of the attention paid to each of the qualities named, and thus prepare the way for entering upon the separate sciences, when more systematic proof will be offered.

First, THERE IS AN ORDER IN NATURE IN RESPECT OF NUMBER.—This important truth, long believed in before it could plead any scientific evidence in its favour, was established and brought into prominence when Kepler unfolded the three laws which have formed, historically, the foundation of modern astronomy. It was

* A more scientific classification would probably give us active property instead of colour, and including colour. There is a curious combination of active properties constituting individual objects, and enabling us to classify them, which will be referred to in B. iii. c. 1 & 2, but which cannot be fully cleared up till we know more of the latent forces of nature.

the confident expectation that there would be found some such principle of order which led that ingenious and persevering sage to make calculation upon calculation, and devise one hypothesis after another, till, after nineteen unsuccessful attempts, his fine genius and his industry were rewarded by the discovery of the true laws of the planetary movements. These laws are,—that the planets move in orbits, which are elliptical in shape; that if you draw a line from the planet to the sun, the areas described by that line in its motion round the sun are proportional to the times employed in the motion; and that the squares of the periodic times are as the cubes of the distances. The first of these is a law of forms, the other two are laws of numbers. The discoveries of Kepler prepared the way for the still more important ones of Sir Isaac Newton. When the immortal work of this greatest of inductive philosophers was published, it was seen that the laws of Kepler were not original but derivative; but the original law now unfolded belonged to the same class; for the law of gravitation, the best established and the most universally operative law yet determined, is a law of numbers. Turning to chemistry, we find that ever since it emerged as a science there has been a constantly renewed attempt to reduce its laws to a numerical expression. The only laws which can be reckoned as certainly determined in this science possess this character. The great law which lies at the basis of all the compositions and decompositions of substances, is that of definite proportions for equivalents, as expounded by Dalton. In the same science Gay Lussac discovered an arithmetical law, regulating the combination of gaseous substances, which unite in very simple proportions, according to volumes. Lest it should be thought that we are making a fanciful reduction of the operations of nature, we are happy to be able to bring to our aid the name of Sir John Herschel. "Chemistry," says he, "is, in a most pre-eminent degree, a science of quantity, and to enumerate the discoveries which have risen from it from the mere determination of weights and measures, would be nearly to give a synopsis of this branch of knowledge. We need only mention the law of definite proportions which fixes the composition of every body in nature in determinate proportional weights of its ingredients. *Indeed, it is a character of all the higher laws of nature to assume the form of a precise quantitative statement.* Thus the law of gravitation, the most universal truth at which the human reason has yet arrived, expresses not merely the general fact of the mutual attraction of all matter, not merely the vague statement that its influence decreases as the distance increases, but the exact numerical rate at which that increase takes place, so that when the amount is known at any one distance it may be calculated exactly for any other."* Similar language is used by Humboldt:—"The progress of modern physical science is especially characterized by the attainment and the rectification of the mean values of certain quantities by means of the processes of weighing and measuring. And it may be said that the only remaining and widely diffused hieroglyphic characters still in our writing—numbers, appear to us again as powers of the cosmos, although in a wider sense than that applied to them by the Italian school."†

In looking at other departments of nature, we find similar examples of numerical order. Thus, ten is the typical number of the fingers and toes of man, and,

* Herschel's Natural Philosophy, Art. 116.
† Cosmos, translated by Ottó, vol. i. p. 64.

indeed, of the digits of all vertebrate animals. It is also a curious, though perhaps not very significant circumstance, that in mammalia seven is the number of vertebræ in the neck,* and this whether it be long as in the giraffe, or short as in the elephant, whether it be flexible as in the camel, or firm as in the whale. In the vegetable kingdom we find that two is the prevailing number in the lowest division of plants, the acrogenous or flowerless; thus, 2, 4, 8, 16, 32, 64, &c., are the number of teeth in the mouth of the capsule in mosses. Three, or multiples of three, is the typical number of the next class of plants, the monocotyledonous or endogenous; and five, with its multiples, is the prevailing number in the highest class, the dicotyledonous or exogenous plants. We shall shew, as we advance, that a curious series, 1, 2, 3, 5, 8, 13, 21, 34, &c., in which any two numbers added together give the succeeding one, regulates the arrangement of the leaf appendages of plants generally, and in particular of the leaves and the scales on the cones of firs and pines. In the inflorescence of the plant we find that the outer organs, or sepals, always alternate with the petals which are next them, and that the whorl of organs further in, namely, the stamens, is generally either the same in number as the petals, or some multiple of them. When there is an exception to this rule there is reason to believe that there has been some abortion of the stamens; and the traces of this abortion are not unfrequently visible in the rudiments of the organs undeveloped.

Secondly, There is an Order in Nature in respect of Time.—It is obvious that all such laws can be expressed in proportional numbers, taking some fixed time

* Apparent or real exceptions will be referred to afterwards.

as a unit. But we are here introduced to a new fundamental power, deserving of being put under a separate head. For the laws of which we are now to speak imply a peculiar arrangement in reference to time. We see the principle most strikingly exhibited in those movements of natural objects which are periodical. No doubt, there is some disposition of physical forces necessary to produce this periodicity; but this just shews all the more clearly that an arrangement has been made to produce the regularity. The ancients were much struck with the order in respect of time of the celestial motions. The stars, the planets, and even the comets, were seen to perform their revolutions in certain fixed times. Some of them seem to depart from this rule only to exemplify it the more strikingly, for their irregularities, which are periodical, are as methodical as their more uniform movements. There have been regular epochs, to all appearance, in the changes on the earth's surface, and in the succession of plants and animals, as disclosed by geological science. The variations of magnetism on the earth's surface seem to be periodical, and attempts have been made of late to connect this cycle with that which the spots of the sun are known to follow. There is a beautiful progression, as shewn by the science of embryology in the growth of the young animal in the womb, and the whole life of every living creature is for an allotted period. The plants of the earth have their seasons for springing up, for coming to maturity, and bearing flowers and seeds; and if this order is seriously interfered with, the plant will sooner or later be incapable of fulfilling its function. Thus the hyacinth may be prematurely hastened into flower for one season, but the next year it will be found impossible to make it flower or produce seed. In this way great natural events, and especially the life of animals and plants, the movements of the heavenly bodies, and the eras of geology, become to us the measurers of time, rearing up prominent landmarks to guide us as we would make excursions into the past or future, and dividing it for our benefit into days and months, and seasons, and years, and epochs.

Thirdly, THERE IS AN ORDER IN RESPECT OF COLOUR RUNNING THROUGH NATURE.—Colour is not without its significance among the works of man. Every nation, every regiment has its distinctive colours upon its flags, which are its visible symbols and representatives. Colour appears as a peculiar mark on the stamps impressed by the post-office, and on many of our public conveyances. It is used as a signal by sea and by land, in our ships and on our railways; it announces danger and proclaims safety. It has also, we are convinced, a meaning in nature. It has been far too generally supposed that colour obeys no laws in natural objects. It has been a very common impression, that it is spread indiscriminately over the surface of earth and sky, animal and plant. We are sure that further research will shew that this is a mistake. It is true that colour has not so much value as form and structure in the classification of plants and animals. Still, we find that some tribes of algæ are arranged by Harvey according to their colours, and that some fungi are classified by Berkeley according to the colours of their minute seeds. We are convinced that, amidst all the apparent irregularities, there will be found to be some fixed principles in the distribution of colours in the animal and vegetable kingdoms, and, indeed, over the whole surface of nature. Seldom or never, for example, are the two primary colours, blue and red, found on the same organ, or in contact on the same plant.

Liable to certain modifications, which are limited, it is probable that there is a fixed distribution of colour for many families of animals and plants, and that this distribution is fixed within still narrower limits for the species. It is certain, whether we are or are not able to seize it, and turn it to any scientific or practical purpose, that there are plan and system in the arrangement of colours throughout both the animal and vegetable worlds. Every dot in the flower comes in at the proper place, every tint and shade and hue is in accordance with all that is contiguous to it. We shall shew at considerable length as we proceed, that the distribution of colours in the vegetable kingdom is in beautiful accordance with the now established laws of harmonious, and especially of complementary colours. We shall likewise point out some very curious and interesting relations between the forms and colours of plants. The eye testifies, too, that there is an order in respect of colour in the decorations of insects, in the spots and stripes of wild beasts, and in the plumage of birds. "He who," says Field, "can regard nature with the intelligent eye of the colourist, has a boundless source of never-ceasing gratification arising from harmonies and accordances which are lost to the untutored eye."

Fourthly, THERE IS AN ORDER IN NATURE IN RESPECT OF FORM.—We use the word form in a large sense, and as including not only figure, in the narrow sense of the term, but structure, which is the relation or connexion of forms. Great attention is evidently paid to this quality in the construction of natural objects. It appears before us as a significant element in every department of nature. The planets, with their satellites, have a definite spheroidal shape, and they move in orbits which have a certain outline in space, namely, the elliptic. It is because strict regard is paid to this principle in the structure of the universe, that the science which treats of forms, that is, geometry, admits of an application to so many of the objects and arrangements of nature. And here it is worthy of being noted that the ancient geometers, from a general idea of the importance of forms, had carefully investigated the properties of those figures called the Conic Sections, (because capable of being produced by sections of the cone,) at a time when no very important application could be made of the propositions established by them. When Kepler discovered that the planets moved in elliptic orbits, the properties of the ellipse, unfolded so many centuries before by Apollonius and others, were ready to be applied to the solution of a host of important questions connected with the movements of the celestial bodies. It is instructive to notice that the clusters of stars revealed by telescopes of great power, shew regular forms, some of them being round, and a number of them having apparently a spiral tendency.

In the mineral kingdom, we find forms playing an important part. In circumstances admitting of the operation, most (if not all) minerals crystallize—that is, assume regular forms. These forms are mathematically exact in a variety of ways. Every perfect crystal is bounded by plane surfaces, its sides are parallel to each other, and the angles made by its sides are invariable. Each mineral assumes certain crystalline forms, and no others. These forms have now an important place allotted to them in the classification of minerals. They have been expressively designated the geometry of nature.

But it is among organized objects that we find form assuming the highest significance. Every living object composed though it be of a number, commonly a vast number and complication of parts, takes, as a whole, a definite shape, and there is likewise a normal shape for each of its organs. The general or normal form which any particular tribe of plants or animals assumes, is called its type. Animals and vegetables, it is well known, are classified according to type; and they can be so arranged, because types are really found in nature, and are not the mere creation of human reason or fancy. It is because attention is paid to type, and because it is so fixed and universal, that it is possible to arrange into groups the innumerable natural objects by which we are surrounded. Without some such principles of unity to guide him, man would have felt himself lost, as in a forest, among the works of God, and this because of their very multiplicity and variety. In some cases the forms assumed by organic objects are mathematically regular. A series of beautiful rhomboidal figures, with definite angles, may be observed on the surface of the cones of pines and firs. It may be noticed, too, how the leaves and branches of the plant are placed round the axis in sets of spirals. The spiral structure is also very evident both in the turbinated and discoid shells of molluscs. Mr. Mosely has shewn that the size of the whorls, and the distance between contiguous whorls, in these shells, follow a geometrical progression; and the spiral formed is the logarithmic, of which it is a property, that it has everywhere the same geometrical curvature, and is the only curve, except the circle, which possesses this property. Following this law, the animal winds its dwelling in a uniform direction through the space round its axis. "There is traced," says Mr. Mosely, "in the shell, the application of properties of a geometric curve to a mechanical purpose, by Him who metes the dimensions of space, and stretches out the forms of matter according to the rules of a perfect geometry."* We are reminded of the ancient Platonic maxim, that Deity proceeds by geometry.

The lower tribes of animals and plants often assume mathematically regular forms, such as the triangular, polygonal, cylindrical, spherical, and elliptical. It is seldom, however, that we meet with such rigid mathematical figures in the outline of the higher orders of organic beings. Those who have any sense of beauty will be grateful that trees are not triangular, that animals are not circular in their outline ; in short, that they have not taken any such painfully exact shape. Still, the forms of organic objects—such as the sweep of the veins of leaves and the outline of trees—though more flowing and waving, are evidently regular curves. There is truth, we suspect, in a favourite maxim of Oersted, "that inorganic beings constitute the elementary, and organic the higher geometry of nature."

Besides the typical resemblances which enable us to classify plants and animals, and the beautiful curves which do so gratify the contemplative intellect, there are certain correspondences in the structure of organs which seem to us to be especially illustrative of a plan intelligently devised and systematically pursued. At an early date, these struck the attention of persons addicted to deep reflection, but it is only within these few years that they have been scientifically investigated and expounded. Aristotle noticed the correspondence between the hands of man, the fore-limbs of mammals, and the wings of birds, and between the limbs of these animals and the fins of fishes, and spoke of it as an interesting species of

* See Philosophical Transactions for 1838.

† Soul of Nature, Horner's translations, p. 343

analogy, (καὶ' ἀναλόγιαν.) The profound mind of Newton used to muse upon the symmetry of the animal frame: "Similiter posita omnia in omnibus fere animalibus." These correspondences, so far as vertebrate and certain portions of invertebrate animals are concerned, have now been examined with great care, and we have a set of well-defined phrases to explain them.

A *homologue* is defined as the same organ in different animals, under every variety of form and function. Thus the arms and feet of man, the fore and hind feet of quadrupeds, the wings and feet of birds, and the fins of fishes, are said to be all homologous.

The corresponding or serially repeated parts in the same animal are called *homotypes.* Thus the fingers and toes of man, indeed the fore and hind limbs of vertebrate animals generally, are said to be homotypal.

The phrase *analogue* has been reserved for another curious correspondence, found both in the animal and vegetable kingdoms. By an analogue is meant an organ in one animal having the same function as a different organ in a different animal. The difference between homologue and analogue may be illustrated by the wing of a bird and that of a butterfly; as the two totally differ in anatomical structure, they cannot be said to be homologous, but they are analogous in function, since they both serve for flight.*

These phrases, and the ideas on which they are founded, have taken their rise from the animal kingdom. But similar, though by no means identical, correspondences have been detected in the vegetable kingdom. The branch of botanical science which treats of the forms of plants is called morphology, and is now regarded as the

* See Owen on Homologies of Vertebrate Skeleton, p. 7; and Agassiz and Gould's Comparative Physiology, p. 5, where the terms are affinities and analogues.

fundamental department of botany. We shall shew, as we proceed, that comparative anatomy and vegetable morphology supply illustrations, at once copious and striking, of an all-prevailing order in nature in respect of form or structure.

As this order of facts comes before us, we shall see that science, in its latest advances, is fulfilling some of the anticipations of large-minded observers and deep thinkers, who, in earlier and unsophisticated times, looked upon nature with a fresh eye, and believed in the existence of a profound plan in it, when they were not able to give a scientific reason for their conviction. Systematic research is only coming up in these later years to the native beliefs and expectations which sages entertained from the beginning. But there are these important differences between the early glimpses and the later discoveries:—that what was at first guess and vaticination, has become demonstration; that what was at first a mixture of fact and speculation has become, by the inductive methods of weighing and measuring every phenomenon, unadulterated truth; and we may add, that the realities disclosed by science far transcend in grandeur and true dignity the loftiest musings of the profoundest sages or the most brilliant speculators.

It is to be regretted that the recent discoveries as to a harmony of structure running through the whole organic kingdoms have been turned by some to improper purposes. The famous German poet, Goethe, who did so much by his doctrine that all the appendages of the plant are leaves, or transformed leaves, (he should have said, formed after the same model as the leaf,) to found a scientific botany, has not defined his religious creed (we rather think he could not define it); but it is evident that he was by no means inclined to look upon nature as the work of a personal God. The celebrated French comparative anatomist, Geoffroy St. Hilaire, who laboured so effectually to prove that there is a unity of composition in the animal structure, unfortunately (though no atheist) speaks in a contemptuous manner of final cause.* Lorenz Oken, who propounded the idea that the skull is a vertebrate column, (he should have said that the skull is formed after the same model as the back-bone,) was a pantheist, and sought, in a mystical rhapsodical manner, to find the beginnings of existence and of life without calling in a living or a personal God.† Yet the ideas which these men expounded, after being first denied and then modified and improved, have received the all but universal consent of scientific inquirers. Admitted, as they now are, among the established generalizations of science, and constituting, as they do, the most brilliant discoveries in natural history of the past age, they cannot be overlooked in a natural theology suited to the middle of the nineteenth century. If they are hostile—as we believe they are not—to the cause of religion, then let their exact force and bearing be measured ; and if they are favourable to theology, natural and revealed,—as we hope to be able to shew that they are, when properly interpreted,—then they require from their number and value, to have a very prominent place allotted to them. We have here a class of phenomena to which Paley has never once alluded in his Natural Theology, and which are referred to only in an incidental manner, and without their meaning being apprehended, in one or two passages of the Bridgewater Treatises.‡ The authors of

* See Vie, Travaux, et Doctrine Scientifique d'E. Geoffroy St. Hilaire, par son Fils, c. ix.

† See Physio-Philosophy, *passim*.

‡ Dr. M'Cosh attempted this in an article in the North British Review, for August 851, of which this treatise may be considered as an expansion.

these works are not to be blamed for this omission, for in their day the facts had not been discovered, or, at least, admitted into acknowledged science. But now that they have taken their place, and that a very high place, among settled doctrines, it is time to examine their religious import and tendency. They will be found not to be isolated or exceptional in their character, but to belong to a large and wide-spread class, possessing a deep theological signification.

It is not pretended that these facts do of themselves prove that there is a living and personal God, clothed with every perfection. But they are fitted to deliver us from several painful and degrading notions, which may be suggested by the human heart in times of unbelief, or by persons who have been lost in a labyrinth built by themselves, and who are not unwilling that others should become as bewildered as they are. They prevent us from feeling that we, and all things else, are the mere sport of chance, ever changing its procedure, without reason and without notice, or, what is still more dreadful, that we may be crushed beneath the chariot wheels of a stern and relentless fate, moving on without design and without end. They shew us what certainly looks very like a method pursued diligently and systematically—very like a plan designed for some grand end, so very like it that it behoves the sceptic to take upon himself the burden of demonstrating that it can be anything else. Taken along with their proper complement, the special adaptation of parts, they exhibit to us an enlarged wisdom, which prosecutes its plans methodically, combined with a minute care, which provides for every object and every part of that object. Conjoined with higher considerations, and, in particular, with certain internal principles, which have the sanction of the very constitution of our minds,* they disclose to our faith a God who sees the end from the beginning, and who hath from the first instituted the plan to which all individual things and events have ever since been conformed. These objects so regularly constructed, and modes of procedure so systematic, fill the mind, and prepare us, if they do no more, to wait for the disclosure of a loving being who may fill the heart. For the intellect is not satisfied with contemplating, unless the heart be at the same time satisfied with loving. It is the grand mistake of not a few gifted men, in these latter ages when physical nature is so much studied, to imagine that the order and loveliness of the universe, its forces, its mechanism, its laws, its well-fitted proportions, will of themselves satisfy the soul. It will be found that all these, however fondly dwelt on, must, in the end, leave the same melancholy and disappointed feeling as the sight of a noble mansion doomed to remain for ever tenantless—unless they lead on to love, and such love as can only be felt towards a living and loving God.

* See article on Theistic Argument, in Appendix to Method of Divine Government, fourth edition.

CHAPTER II.

NATURE OF THE SPECIAL ADJUSTMENTS.

SECT. I.—NEED OF SPECIAL ADJUSTMENTS IN ORDER TO THE BENEFICENT OPERATION OF THE FORCES OF NATURE.

"ORDER is Heaven's first law," and the second is like unto it, that everything serves an end. This is the sum of all science. These are the two mites, even all that she hath, which she throws into the treasury of the Lord; and as she does so in faith, Eternal Wisdom looks on and commends the deed. As the separate physical sciences advance, they will necessitate the rise of combining sciences to collect their separate truths; and this they may best be able to do under the two heads of order and special end. The science which treats of a certain important department of the first of these has already a suitable name allotted to it, and is called Homology. But we need a word to embrace the whole, and we propose that this be Cosmology—that is, the Science of the Order in the Universe. We are aware that this term has been unfortunately devoted to an unattainable inquiry, which would penetrate into the origin of worlds; but this makes us the more anxious to rescue so excellent a phrase from so degraded a use, and give it a profitable application. The other general science has already an admirable name appropriated to it in Teleology, or the Science of Special Ends.

Physical science, at its present advanced stage, seems to be at one with the Word of God, in representing all nature as in a state of constant change, but with principles of order instituted in order to secure its stability. "ONE GENERATION PASSETH AWAY, AND ANOTHER GENERATION COMETH: BUT THE EARTH ABIDETH FOR EVER. THE SUN ALSO ARISETH, AND THE SUN GOETH DOWN, AND HASTETH TO HIS PLACE WHERE HE AROSE. THE WIND GOETH TOWARD THE SOUTH, AND TURNETH ABOUT UNTO THE NORTH; IT WHIRLETH ABOUT CONTINUALLY, AND THE WIND RETURNETH AGAIN ACCORDING TO HIS CIRCUITS. ALL THE RIVERS RUN INTO THE SEA: YET THE SEA IS NOT FULL; UNTO THE PLACE FROM WHENCE THE RIVERS COME, THITHER THEY RETURN AGAIN. ALL THINGS ARE FULL OF LABOUR; MAN CANNOT UTTER IT: THE EYE IS NOT SATISFIED WITH SEEING, NOR THE EAR FILLED WITH HEARING." There seems to be no such thing as absolute rest in nature. We are impressed with the fickleness of the winds and the restlessness of the waves; but the truth is, every other object is infected with the same love of change. There is probably no one body in precisely the same state in every respect for two successive instants. We think that we are stationary, but, in fact, we are being swept through space at a rate which it dizzies the imagination to contemplate. Every object in nature seems to have a work to do, and it lingers not, as it moves on, in the execution of its office. It exists in one state and in one place this instant, but it is changing meanwhile, and next instant it is found in another state or in another place. But there is an equilibrium established among these ever moving forces, and the processes of nature are made like the wind, to return according to their circuits.

So far as inductive science has been able to penetrate, it would appear that the active physical powers of the universe consist of a number of forces, or rather, we should say, properties, each with its own tendency or rule of action, and yet all intimately connected the one with the other, that is, correlated. I wave my hand in the air, and in doing so, I set mechanical power a-working. "The motion," says Mr. Grove, "which has apparently ceased, is taken up by the air, from the air by the walls of the room, &c., and so, by direct and reacting waves, continually comminuted but never destroyed."* The production of mechanical power may be more distinctly seen if the hand is employed to move a machine. Mechanical power, it is well known, generates heat, and this heat, according to Mr. Joule, is in proportion to the mechanical power exercised. Heat may lead to chemical action, as when bodies are decomposed by a rise in the temperature. Chemical action is always accompanied by electricity, and electricity may produce light or galvanism or magnetism. Galvanism, again, may have an effect on nervous or muscular action, and muscular action may produce mechanical power. Thus we have the various known (or rather, perhaps we should say, unknown) forces producing or exciting each other, according to laws which have not yet been fully determined. Nay, if we turn in upon the organism itself we shall find traces of a similar circuit. For whence the muscular action that originated the actions which we have mentioned? Tracing it inwards, we find it conducting us to the nerves and the brain. But the brain is not an inexhaustible, nor is it a self-filled fountain of physical power; on the contrary, if exercised in excess it becomes deranged in all its functions, or exhausted. In order to restoration of power, it needs, as every one knows, nightly rest, and also sustenance; and, on inquiring into the source of this suste-

* Grove's Correlation of Physical Forces, 2d edit., p. 17.

nance, we find that it is derived from without, from animals and plants. Again, animals are fed by other animals and by plants, and plants by unorganized matter. The circuits are thus made to include all physical powers, organic and inorganic. All these forces, distinct from each other, (so far as we know,) but intimately correlated, are made to balance each other, and to run in circles.*

We have introduced these generalized facts, which are independent of all speculations as to the nature of the physical forces, for the purpose of shewing that these natural powers are all blind in themselves, and require an arrangement to be made—and this arrangement must proceed from intelligence—in order to their beneficial action. Heat, light, electric action, chemical composition and decomposition, organic affection—these are among the most powerful instruments of good in our world, but they become the most potent means of inflicting evil. In their bearings towards animate objects capable of pleasure and pain, they may all be benignant, but they also spread misery and destruction. There is obvious need of a disposing mind to cause these various forces to act in harmony, and to issue in wise and benevolent results. "Elements," says Faraday, "the most seemingly unmanageable and discordant, are made to watch like ministering angels around us—each performing tranquilly its destined function, moving through all

* It is to be specially noticed, however, that there has been a power here exercised which is not thus dependent on the others. We refer to the mental power which willed the bodily action. The oldest definition of mind represents it as essentially a self-moving power. We must ever set ourselves against the idea maintained by some, that mental power is correlated to the physical and vital forces, as these are correlated to each other. We never can believe that the devotedness of the patriot, the self-sacrificing spirit of the martyr, or the heroism which resists bribe and temptation, are capable of being excited by heat, light, and magnetism, in the same way as these can be excited by each other. But still it is true that mind, we mean the human mind, can merely direct physical force: it cannot create or originate it, it can merely turn it this way or that; but the power exists prior to any mental effort being directed towards it, and when it is set a-working, by the needful conditions being supplied, it follows it own laws.

the varying phases of decomposition, decay, and death—then springing into new life, assuming new forms, resting in passive inactivity, or assuming the extreme of violence, according as either may be suited to accomplish the appointed end."*

It will be necessary at this place to state an important distinction which Dr. Chalmers had the merit of introducing into natural theology in a formal manner.† He calls on us to notice how, the laws of matter being as they are, the results might have been different if a different set of collocations had been made of the bodies obeying these laws. Thus the law of gravitation still being as it is, the planetary bodies would have been moving in a very different manner from what they do, had they been differently situated in reference to the sun and to one another. Had they not, for example, revolved in nearly one plane, they might in their revolutions have come into violent and destructive collision with each other. This is prevented by their being so disposed that their spheres can never intersect each other, that is, by their skilful collocation. Dr. Chalmers thinks that the argument in favour of the existence of God should be founded on the collocations of matter rather than the laws of matter.

The distinction is undoubtedly a sound one. In all discussions as to the material universe, we must set out with assuming the existence of body occupying space and exercising force, or rather active property. Now, it may be admitted that it is doubtful, to say the least of

* Faraday's Lectures on Non-Metallic Elements.

† Reference had no doubt been made to it before, as when Paley (Nat. Theol., c. iii.) says, "I speak not of the laws themselves, but such laws being fixed, the construction in both cases is adapted to them." But we owe the systematic announcement and exposition of it to the eminent Christian philosopher we have named. It is developed with his usual amplitude of illustration in his Bridgewater Treatise and in his Natural Theology. A distinguished living writer who has done much towards introducing clearness into the logic of physical science, has adopted it, and made some new applications of it. See Mill's Logic, vol. i. p. 529, 2d edit.

it, whether we are entitled to argue that the mere extension of matter, that is, the circumstance that it occupies space, implies that it has been created. It might be further allowed, without any prejudice to the argument in behalf of the Divine existence, that the mere possession of active properties does not prove, in a manner convincing to every one, that matter has been formed by an intelligent being. The opponent, whether inclined to materialism or pantheism, might urge that in contemplating the material world merely as exercising force and capable of motion, we are not imperatively called to suppose anything else than that power, be it a material thing, or be it a spiritual thing (as the pantheist maintains), resides in the bodily substance itself. The argument of the pantheist, as against the materialist, would no doubt be overwhelming in such a case. The pantheist would be able to shew without difficulty that in the exercise of chemical, electric, luminiferous, calorific, and vital force, there is vastly more than mere extension or dead matter, and this he would call spiritual power. But all this does not tend to prove that this spiritual power (so called) is of the nature of Intelligence, compassing an end by means employed for the purpose. When we have established on other grounds, the existence of a Divine or even of a spiritual being, it might then be reasonably maintained that these physical powers, which have been shewn of late years to be more wonderful than men ever supposed them to be before, are not independent of the Divine Power, but are rather one of the expressions of it. But when we are proving the being of a God, it might not be prudent to peril the whole argument on the principle that the exercise of active power implies an intelligent and a personal God. It might be safer, to say the least of it, to argue the existence of Intelligence, not from matter considered simply as extended or as possessed of force, but from the material universe as it actually presents itself, with its graceful forms, its lovely colours, its skilful adjustments, and harmonious laws. There are questions agitated in the present day in regard to the precise nature of the physical forces which strict inductive science is not yet prepared to settle, and there have been questions started as to the potency of matter in itself, which, in our opinion, the human intellect cannot very satisfactorily answer, and which may at least be answered in more than one way by different parties, with views and principles all equally favourable to religion.

It seems more than probable that the very original properties of matter, whatever they be, have a rule, a law, so constituted as to suit them admirably to the purposes to be served by them in the universe. But this cannot be conclusively demonstrated till we have reached the ultimate properties of matter; and we are not certain that we have found any one of the original forces of nature. The law of universal gravitation and the law of chemical affinity might seem to approach the nearest to simple and unresolvable powers; but the illustrious discoverer of gravitation did not look upon it as an essential or ultimate property of matter, and Dalton represented chemical proportions as resulting from the size of the elementary atoms, and in the present day an eminent scientific man has proposed to resolve gravitation into a simpler property with a collocation suited to it; while chemists generally are by no means inclined to affirm dogmatically that we know the original power from which the phenomena of the combination of bodies proceed. Were we at liberty to assume that these are ultimate properties, it might not be difficult to shew that there is a beautiful correspondence between the law of gravitation and the mundane system through which it operates, and between the relations of the various chemical equivalents. But as we are not sure that we have gone down to the fundamental properties of matter, all that we can argue is, that if the adaptations do not consist in the adjustment of the original law to the objects, they must consist in the adjustment of the objects to that law. The truth seems to be, that they consist in the adjustment of the one to the other by Him who instituted both.

But by no process can we get rid of these original adjustments. There is need, as Mr. J. S. Mill says, not only of a law of causation, but of a collocation of causes, and this collocation he shews "cannot be reduced to any law," that is, any natural law. With him, therefore, it is an ultimate fact of which he can make nothing. "We not only," he says,* "do not know of any reason why the sun's attraction and the tangential force co-exist in the exact proportion they do, but we can trace no coincidence between it and the proportions in which any other elementary powers in the universe are intermingled." But this we can clearly perceive, that if these proportions and coincidences had been different, there would have been confusion throughout the universe; that if the centripetal force had been proportionally greater, the earth and all the planets would have been drawn into the body of the sun; and that if the centrifugal force had been much increased, the earth would have wandered into regions so far from the sun that all living beings must have perished. The beauty and fitness of these coincidences and proportions compel us to see, that though they do not proceed from natural law, they must proceed from an Intelligence planning all things, and the relations of things, from the beginning.

* Mill's Logic, vol. ii. p. 44.

Taking these principles along with us, we are entitled to say that mutual adjustments are necessary in order not only to individual effects of a beneficent character, but also to those general results of an orderly description, which are very commonly and very properly called laws of nature. We call the general facts observed by Kepler laws, but they are evidently the result of the relation of the planets to the sun, and of their centripetal to their centrifugal tendency. We talk of the law of the plant according to which it springs up, assumes certain forms, bears leaves and seed; but every one sees that we have here a complex effect proceeding from a vast number of arrangements, in which the laws of vitality, whatever they be, with the laws of moisture, heat, light, and electricity, are all made to act in unison. It seems to be a law of the appendages of the plant, of branches, leaves, and scales, that they are arranged in a spiral manner round the axis; but no one looks on this as a simple law; it is obviously the result of certain methodical dispositions. We suspect that most of what we call laws of nature, that most of the principles of order observable in nature, are of this compound or derivative character. They are the harmonious result of adjustments many and varied among a vast number of bodies and of forces, which, in our present state of knowledge, we must regard as different from each other, and which at least require adaptations to be constituted in order to their operation in a beneficent manner.

If these remarks be just, we are entitled to argue, that there has been adaptation not only in two or more bodies being so arranged as to produce an isolated effect of a benign character, but also in their being so disposed as to produce general laws or general results, these being wide-spread and continuous, stretching through extensive regions of space, and prolonged through many successive ages, such as the seasons, and the regular forms and periods of plants and animals. These—indeed all the principles of order in respect of number, time, colour, and form—are entitled to be called laws. But they are not original, they are derivative laws, not simple but composite, and the result of arrangements. We are thus enabled to connect the principle of order with the principle of special adaptation ; for it is required in order to the existence of general order, that there should be adaptation upon adaptation, and these necessarily of a most ingenious and far-reaching character.* We shall have occasion to return, as we proceed, to this subject, as serving to combine general law and special use in a higher unity.

SECT. II.—THE ADJUSTMENTS ARE DESIGNED, AND NOT CASUAL. NATURE OF CHANCE.

The argument from design in behalf of the Divine existence, has sometimes been so stated as to make its main premiss a mere truism, and the whole argument a begging of the question. It sets out with the maxim, that whatever exhibits marks of design must have proceeded from a designing mind ; but by exhibiting marks of design, is meant proceeding from a designing mind, and thus the whole ratiocination is nothing but the pompous repetition of the same proposition. When put

* As the arrangements needful are not only very numerous but very varied, it is proposed that the word adaptation or adjustment should be substituted for collocation—a phrase which seems to confine the arrangements to those of place, whereas they may also include time, number, active property, &c. As these adjustments are necessary even to the production of those uniform results which we call laws of nature, the proper distinction is not between the laws of matter and the collocation of matter, but between the properties of matter and the adjustments required in order to their beneficent act on. See Method of Divine Government, Book II. chap. i. sect. ii. and iii., 4th edit.

in this way, the argument is easily repelled and turned against him who urges it. But it is not thus that it has been propounded by any skilful defender of religion.

The argument from final cause, properly understood, is derived from those concurrences and correspondences of agents to produce a given end, which everywhere fall under our notice. These mutual adaptations of different and independent powers are so numerous, so curious, and so beneficent, that they clearly shew that there has been an Intelligent Being arranging them beforehand. They cannot proceed from chance, and we therefore conclude that they must proceed from design.

And this leads us to inquire what is meant by the word Chance, what is usually meant by it, and what is the proper meaning of the phrase. A thousand errors have been lurking in the confused ideas afloat on this subject, and we must be allowed to say that we have seldom found the nature of chance thoroughly expounded, or the various meanings of the word distinctly stated. The ancient atheists argued that there was such a thing as chance, and ascribed to it the formation of the universe. Modern materialists and pantheists maintain that there is no such thing as chance, that there can be no such thing, and thence argue that there can be no traces of design, since all things proceed from a chain of physical or metaphysical causes. We are convinced that the one as well as the other of these parties is mistaken. We mean to shew, in opposition to the modern, that there is such a thing as chance, and, in opposition to the ancient, that there are adjustments in nature which cannot proceed from chance.

In maintaining, however, that there is really such a thing as chance, it is proper to announce that there cannot be chance in this sense, that there is an event without a cause. It is not necessary in the present day to institute any proof of this ; there is no principle more firmly established or more universally admitted. There may be a difference of opinion as to the nature of cause and effect, and a still greater diversity of view as to the nature of the belief in causation, whether it is derived from internal or external sources, but there is none as to the law or the fact itself. It is admitted that in our world no event happens without a cause. In this sense chance does not exist. "There is no such thing as chance," says Hume. Some would say that it cannot so much as be conceived to exist.

But still there are senses, and these most important senses, in which there may be said to be chance in our world. The word chance, and the corresponding words accident, casualty, fortuity, may be used, and have an intelligible meaning when used in *two different senses.*

First, To use the language of Professor De Morgan, "the word chance, in the acceptation of probability, refers to events of which the law or purpose is not visible ;" and elsewhere, "events *do* happen by chance, for they certainly do happen so that we can see no reason why they should not have been otherwise."* In this sense, whether looking forward to the future, ever dimly seen, or to the present or the past as so far unknown, we may speak of chance, that is, of events of which we do not see the cause or purpose. As thus used, however, the word is significant merely of our ignorance, or rather of the necessary limits set to our knowledge. In this sense it can have no application to the Divine mind, which is ever cognizant, of the antecedents and consequents, of the intention and the issue, of all that has occurred, or that is occurring, or that will occur. As thus employed, the

* De Morgan on Probability, p. 23; and Theory of Probabilities in Ency. Metrop.

word can have no place for or against us in the argument which we are now advancing. The limit of our knowledge cannot settle the question as to whether the adjustments in nature are or are not designed.

Secondly, Things may be said to be casually related to *each other when the relation between them is not that of cause and effect, nor designed by the person producing them.* Every event has a cause, but every event is not causally connected with every other which may happen about the same time or place, or have some relation to it of property or number. This part of the truth is expressed by Mr. J. S. Mill,—"Facts causally conjoined are separately the effects of causes, and therefore of laws, but of different causes, and causes not connected by any law. It is incorrect, then, to say, that any phenomenon is produced by chance; but we may say that two or more phenomena are conjoined by chance, meaning that they are in no way related through causation, that they are neither cause and effect, nor effects of the same cause, nor effects of causes between which there subsists any law of co-existence, nor even effects of the same original law of collocation."* The meaning of the phrase, "law of collocation," and the use to which it may be turned in the theistic argument, as pointing to a designed adjustment in the original constitution of things, have already been noticed.

So much, then, for casual as distinguished from causal connexion. But casual connexion may also be opposed to contrived connexion. It is needful to illustrate this, for it is a position of great importance in our argument. An agriculturist, let us suppose, is using the means necessary to secure a crop from his ground. Every step which he takes must have a causal connexion with something going before and something coming after; to this

* Mill's Logic, Book III. chap. xvii.

there can be no exceptions whatsoever. But among the many agencies he sets a-moving there will be some which have no discoverable mutual relation, while there will be others which very visibly have such a relation, which, we would have it observed, may either be casual or designed. Thus it may be by accident that he began to plough the land on the same day as he did the previous year; by chance that the two horses in a particular plough are of the same age; that his harrows, constructed by different makers, are painted the same colour; that the workmen employed by him have the same Christian name; and that he has precisely the same extent of land in crop as in the previous year. There may be many such relations and correspondences which persons of a particular turn of mind find pleasure in noticing, and this because they are purely casual. But there are other connexions which are not of this fortuitous character. It is not by accident that he begins his work about the same season as he did the previous year; that he has put two horses into his plough; that the ploughing has been followed by sowing and harrowing; that he has workmen engaged in tilling his ground, and a certain portion of his whole ground under cultivation. There is here an evident distinction between two sets of events, and this distinction does not arise from the one class having causes, whereas the others have not, nor from the two proceeding from altogether unconnected laws of collocation, but from the one being designed as a mean toward an end, and the other not being so designed, as having no reference to that end. This distinction between the concurrence of independent means intended to produce an end, and mere coincidences which promote no special end, is an all-important one in the argument from design or final cause.

According to these views we cannot speak of an event being produced by chance. Such language has either no meaning, or a meaning opposed to the universally acknowledged principles of all science and all philosophy. In respect of causal connexion, chance has and can have no place; it is absolutely excluded. But in respect of other connexions of co-existence or succession, of number and property, there is room for chance, and, as opposed to chance, of designed coincidences and correspondences, and a co-operation of associated means for the production of a given end. In respect of production there can be no such thing as chance, but in respect of disposition there may. There are mutual relations which are not designed, even as there are relations which are designed. We cannot speak of accidental *occurrences*, but we may speak of accidental *concurrences*. We are to shew that in the place where there is room for chance, there we have the most striking examples of design.

It may be difficult at times to determine whether certain events or phenomena are conjoined by chance, or whether an arrangement has been made to produce the conjunction. It is no proof of an intended connexion that they have been conjoined once or twice, or a few times. Nor can any absolute rule be laid down as to frequency of co-existence, which shall decide every supposable case that may arise. But there are cases of designed concurrence so clear that they do not admit of a moment's hesitation. When we see independent agents all moving towards one end—when we see stone, lime, wood, glass, slate, and lead, all combined in a house—when we find various kinds of metals, and wheels, pulleys, cylinders, of various shapes and sizes, conjoined to produce a machine, we at once say the connexion cannot be accidental, but is the result of arrangements made to secure a contemplated end.

Let us suppose that, on entering a room, we discover on a table before us five or six balls formed into a ring-like figure, we do not allow ourselves for one instant to imagine that the balls came hither of their own accord, and without any one placing them there; but it may be a question whether the mutual arrangements involved in the figure are accidental or designed. This question would at once be settled if we saw other five balls on the same table formed into a similar figure. We would then acknowledge at once that there can be as little of accident in the mutual arrangement of the balls as in their being brought to this particular place.

These distinctions and explanations enable us to bring out very distinctly the nature of the argument derived from adaptation of parts in favour of the existence of God.

In physical nature we have the universal reign of causation, or every event connected with at least one other event as its cause, and yet another event as its consequence. In regard to this point there is no difference of opinion. But in perfect consistency with this doctrine we may find a number of events occurring at the same time or place, or nearly at the same time or place, or having some sort of bearing towards each other of a purely accidental character. In this sense there is no doubt much of chance in this world, that is, many events have some sort of discoverable relation, which may yet have no intended connexion. The year in which a comet blazes in the heavens may be a year of famine or of fearful wars and intestine feuds, but this does not go to prove that the one was meant to forebode the other. We are quite willing to admit that all these phenomena can be traced up to God—we are sure that God foreordained both the comet and the famine; but it is quite a different thing to affirm that the two have a designed connexion with each other. Every scar upon the rocks of our earth may have been produced by causes set in operation by God, but this will not convince us that there is deep design on the part of God in presenting to us, here and there, on these rocks, a figure, which men discover to bear a rude resemblance to the face of George III., of Nelson, or Napoleon Bonaparte. The fact that there are accidental concurrences, in the sense now explained, will not be urged, by any one who seriously reflects upon the subject, as proving this world is not the product of design, and that there is not design in every department of it. In the works of man which exhibit the clearest signs of contrivance, it is not found that every one part of the work has an intended relation to every other. In the construction of the walls of a church there may be the most careful attention implied in the way in which the stones are made to fit into each other, but it may all the while be purely accidental that two stones of much the same size, weight, or colour, are placed exactly opposite each other.

But wherever there may be chance, there may surely be design likewise. If there may be coincidences which are casual, there may also be concurrences which are contemplated. It is in the very place where there might be accident that we discover the clearest and most convincing evidences of design. Upon observing a number of separate forces acting in union and harmony, we must believe that there has been a designing mind bringing them together and causing them to co-operate. When we see these agencies working in happiest association to produce innumerable effects of a beneficent character—when we find them consenting and consorting throughout thousands or myriads of years or geological ages, the evidence is felt to be overwhelming beyond the power of human calculation. Yet this is the sort of conjunctions and co-operations which is constantly presenting itself to our view. We observe everywhere a host of separate bodies and powers, all tending towards a particular end;—say a number of material substances with the vital agency, the heat agency, the light agency, the electric agency, all conspiring to the production of a living plant or animal; or bone, nerves, and muscles, meeting to give an easy motion to a limb. "How often," asks Tillotson, "might a man, after he had jumbled a set of letters in a bag, fling them out upon the ground before they would fall into an exact poem, yea, or so much as make a good discourse in prose? And may not a little book be as easily made by chance as this great volume of the world? How long might a man be sprinkling colours upon canvas, with a careless hand, before they would happen to make the exact picture of a man? And is a man easier made by chance than this picture? How long might twenty thousand blind men, which should be sent out from the several remote parts of England, wander up and down before they would all meet upon Salisbury Plains, and fall into rank and file in the exact order of an army? And yet this is much more easy to be imagined than that the innumerable blind parts of matter should rendezvous themselves into a world."

We have the mathematical theory on this subject, with a most important application, laid down by an eminent living mathematician. After stating that when we have a question of pure numbers we can absolutely try the question with chance in precisely the same manner in natural theology as we try it in the common affairs of life, Professor De Morgan thus proceeds:*—"Let us

* De Morgan's Essay on Probability, p. 25.

assume, as we must, that a number produced by chance alone, (in the anti-deistical sense of the word,) might as well have been any other as what it is. And further, let us require, before we grant intelligence and contrivance, not merely the presence of an adaptation, which would have been unlikely from chance alone, but two such phenomena perfectly distinct from each other considered as phenomena, each of which might have existed without the other, and both tending to the same object, which would have been defeated by the absence of either. Let it be also granted, to fix our ideas, that we admit as proved a proposition which has a hundred million to one in its favour. This being premised, and laying it down as our object to shew that the necessary result of the theory of probabilities lead to the conclusion that the existence of contrivance is made at least as certain, by *means of it*, as any other result which can come from it, we proceed to state a consequence. The action of the planets upon each other, and that of the sun upon all, (the most certain law of the universe,) would not produce a permanent system, unless certain other conditions were fulfilled which do not necessarily follow from the law of attraction. The latter might have existed without the former, or the former without the latter, for anything we know to the contrary.* Two of these conditions are, that the orbital motions must be all in the same direction, and also that the inclinations of the planes of these orbits must not be considerable. Granting a planetary system, which is what ours is in every respect, except either of these two, and it is mathematically shewn that

* An important note is here appended:—"The only way in which we can guess any two things to be independent. It must be remembered as a result of the theory, that of things perfectly unknown, the probability of their coming to act, when known, against an argument is counterbalanced by the equal probability of the future discovery being on the other side."

such a system must go to ruin; its planets would not preserve their distances from the sun. Neither of these phenomena can be shewn to depend necessarily on the other, or on any law which regulates the system in general. For anything we know to the contrary, then, they are distinct and independent circumstances of the organization of the whole. Now, let us see what are the phenomena in question.

"1. All the eleven planets yet discovered" [that is, when the work was written] "move in one direction round the sun. 2. Taking one of them (the earth) as a standard, the sum of all the angles made by the planes of the orbits of the remaining ten, with the plane of the earth's orbit, is less than a right angle, whereas it might by possibility have been ten right angles.

"Now, it will hereafter be shewn that causes are likely or unlikely, just in the same proportion that it is likely or unlikely that observed events should follow from them. The most probable cause is that from which the observed event could most easily have arisen. Taking it, then, as certain that the preceding phenomena would have followed from design, if such had existed, seeing that they are absolutely necessary, *ceteris manentibus*, to the maintenance of a system which that design, if it exist, actually has organized, we proceed to inquire what prospect there would have been of such a concurrence of circumstances if a state of chance had been the only antecedent. With regard to the sameness of the directions, either of which might have been from west to east, or from east to west, the case is precisely similar to the following:—There is a lottery containing black and white balls, from each drawing of which it is as likely a black ball shall arise as a white one, what is the chance of drawing eleven balls all white?—Answer, 2047 to one against it. With regard to the other question, our position is this :—There is a lottery containing an infinite number of counters, marked with all possible different angles less than a right angle, in such a manner that any angle is as likely to be drawn as another, so that in 10 drawings the sum of the angles drawn may be anything under 10 right angles. Now, what is the chance of ten drawings giving collectively less than one right angle ?—Answer, 10,000,000 to one against it. Now, what is the chance of both these events coming together ? —Answer, more than 20,000,000,000 to one against it. It is consequently of the same degree of probability that there has been something at work which is not chance in the formation of the solar system. And the preceding does not involve a line of argument addressed to our perception of beauty or utility, but one which is applied every day, numerically or not, to the common business of life."

We have quoted this passage mainly for the mathematical principles which it unfolds. Since the treatise was written a great number of small planets have been discovered. These all run in the same direction as the planets previously discovered, and so add enormously to the weight of the argument. It is true that the inclination of some of them is considerable, but their mass is so diminutive that this circumstance is not fitted to produce any permanent disturbance.*

This is the argument from "Final Cause," as it is commonly called. At the same time we are inclined to

* See Herschel's "Outlines of Astronomy," p. 453. Should it be said all these conditions can be accounted for by the hypothesis of the cooling and shrinking of a rotating mass of heated cosmical matter, the answer is, that in order to the production of a world like ours out of such matter, there is need of a whole host of adjustments or collocations. This subject will be formally taken up in the chapter of next Book which treats of the Adjustments of Celestial Phenomena.

look upon the phrase as rather an unhappy one. The word, according to the all but invariable usage of our tongue, points to that which has efficiency; and there is nothing of the nature of power implied in the great class of facts which we are now advancing. In this branch of investigation we are contemplating not so much a cause, as an end aimed at, by a combination of means, by a concurrence of causes. The science which treats of the relation of means and ends has an unexceptionable name applied to it, and is called teleology. It would serve several important ends to have an equally good phrase to denote the class of facts which it is the business of that science to explore. As "typos" and "cosmos" have been naturalized into our language, we wish that some high authority would introduce "telos" likewise. In the absence of any such authorized phrase we shall be obliged to employ final cause, or, in lieu of it, such terms as aim and purpose, end and special end. We are to shew that throughout the whole of nature there is a union and co-operation of means for the production of what are evidently ends, and such special ends as argue a living being arranging the means in order to their accomplishment.

It is not necessary, in order to the conclusiveness of such an argument, that we should be able to say that we have discovered the *ultimate* end aimed at in all these concurrences of means to produce anterior or intermediate ends. There are persons who seek to cloak the hideousness of their atheism under the guise of an affected humility, urging it is not for them to be so presumptuous as to pretend to detect the purposes of Deity. And there might have been some plausibility in this pretext, provided it had been necessary, in order to the validity of the argument, to determine the grand ultimate design of creation. But it is by no means requisite in order to prove the existence of design that we should be able to fathom all the depths of the Divine counsels, and settle what is the last end of the Creator's work. On seeing Napoleon Bonaparte gathering his army to a given point—on finding one battalion coming from one province and other battalions collecting from other provinces, distant from the first and from each other, persons would have been entitled to conclude that these were means, and well-devised means, to an end, and this though entirely ignorant of the ultimate purpose to be effected by the subordinate ends; it would be enough for them that they discovered the immediate end and the means employed to accomplish it. On precisely the same grounds are we justified in maintaining that we observe in nature a singular combination of means towards the production of an end. This end may not be the final end of creation, but still it is an end—a subordinate end, aimed at by a combination of means arranged by intelligence. Nor can this inference be at all affected by the circumstance that these ends are commonly found to be means towards some other and a higher end. In God's works all the means are ends, and all the ends are means, and all means and subordinate ends are obviously concurring towards a final consummation, which man can not fully compass, but which he has abundant reason—from the tendency of the inferior ends—to regard as at once grand and beneficent.

The argument advanced under this head seems a complete one in itself. It does not require in order to its conclusiveness that it should be proven that this world has had a beginning, nor to look to any physical facts except those adduced in the premises. The adjustment of the bodies and forces of nature so as to produce harmonious and useful results, is in itself a proof of an arrangement not casual but planned by intelligence. We require not, in order to its conclusiveness, to specify the time when the adjustments were constituted, nor to shew that God has created matter as well as arranged it, nor even so much as that matter has had a beginning. These other truths may be established more satisfactorily after it has been demonstrated, from the design manifested in the universe, that there is a God the author of the design.

The force of the argument now adduced is not to be turned aside by going back in the chain of causation, and shewing how each of the combined circumstances, which form this means towards an end, has proceeded from a cause. We are not to discard final causes, as Laplace used to do so summarily, as soon as the physical cause of the individual circumstance is pointed out. Nor are we, with Kant, to lay down the principle that we are at liberty to call in final cause only when mechanical cause fails to account for each particular fact. The argument which we adduce in favour of final cause is derived from the wonderful combination of physical causes. It is freely admitted, that in the material universe every phenomenon has had a cause, but this does not weaken the argument founded on the correspondence between a number of associated phenomena, proceeding from different and independent causes. No doubt it forces us to acknowledge that there has been a correspondence in the causes producing such concordant results, but in carrying us back thus far it only opens up larger views of the wisdom and foresight involved in a plan which contemplated such far-reaching consequences. In Divine workmanship, as also in the higher kinds of human workmanship, order and utility are commonly produced by a long previously arranged consortment of means or causes. For example, the crop which the cultivated ground yields is the result of a vast number of preparations, human and Divine too, made long before. It is the peculiarity of the Divine workmanship that we can see in it a set of causes so ordered that they can produce a series or succession of orderly and benign results going on from age to age. The plants and animals now on the earth have all proceeded from progenitors created many thousand years ago, and which were so constituted as to produce an offspring after their kind. To argue from the succession of such effects that they are not designed, is to make the very beauty and perfection of the work a proof that it has not proceeded from an intelligent being.

Nor is the force of the argument to be weakened by the attempt to discover an alleged contradiction; if everything, it is said, comes from God, there can be nothing casual, there is no room for chance, and therefore no room for design as distinguished from chance. Now, it is at once admitted that every physical occurrence may be regarded as proceeding from God; at this point, that is, in regard to the production of the event, there is no room for accident. But while every event comes from God, this does not prove that the coincidences between every two events were designed by Him to produce a specific end. God has no doubt appointed both the eclipse and plague which may have happened the same year, but this does not prove that He designed the one dark event to foreshadow the other. As there may be casual relations in nature, so there may be, so there are, in nature designed concurrences, as distinguished from accidental coincidences. All that is now occurring is doubtless the result of collocations previously made, and in tracing it back we must come to certain original collocations. At this point physical research stops, but all inquiry is not arrested. The mind asks, whence this systematic collocation of agents and forces which has produced such good and useful results for thousands, or it may be, millions of years? The present so full of order carries us back to the past as also full of order, and shews that the system now in operation had been planned from the beginning.

Still less is the force of the argument to be evaded by the miserable subterfuge of certain French materialists, who tell us that this consorting of means and end is the mere condition of existence. When it is found, for example, that certain independent members of carnivorous animals are in admirable harmony, the limbs for running after the prey, the claws for seizing it, the muscles for keeping hold of it, the teeth for tearing it, and the stomach for digesting it, an attempt is made to avoid the force of the appeal by urging that these are the conditions of the existence of the animal. True, we reply, but the argument is derived from the circumstance that these independent conditions should meet so as to enable the animal to exist and to enjoy existence. He who brings in the principle of the conditions of existence will find it, if legitimately followed out, landing him in a designing intelligence no less certainly than the principle of final cause does. The argument, whether for or against theism, is not to be made to depend on a word or the shifting of a word. It is not to be established on the one side by a verbal sophism about design implying a designer, but neither is its overwhelming force to be turned aside by changing the word final cause for conditions of existence. It seems that conditions are necessary to certain existences, and it is the concurrence of these conditions, proceeding from various and independent quarters, which proves so irresistibly that there must have been design in their arrangement and collocation.

SECT. III.—THE OBVIOUSNESS AND COMPLETENESS OF THE SPECIAL ADAPTATIONS.

The argument from adaptation to a particular end is one which addresses itself to every human being. It is suited to every intellect, and comes home to every man's experience.

1. Every manual labourer may see something analogous to the art by which he earns his livelihood operating among the natural objects by which he is surrounded.

The sailor may discover the peculiarities of his craft among marine animals. Thus, among the lower tribes, he has observed a jelly-fish—called by him the Portuguese man-of-war—setting up a sail which consists of a crest surmounting the bladder. He may notice, too, how the mussel and pinna anchor themselves by means of threads of a horny material. The tail of the fish, it is well known, acts as a scuttle, enabling its possessor to plough its way through the deep. The web-foot of the swimmers is an example of what is called "feathering the oar;" when advanced forward the web and toes collapse; the leg (usually so called) of the gillemot and divers is compressed laterally, presenting a knife edge before and behind, and thus gives resistance in the fore and back stroke. It is also worthy of being mentioned, as illustrating the same point, that the whale's tail collapses in the upward but expands in the downward stroke.

The fisher, as he prepares the bladder to make the edges of his net float on the water, may observe that the sea-weed is buoyed on the surface of the deep by a contrivance more ingenious than his own, that is, by vesicles which act as floats. Most fishes have one or more bladders filled with air, the amount of which is regulated by the will of the animal, so that it can vary its depth, sink or rise to the surface, as may suit its purposes. The fisher, too, may see that if he has nets to catch the food needful for his sustenance, so also have spiders and other species of animals.

The shepherd knows how much care and watchfulness are necessary in order to protect his flocks from the wild beasts which attack them, and is thus led to admire the instincts of those animals, such as the deer, which set a watch to give a signal of danger. The hunter knows how much cunning he must exercise in order to come within reach of the wild animals pursued by him, and should not withhold a feeling of wonder when he observes how their instincts lead the brutes to shew such dexterity in avoiding their natural enemies. The weapons with which he and the fisher attack the animals which they wish to seize or kill, do not point more clearly to a purpose, than the instruments, whether claws or teeth, with which they defend themselves. The Aphrodite hispida, for example, is furnished with very curious weapons of defence ; they are harpoons with a double series of barbs, these are retractile, and the animal can draw them into the body by a muscular apparatus, and in order to prevent them, when drawn in, from injuring the animal itself, each barbed spine is furnished with a two-bladed horny sheath, which closes on the barbs in the act of retraction. Some of these provisions have a reference to the native instincts of the animals, others have rather a regard to the position of the species. Thus we find that those liable to be chased as prey often take the colour of the ground on which they habitually feed. The riflemen of our army are dressed in the hue which is deemed least conspicuous, and which is best fitted for concealment; and is there not an equally clear proof of design furnished by the circumstance that fishes are often of the colour of the ground over which they swim, and that wild animals are not unfrequently of the colour of the covert in which they hide themselves? Thus the back of the young turbot may be seen of the same colour as the sand on which it lies. The red grouse and red deer are of the colour of the heath on which they feed, whereas the lapwing and curlew, themselves and their eggs, take the grey hue of the pasture among which they are usually found.

The horticulturist and agriculturist regulate their plans in accordance with the seasons, and in doing so they should observe that the plants of the ground suit themselves in regard to the time of budding, bearing leaves and fruit, to the same seasons, which are all determined by the movements of the celestial bodies. The builder may easily perceive that the woody structure of plants and the bones of animals are constructed on architectural principles, being strengthened where weight has to be supported and pressure resisted, and becoming more slender where lightness is required. The form of the bole of a tree, and the manner in which it fixes itself into the ground, so as to be able to face the storms of a hundred winters, is said to have yielded some suggestions to the celebrated engineer, Smeaton, in the construction of the Eddystone Lighthouse. The architect of the Crystal Palace confesses that he derived some of the ideas embodied in that structure from observing the wonderful provision made for bearing up the very broad leaf of the beautiful lily which has been brought within these few years from the marshes of Guiana to adorn our conservatories. The weaver cannot but notice that there are certain tribes of insects which fashion a web of finer texture than his own. The clothmaker obtains not a little of the material of the fabrics with which he clothes the human frame, from the covering provided for the lower animals, and he derives it all from natural products. When man wishes to protect his body from severe cold, he steals their covering from the lower animals, and by no means of his own devising can he furnish clothing so warm as that which has been provided for the brutes in the Arctic regions. The dyer and calico-printer, with all the aids of modern chemistry, cannot produce such rich and agreeable colours as are made to appear for our gratification in the flowers of plants and the plumage of birds; no doubt through the influence of principles which have not been detected by the very deepest scientific research. Rising higher in the arts we find the painter taking credit to himself for the beauty of his figures and colours; but he cannot, with all his skill and genius, match those lovely ideal forms and exquisite tints which everywhere fall under our eye in nature.

> "Who can paint
> Like nature? Can imagination boast,
> Amid her gay creation, hues like these?
> What hand can mix them with that matchless skill,
> And lay them on so delicately fine,
> And lose them in each other, as appears
> In every bud that blows?"

2. Every kind of contrivance, every principle of mechanism used by man, is visibly employed in the operations of nature. The lamp placed in a window to direct the benighted traveller, the lighthouse erected on the harbour to guide the mariner to a place of safety, are not clearer and more decided illustrations of purpose than

the phosphorescent spark by which the glowworm allures its mate in the darkness of night. What contrivances does man resort to in order to keep his dwelling warm and comfortable, but the physiologist will tell him that there are still more wonderful schemes devised for keeping up the heat of the bodily frame.

Every mechanical power employed by man is at work in nature. There is as much skilful leverage in the human frame as in the most ingenious human machine. The pulleys by which heavy bodies are lifted from the ground do not give such clear indications of means and end, as the tendons and muscles by which the bones are moved. The mechanician has often a large cylinder running across or through his works, and to this he attaches the lesser parts of his machinery. Have we not a similar contrivance in the backbone of the higher animals, and the axis of the plant, constituting the support of all the appendages? Every one who has seen the cord of plaited iron by which a carriage is dragged up an inclined plane, and has noticed how in it strength and flexibility are combined, should be prepared to admire the different means by which the same end is effected in the backbone of all animals, but especially in that of such animals as the eel and the serpent. The mechanician who wishes to combine the saving of materials and lightness with strength, makes his cylinder a hollow tube: it is on this principle that Messrs. Stephenson and Fairbairn have spanned the Mersey by a tubular bridge; but the principle was in operation before man adopted it, or was created to observe it, in many of the bones of animals which are hollow. Found in the bones of all grades of living creatures, it is carried out to the greatest extent where most needed in the bones of birds, so as to allow them to float in the air. In the case of birds, too, the air from the lungs permeates the larger bones as well as the smaller parts, the higher temperature of the body (108°–112° F.) rarefies it, and imparts an increased buoyancy to the whole frame.

Every joint in the animal frame can be shewn to be exactly suited to the function which it has to perform. Where motion backward and forward in one direction is all that is required, we have a common joint; where motion all round is necessary, we have, as at the shoulder and hip, the ball and socket-joint admitting of a rotatory motion round a ball. We have a beautiful example of ball and socket-joint in the sea-urchin, the spines of which have a cuplike cavity at the base, which is fitted to a converse tubercle on the shell, fixed by ligaments, and combining strength and great freedom of motion. In some parts of the animal frame, a single bone is all that is required, and more would injure the strength; in other parts, as in the fore-arm, a kind of rotatory motion is furnished by two bones, a radius and an ulna, so adjusted as to move to some extent round each other.

Almost every sort of instrument employed by man has something resembling it in the operations of nature. The parts of the mouth of insects are made according to the instincts and habits of the animal, to act now as saws, now as knives, and, in the case of the leaf-cutting bees, the mandibles become scissors. The hyena is led by its instincts to crush the bones of carcases and feed on them; and when certain teeth of that animal were shewn by Professor Owen to an engineer, they were declared by him to be admirable models of hammers to break stones for roads. The tongue of many shell-fish, that of the common limpet for instance, has numerous siliceous spines, and the organ is used as a rasp or drill. One end of the shell of Pholas resembles a file, and, by varied motions, the animal makes for itself tunnels in clay and in other substances. The foot of the mole is an admirable tunnelling instrument, and enables it to construct for itself those subterranean passages through which it is led, by its instincts, to wend its way in search of food.

Instruments of a more peculiar nature,. and instruments invented by man only at a late date in the history of the race, have all along had their analogues in nature. Millstones are selected because they have gritty materials in the midst of softer substances; and we find that, on a like principle, soft and hard matters are mixed in the grinding-teeth of mammals. The cupping instruments of surgery were anticipated in the animal kingdom; the mouth of the leech combines in itself the offices of cupping-glass and scarificator; hence the importance of the animal, as a remedial agent. It is also worthy of notice in regard to this animal, that the capacious stomach, with its lateral appendages or reservoirs, enables it to extract a very considerable quantity of blood before being detached. Some of the feet of argulus foliaceus, a parasite on various fresh-water fishes, are so modified that they act as real suckers or cupping-glasses; by a certain arrangement of muscles the animal can exhaust the cavity of its disc-like feet, and produce a vacuum, and is thus enabled to stick closely to the body of the fish.

The tubes and pipes which conduct water and gas through all the streets and dwellings of a great city, are not such ingenious contrivances as the veins and arteries which convey the blood to every extremity of the frame. The means by which water is forced to rise in a pump are not so wonderful as those by which, proceeding on a different principle, fluid is made to mount in the plant to the most distant twig and leaf. We construct valves to allow fluids to pass in one direction, but to prevent them from flowing back in the opposite direction; but before man devised such agency they were already in his own veins; and it was upon noticing them that Harvey, proceeding, as he tells us, on the principle that they were there to serve a purpose, was led to the discovery of the circulation of the blood. In the back of the mouth of the crocodile are two cartilaginous plates or valves, one above, the other below; these, acting as floodgates, cut off communication between the mouth and throat, so that the animal can hold its prey underneath the water till dead, and itself continue all the while to breathe by its nostrils.

3. Among the most curious special modifications are those in which there is a provision made beforehand for the support of living creatures not yet in existence. Every one sees that there is foresight implied in parents laying up wealth to promote the future comfort of their children; but there are equally clear evidences of forethought in the anticipations found among natural objects. In expectation of the birth of her child the mother makes preparation for its clothing and comfort; but there has been a preparation by another Designing Mind, so as to cause the milk to flow at the very time at which it is required for the sustenance of the infant. In the case of animals developed from the egg, we find a store of nourishment laid up beforehand in the yolk, part of which is absorbed as food by the young chick or reptile. In the egg-cases of the common white whelk of our coasts there is a farther provision made for the sustenance of the young animal, in the form of a supplemental yolk, as it might be called. Each case, or capsule, contains several hundred bodies having the appearance of embryo, but only a small number in each capsule becomes living

creatures. There can be no doubt, from Dr. Carpenter's observations, that these few are developed by the metamorphosis of the contents of their own yolks, but their growth or increase in the size depends on the fact that they swallow and feed upon the additional or supplemental yolk.*

4. Not only are the different parts of the animal and plant suited to each other, but there is a perfectibility about them—they are better adapted than anything else to the accomplishment of their end. There are examples of this which have now become commonplace by the eloquent expositions of them by Lord Brougham and others. Every principle followed by the skilful optician in the construction of artificial glasses has been attended to in the formation of the eye, and difficulties which long impeded the formation of perfect glasses were obviated all along in the structure of the natural organ. Every one interested in such investigations knows that bees economize, on mathematical principles, the space which they occupy and the wax which they employ, by building their honeycombs of double layers of hexagonal cells, and by having the floor of their cells made of three square planes meeting at a point and at a particular angle. It is now said that this is produced by the compound eye of the bee being divided by hexagonal marks; "and as the motions of the muscles of animals are directed very much by the mode of admission of light, the shape of the cells may be in accordance with that of the surface of the eyes."† Be it so, it is only a new illustration of the adjustment of natural instinct and the structure of an organ to produce an end which

* Journal of Microscopical Science, April, 1855.

† Swan on the Brain in Relation to the Mind, p. 29. We are not convinced that the explanation given by Swan meets all the phenomena.

must have been contemplated, not by the intelligence of the bee, but of Him who gave to the bee its endowments. It has been shewn by mathematical investigation, that the shape of fishes is that which is best fitted to enable them to cleave their way through their native element. At the time when it was disputed whether Newton or Leibnitz was the inventor of that calculus which has opened the way to such splendid results in various branches of science, John Bernouilli addressed a letter to the most distinguished mathematicians of Europe, challenging them to solve two difficult problems, one of which was to determine the line through which a falling body would descend most swiftly. Both of the distinguished men referred to, (and also M. de L'Hopital,) were able to solve the problem, and declared the line of swiftest descent to be not a straight line but a particular curve called the cycloid. Now, it is believed that it is by this very swoop that the eagle descends upon its prey. The question presses itself upon us, Who taught the birds of the air the line of swiftest descent, the discovery of which was believed to test the highest mathematical skill?

We have already referred to the univalve shells of molluscs as illustrative of the principle of order.* There is another circumstance in connection with these shells worthy of being mentioned here, as connecting the principle of general order with that of special adaptation. In aquatic molluscs, the shell must not only be a habitation for the animal, but a float, which it becomes, by the portion of the narrower extremity of its chamber left unoccupied. But in order to preserve its buoyancy, and enable the animal to ascend and descend the water at will, it is necessary that the increment of the capacity of its

* Above, p. 23.

float should bear a constant ratio to the corresponding increment of its body—a ratio which always assigns a greater amount to the increment of the shell than to the corresponding increment of the animal bulk. Now, it is in accordance with the geometrical character of the form assumed, that the capacity of the shell and the dimensions of the animal do increase in a constant ratio, causing the whole bulk of the animal to bear a relation of constantly increasing inequality to the whole capacity of the shell. "God," says Mr. Mosely, "hath bestowed upon this humble architect the practical skill of a learned mathematician."*

5. It is a circumstance of great significance, that parts of animals which, to superficial observers, might seem useless, or even cumbersome and inconvenient, have been found, in the progress of discovery, to serve most important ends in the economy of life. The hump of the camel might readily be regarded as a very unseemly encumbrance, and we find even the distinguished naturalist, Buffon, speaking of these humps, and of the callous pads on the legs of that animal, as mere marks of degradation and servitude. A little patient investigation, however, suffices to shew that these parts of their frame, like every other, fit these useful creatures for the purposes served by them in the regions which they inhabit. It has often been remarked that the abundant supply of fluid laid up in the cells of one of the stomachs, is a beautiful provision for enabling the animal to endure a long continuance of thirst; and it can be shewn that the enlargement of their feet, with their convex soles, allows them to tread easily on the loose, yielding sand of the desert; that the callosities or pads on their legs permit them to lie down and repose on scorching surfaces; and

* Philosophical Transactions, 1838.

that their humps are supplies of superabundant nourishment provided for their long journeys, so that, when deprived of other food, their frames feed on this nutriment; and it has been observed that, at the close of a long journey, their humps have been much diminished in size.

We are not surprised to find a man so proverbially vain as Buffon failing to discover marks of design in the hump of the camel, but it is rather wonderful to find Cuvier, whose heart was so filled with admiration of the Divine wisdom, speaking somewhat doubtfully of the sloth.* Its peculiar structure would, to use his language, have been inconvenient if it had been intended that it should support itself on its limbs, like most vertebrated animals. But however incapable of walking, its frame is admirably constructed for enabling it to hang by its limbs on the branches of trees. Amid the great intertangled forests of South America, stretching for hundreds of miles, it is by no means so slow in its movements; at least its motion is sufficiently quick to admit of its gathering its sustenance. It has long, coarse, shaggy hairs to protect it from insects; it clings to the bough of the tree by its two hinder claws, and commonly also by one of the fore-limbs, and it employs its other arm in hooking in the foliage on which it browses. It can fling itself from one branch of a tree to another; and in the more open parts of the forest, it can take advantage of windy weather to throw itself from the tree which it has stript to another covered with rich and tempting foliage. Such facts as these go to prove that it is our own ignorance and presumption which lead us to complain of the inconveniences of nature, and that a little more knowledge, and, better still, a little more humility and patience, would lead us to discover and acknowledge, that there

* Règne Animal, vol. i. p. 224.

are admirable wisdom and benevolence even in those parts of God's works which may seem to be useless, or even injurious.

The problem which we are seeking to help to solve, is stated so aptly and felicitously in the opening address of the President at the last meeting of the British Association for the Promotion of Science,* that we cannot refrain from quoting the language. "In physiology, what is the meaning of that great law of adherence to type and pattern, standing behind, as it were, and in reserve, of that other law by which organic structures are specially adapted to special modes of life? What is the relation between these two laws; and can any light be cast upon it derived from the history of extinct forms, or from the conditions to which we find that existing forms are subjected? In vegetable physiology do the same or similar laws prevail; or can we trace others, such as these on the relations between structure, form, and colour, of which clear indications have already been established?" These questions may best be answered by going round the various kingdoms of nature, and placing examples of the two governing laws alongside of each other.

* Duke of Argyle's Address as President of the British Association.

BOOK SECOND.

CO-ORDINATE SERIES OF FACTS, GIVING INDICATIONS OF COMBINED ORDER AND ADAPTATION THROUGHOUT THE VARIOUS KINGDOMS OF NATURE.

CHAPTER I.

THE MINUTE STRUCTURE OF PLANTS AND ANIMALS

SECT. I.—ORDER IN THE STRUCTURE OF THE CELL.

WE are to be chiefly occupied in these chapters in displaying the skill to be found in the plant and animal, as built up into their finished forms, with all their harmonious proportions and varied fitnesses. But before inspecting the finished temple, we may take a look at the materials of which it is built, and these we shall find to be like the stone of Solomon's temple, which "was made ready before it was brought thither, so that there was neither hammer nor axe nor any tool of iron heard in the house while it was building."

It has long been admitted among botanists, that the cell is the typical element in the structure of the plant, that the lower forms of plants actually consist of cells separate and independent, and that the higher are built of the same material, compacted into masses of varied texture.

The general structure of the vegetable cell is very simple. On the outside there is a transparent membrane, called cell-wall, enclosing another part which has received various names, as endochrome, or internal utricle. In the fresh cell the cell-wall and internal utricle are often in such close contact that the presence of the internal layer may be overlooked; but the action of various chemical agents produces shrinking of the inner layer, and thus its presence may be demonstrated. The primary form of the entire cell is stated by some authors to be spherical; the principal modifications in shape are generally regarded as departures from that type. We are inclined to direct attention to the typical structure, rather than to insist on a unity of primary form, since the latter may depend on the original development of the cell. The most usual structure of the animal cell is essentially the same as that of the vegetable cell.† The question of this identity, in other words, as to their being referrible to a common type, has been recently examined by Professor Huxley, who has proposed a new and convenient nomenclature. The outer part, or cell-wall, he calls *periplast*, or periplastic substance, and the contents he calls *endoplast*. The homologies of the parts of the animal and of the vegetable cell had been the subject of discussion; Professor Huxley has arrived at the general result, that "in all animal tissues, the internal part called nucleus is the homologue of the contents or internal utricle of the

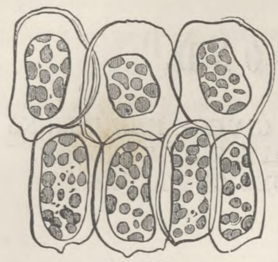


Fig. 1.*

* Fig. 1. Section of leaf of Agave, shewing the cell-wall and contents.

† Sometimes that which corresponds to the internal part is alone present, in some of the lower forms of both animals and plants.

plant, the other elements being invariably modifications of the cell-wall or periplast."

The elements, therefore, of all animals and plants are referrible to a common type.

Animal-cells and plant-cells are microscopical, and this is true whatever be the size of the entire animal or plant. These minute cells bear the same relation to the entire organism as the component materials of a building to the whole fabric.

SECT. II.—SPECIAL MODIFICATIONS OF THE CELL.

1. *In Plants.*—Having found traces of unity in the elementary structures of the plant, we proceed to inquire into the relation between modifications of such and the performance of certain functions necessary in the economy of the plant, and essential to its existence and increase.

Modifications of the cell have generally an evident relation to some particular end to be accomplished, as, for example, to increase the density, the tenacity, or the resisting power, or to furnish a passage to the fluids needful to the life of the plant. The stone of a cherry presents an example of cells specially modified with the view of increasing the power of resistance. This is accomplished by additional layers to the cell-wall, which thus becomes very much increased in thickness. Similar modifications are met with in certain fruits—nuts, for

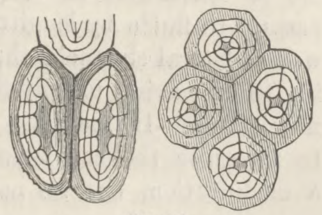


FIG. 2.*

* FIG. 2. Gritty matter of pear, longitudinal and transverse sections; magnified. The stone of a cherry or peach presents the same structure.

instance, and in the skin of some seeds. We need scarcely add how admirably such tissues are fitted to give protection to the important parts within. The so-called wood or woody fibre consists of elongated cells, the walls of which are often thickened by secondary deposits, thus adding great tenacity and durability to the material. The woody part of trees, as well as of smaller plants, consists mainly of this substance; it abounds where firmness, tenacity, and elasticity are needful in the economy of the plant; and in the form of flax, hemp, &c., man turns it to good account for his own purposes.

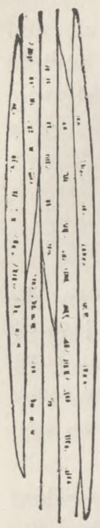


FIG. 3.*

Again, when free circulation of fluid is necessary, we find a tubular structure provided; the different modifications of vascular tissue, known under the names of ducts, spiral vessels, &c., are examples. The peculiar vessels admitted to exist in certain plants having a milky sap, are modifications of cells for a special purpose; they are so constituted as to give free passage to fluids by longitudinal as well as lateral channels, the adjoining tubes having usually free communication. It may not be easy to recognise the cell type in such a modification, but its nature becomes patent, if we suppose that a number of cells, of whatever form, are attached in linear series, and that the

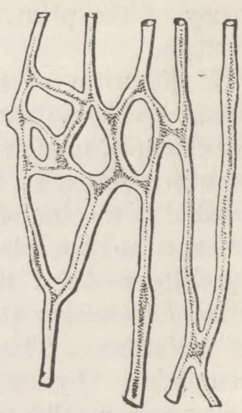


FIG. 4.†

* FIG. 3. Wood or woody tissue, composed of spindle-shaped cells.
† FIG. 4. Milk-vessels from dandelion.

partitions between them become obliterated; it is obvious that a continuous tube or duct will be the result.

The pollen or fecundating matter of the plant, so essential to the continuance of the species, consists of transformed cells, and the first trace of the new plant is also a cell, which is stimulated to full development by the contents of the pollen cell.

These are some of the principal modifications of the vegetable fabric; a general plan prevails, which plan is made to accommodate itself to some particular purpose, whether this be to produce a tough or elastic fibre, a hard structure for defence, or a tube required for the passage of fluids. In the absence of such special and evidently designed adaptations it seems evident that the plants which have been so bountifully disseminated over the surface of our world, would be unavailable for various economic purposes, man could not derive from them food and clothing for his person, nor covering and furniture to his dwelling; nay more, the very existence of many vegetable forms is dependent on the special modifications of their simple elements.

2. *In Animals.*—The higher endowments of the animal organism imply, in the way of final cause, greater departures from the primitive cell structure, and, accordingly, we meet with a greater number of more widely diverging modifications. The researches of different observers have, however, tended to shew that a common plan regulates the nature of the primary tissues. We may now proceed to inquire into modifications bearing a relation to some necessary end in the economy of the animal.

The thin pellicle which is separated from the skin in consequence of a scald, or the application of a blistering plaster, is called *Epidermis;* in its different layers we can distinctly trace transitional forms of the typical cell

This part, thin and delicate although it be, is admirably fitted to give protection to the tender and sensitive true skin which lies beneath it, without at the same time interfering with the function of sensation or touch exercised by the latter. It is specially worthy of notice that where protection is more essential than sensation, there is frequently a very evident increase in the thickness of the cuticle, as in the soles of the feet and other parts.

Fig. 5.*

Over all the internal free surfaces of the animal body, such as the digestive canal, &c., there is a covering, denominated *Epithelium*, essentially of the same nature as the Epidermis; the two are, in fact, continuous, and there is a gradual transition from the one to the other. There are two principal forms of epithelium; the first consists of flat polygonal cells, the second is composed of others almost cylindrical, the free surface of the latter often shewing a fringe of minute filaments, called cilia. Both these kinds serve to protect the delicate surfaces on which they lie, and doubtless act as secreting organs. The cilia of the second form of epithelium, by their rapid motion, propel over the surfaces fluids necessary for lubrication and other purposes, and, no doubt, aid in the expulsion of foreign bodies of small size.

Fig. 6.†

The *Adipose Tissue*, or *Fat*, as it is commonly called, presents a very fine example of the cell type. The fat-cells may

* Fig. 5. Oblique section of epidermis, shewing its cellular structure,

† Fig. 6. Cells of fat, or fatty tissue

be either spherical or polygonal, the latter being produced by the mutual pressure of aggregated cells. The contents consist of oily matter, which each cell has the peculiar power of forming. The masses of fat thus constituted are reservoirs of nourishment, to be used up as occasion requires, and in some cases serve as a soft bed for delicate organs, such as the eye. The rounded contour of the body depends in a great measure on the presence and regular distribution of this material. Where it is needed we find it, and where its presence would be inconvenient it is never formed. Thus, in the palms of the hands, soles of the feet, &c., it is generally abundant, and serves as a protection against pressure; it is never deposited in the eyelids, where its accumulation would undoubtedly be an obstacle to the action of those important appendages of the organ of vision. Further, being a bad conductor of caloric, its abundance in certain animals of cold regions, tends to prevent loss of animal heat; and in some aquatic species, as the seal, its presence diminishes the specific gravity of the whole body, and thus facilitates certain movements of the animal.

The *Tendons*, *Ligaments*, &c., are examples of fibres knit together, and occupying certain parts of the body for the performance of special functions. It is admitted that all varieties of these may originate from cells, which are skilful modifications of the type, admirably fitted to accomplish the end they are made to serve. There are two different kinds of fibre, the white and yellow. The white is inelastic, the yellow is highly elastic. The former is present in the animal body wherever strength and economy of space are requisite, and wherever important organs require protection and support. Tendons and ligaments, the membranes which cover the brain and soft parts of the eye, &c., consist of inelastic fibre. By means of the yellow elastic fibre the claws of the feline tribe are kept retracted when not in use, and a strong band of the same material, stretching between the head, neck, and back, and acting as a natural spring, enables many animals to keep their heads up without any active effort on their part.

Cartilage, or *Gristle*, consists mainly of cells, with intervening connecting substance, which may be homogeneous, as in the purer forms of cartilage, properly so called, or the cells may have in the interstices white or yellow fibre besides. Elasticity, flexibility, as well as solidity, are properties possessed in an eminent degree by cartilage.

The cartilaginous and fibro-cartilaginous modifications of the cell type are produced in parts of the body where a solid material possessed of the properties above mentioned is required. The flexibility and strength of the soft part of the nose and of the external ear are owing to the combination of cartilage and fibre. The ends of the bones forming the joints, have a covering of cartilage, and being thus padded, they are less liable to injury by sudden shocks. The peculiar properties of the materials in question perform an all-important function in the economy of the parts concerned in the formation of the voice. The strength and elasticity of the entire spinal column or back-bone depend chiefly on the intervening cartilages by which the entire series of pieces is connected.

Muscular Tissue or *Muscle*, constituting the flesh, commonly so called, presents, on careful examination, no very remote departure from the cell type; in fact, the muscular tissue is essentially composed of modified cells, which, being first arranged in linear series, with greater or less regularity, subsequently unite to constitute the elementary fibres. It is unnecessary in such a work as this, to enter into details regarding the two varieties of muscular tissue, called striped and smooth, and their respective properties; suffice it to say, that both perform most important functions in the animal economy. The active motions under the control of the will present the greatest possible variety in the amount of force exercised and the resulting effect. How different the enormous muscular power exerted by the whale, when it throws itself entirely out of the water, from that put forth in the motions of the eyelids, or of the little muscles which are concerned in the modulation of the voice, and yet both are formed by the same tissue! The giant steam-hammer which can weld a mass of iron, or simply crack the shell of a nut, is not more capable of control, and exercises no greater comparative range of force, than does the muscular apparatus of the animal frame. In singular contrast with those masses of muscular matter subject to the control of the will, are those over which we have no control, such as those of the heart, alimentary canal, &c. But wherever voluntary or involuntary muscles occur, they are found precisely where each is most necessary in the animal economy.

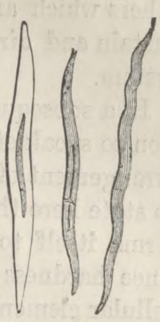


FIG. 7.*

The Bones.—But organs of a harder texture than any of those already described, are required in the animal frame, either to protect important parts, or to serve as levers for the active functions of certain muscles. Without the bones the goodly frame of animals would be use-

* FIG. 7. Smooth muscular fibre from the renal vein in man; shews cell type.

less ; a due combination of soft and of hard parts is necessary ; active organs of motion must have relation to others which are passive ; levers must be provided to sustain and direct the force exercised by the muscular system.

In a subsequent part of this work we shall have occasion to speak of types and modifications in the general arrangement of the animal skeleton ; it may be sufficient to state here that in minute structure the skeleton conforms itself to the same type as the soft parts. But since hardness is requisite, there is superadded to the cellular element a very large proportion of earthy matter, consisting chiefly of phosphate of lime.

Nervous Tissue is another modification of the cell type, for a very important function in the animal frame. The presence and peculiar functions of the nervous system specially distinguished the animal from the vegetable kingdom. The intercourse of animals with their fellows, and with the external world, depends on the presence of a system of nerves, which are necessary to sensation and to the exercise of every mental endowment. Whatever may be the form under which nervous matter appears in the animal body, whether fibres or ganglia, the modification of the cell type can be traced in course of the development.

Not only, however, do cells, or their modifications, act an important part in the protection of surfaces, the support and strengthening of organs, and the performance of various active motions, they are also the chief instruments in other functions of the animal economy. With the exception of the simplest or very lowest tribes, there is in all animals a system of *Vessels* for the conveyance of fluid ; these owe their primary origin to cells arranged in linear series. In all animals having a true circulation, simple isolated cells form an important part of the circulating fluid; the *Blood-Corpuscles*—as they are commonly called—to which that fluid owes its colour, are truly referrible to the cell type. The food, after undergoing certain changes in the stomach and alimentary canal, constitutes the fluid called chyle; it is admitted that certain Epithelial cells select and absorb the materials of the chyle, and, becoming turgid with them, subsequently transfer them to minute vessels—the lacteals, which convey them to the blood-vessels. In the stomach and alimentary canal, certain cells are actively engaged in pouring out some peculiar and useful secretion. In the stomach such cells are continually forming new broods, which pass out in great numbers, their contents yielding matters necessary in the process of digestion.

There are organs whose function it is to separate matters for some special use, as the milk for the nourishment of the young, or to remove substances whose presence would be injurious if retained. It is unnecessary here to enter into details regarding these various organs; suffice it to say that their essentially important parts belong to the cell type. In short, we find that in the animal body some special modification of the cell is concerned in every important function. Cartilage, bone, muscle, nerve, serve different ends in the animal economy, but the cell is the essential element in each. The formation of an image in the eye is mainly effected by the optical properties of parts having a cellular origin, and the impression is conveyed by another tissue, which, as we have already stated, may be referred to the same general type.

In a subsequent section we shall have occasion to allude to the general structure as well as modifications of *Teeth.* Details respecting their mode of development would be out of place here ; it may be sufficient to state that cells perform an essential part in the formation of every tooth.

Nails, Hoofs, Horn, are all essentially Epidermic products, and necessarily partake of the nature of that part of the skin, that is, are modifications of the cell. Their importance in the animal economy is too obvious to require discussion, serving as they do to protect delicate parts, and to act as means of defence and offence.

Hairs and Feathers, notwithstanding their variety in color and texture, have a common origin in cells. The thick and warm fur of the hare, the smooth and silky coat of the mole, the spines of the hedgehog, the quills of the porcupine, and the coarse hairs—resembling split whalebone—of the elephant and ant-bear, are all mere modifications of the elemental cell, and each has a reference more or less obvious to the habits of the animal. The hairs of the mole are closely set, they stand out perpendicularly ; in other words, have no particular shed, and thus present no obstacle to the rapid movements of this burrower when traversing its narrow and intricate subterranean tunnels. The spines of the hedgehog and the sharp quills of the porcupine are respectively admirable means of protection to these otherwise defenceless animals. Feathers, constructed, as we have said, after the same cellular type as hairs, present similar modifications in character, varying with the habits of particular birds. The soft plumage of owls enables them noiselessly to steal on their agile prey. The thick-set feathers and down of divers and other aquatic birds, effectually repel the water and prevent soiling of surface, as well as loss of animal heat.

CHAPTER II.

THE FORMS OF PLANTS.

SECT. I.—TRACES OF ORDER IN THE ORGANS OF PLANTS.

"WHEN Jupiter," says Herder, "was summoning the creation, which he meditated in ideal form before him, he beckoned, and Flora appeared among the rest. Who can describe her charms, who can image forth her beauty? Whatever the earth showers from her virgin-lap was mingled in her shape, her colour, her drapery." We are to attempt no description of her beauty, which can be appreciated only by those who look upon her charms directly, and not through any representation of them. But we are to attempt to give something like a scientific account of that development and structure, of that disposition of parts and distribution of colours, which mainly contribute to give to the plant its graceful proportions and its loveliness. Our present aim is to show that there are system and design in the progress of the plant, from the time it springs from the seed to the time when it yields seed, and that there are determined types to which all its organs are made to conform themselves.*

Botanists describe two modifications in the structure of the seeds of the higher forms of plants. In a pea or

* We are to confine our illustrations to flowering plants, partly because the order in these classes of plants is most easily explained, but mainly because the morphology of the lower tribes of plants has not been so fully investigated.

4*

bean, we observe that the principal bulk of the seed consists of two large bodies in close contact ; they are called seed-lobes, or seed-leaves, and, technically, Cotyledons. When two are present, the plant is a Dicotyledon. Between these organs we observe the rudiments of the future stem and leaves. In other plants, such as the oat, wheat, Indian corn, etc., there appears to be only one cotyledon, and such plants are called Monocotyledons.

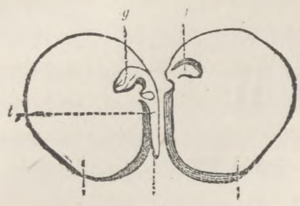


Fig. 8.*

There is a difference between these two kinds of seeds as regards the process of germination ; but it will suffice for our purpose, to state that in both there is a general tendency in one part to fix itself in the soil, while the other tends to raise above it into the air ; the former is the root or descending axis, the latter the stem or ascending axis. Mere position in reference to the soil is not, however, an invariable test of the nature of a part whether stem or root ; for there are not a few instances in which the true permanent stem is underground, as well as the proper root. But whatever be the position of these organs, we may see in the plant a continuous principal axis, one part of which constitutes the root, and the other the stem. Attached to the latter there are various appendages.

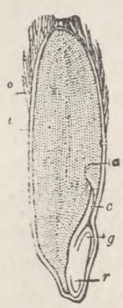


Fig. 9.†

* Fig. 8. Embryo of Pea, shewing the point where the young root arises, *r*; the young stem or plumule, *g*; the stalk, *t*; connected with the cotyledons, *c c*, which are separated and laid open; *f*, the depression in which the plumule lay.

† Fig. 9. Vertical section of grain of oats, shewing the embryo plant at the lower part, consisting of *r*, the parts whence the roots proceed; *g*, the young stem; *c*, the single cotyledon. The covering of the entire grain, *o*; covering of the seed proper, *t*; the nourishing matter, or albumen, *a*.

On the ascending axis of the plant, we observe two kinds of appendages, *leaves* and *buds*. These last, however, are mere repetitions of the plant; each bud consisting of a short axis, and of lateral organs—the young leaves.

The *Leaf*, therefore, is the only essential typical appendage of the vegetable organism. It requires no minute description here; the most inexperienced observer can recognize it; it belongs to the class of "common things." The study of its many forms lies within the province of the botanist.

While this typical appendage varies in outline, its general structure is simple enough. The outer surface

Fig. 10.*

Fig. 11.†

Fig. 12.‡

has a covering called cuticle or skin; the internal portion, or parenchyma, as it is technically called, has ramifying

* Fig. 10. To shew curved venation of Endogen.
† Fig. 11. To shew divergent venation of Endogen.
‡ Fig. 12. To shew netted venation of Exogen—cherry leaf.

through it the parts called veins.* These different parts, of which the leaf is made up, are all modifications of the typical cell, already described. Botanists have described a difference of the arrangement of the leaf-veins, between monocotyledons and dicotyledons. In the first of these two classes, there may be simple veins running more or less parallel to each other from end to end of the leaf (*Fig.* 10), or there may be only one principal vein (midrib) giving off lateral veins, all of which run parallel to each other (*Fig.* 11). In dicotyledons, on the other hand, there may be one or more principal veins giving off numerous branches and branchlets on each side, thus constituting a more or less complicated network (*Fig.* 12). Lilies, palms, bananas, &c., present examples of parallel venation; the oak, beech, &c., have the netted form. But it may further be observed, that there is a relation between the structure of the stem and of the seed, and the venation. Dicotyledons have

Fig. 13.*

Fig. 14.†

the stem conposed of concentric annual zones, as may be seen on a transverse section. Monocotyledons present no such appearance, the vascular parts do not form concentric zones, but are broken up into bundles, giving a

* Skeleton leaves, either prepared artificially or found among fallen leaves after long exposure to the weather, consist of these alone, skin and parenchyma having disappeared.

* Fig. 13. Transverse section, stem of oak, an Exogen, or dicotyledon.

† Fig. 14. Transverse section, stem of palm, an E^dogen, or monocotyledon.

dotted appearance to the stem when cut across. We may now proceed to examine certain appendages of the stem, in order to shew that although they are named as if different in nature from stem and leaf, they are in reality modifications of one or other of these.

Stipules are leaf-like organs, situated on either side of the point at which the leaf is attached to the stem, sometimes adhering to the stalk of the leaf, at other times free. They have various forms, and differ also in size and texture, according to the plant in which we examine them. It may be observed, however, that they are not always present, and are not therefore necessary organs. They are evidently modifications of the leaf, and have the same general structure and functions.

Pitchers.—These remarkable and beautiful appendages might afford models to the potter in the construction of vases for ornamental and useful purposes. Those of the Sarracenia of North America, usually called Indian-cups, and the still more remarkable and elegant organs of Nepenthes, or true pitcher-plant, are examples. They are all admitted by botanists to be merely modifications of the leaf type.

Phyllodia, so called from their leaf-like appearance, are present in not a few plants. In some Australian acacias they are flattened leaf-stalks ; when young, they are of narrow dimensions, and actually bear true leaves of small size ; when the true leaves drop off, these modified leaf-stalks increase in breadth. In some shrubby species of wood-sorrel, the transition from leaf-bearing to leafless flattened stalks can be clearly traced.*

Hairs, *scurfs* or *scales*, *glands*, *stings*, and *prickles*, &c.,

* The phyllodia of Butcher's-broom, of Xylophylla, and of Phyllocladus, usually considered to be flattened and leaf-like branches, may be taken as proof of the relation between branch and leaf.

are simple prolongations and modifications of the cells which form the external covering of the leaf or stem. In dandelion, and numerous other plants of the family Compositæ, as well as of some other natural orders, the divisions of the calyx become transformed into hairs or hair-like organs. Lenticular glands or lenticels, supposed to be connected with the formation of new or adventitious roots, and peculiar in their nature, are now known to be the homologues of cuticular appendages. They present, in different cases, a gradation to hairs, glands, &c. (See *Comptes Rendus*, August 1855.)

Spines are abortive branches ending in sharp points. That this is their nature is evident from such cases as the following: first, they often produce buds and leaves, as in the hawthorn; second, they have the same general structure as the stem and ordinary branches, and are therefore not appendages of the surface merely; third, they occasionally become branched, as in Gleditschia.

Tendrils are thread-like organs, which have the same properties as twining stems. They vary in their true nature. In Gloriosa superba, the midrib or principal vein of the leaf becomes lengthened, and assumes the appearance and functions of a tendril. In the Vanilla plant, the whole leaf sometimes undergoes a similar transformation. In the pea, vetch, &c., which have compound leaves, the end of the common footstalk forms the tendril. In Lathyrus aphaca, not merely the end, but the entire stalk of the compound leaf assumes a similar form. That such is the nature of the tendril in this plant is evident from the fact that occasionally a small leaf is developed upon it. In Smilax, the two tendrils at the base of the leaf are the homologues of the two stipules, and the solitary thread-like appendage or tendril at the point of attachment of the cucumber leaf, is also the representative of a stipule. The tendrils in passion-flower are the homologues of terminal, and in the vine, of lateral leaf-buds.

The tasteful eye cannot fail to be delighted with the liveliness and freshness of summer tints, and the gorgeousness of autumnal colouring, in the foliage of our forest trees. Variety of form and diversity of size add to the æsthetic feelings called forth by the umbrageous canopy of the vegetable world. Our pleasure and admiration are greatly enhanced when we proceed to examine more closely the disposition of the several parts. A casual glance, indeed, at a tree in full leaf, might leave upon the mind the impression that its parts were arranged according to no law, but this arises from the exuberance of the leafy covering hiding the wonderful method in the structure. A careful examination will soon reveal to us that vegetable arrangements are subject to mathematical laws, not less exact in themselves (though admitting, for special ends, of wider deviations) than those which regulate the movements of the planets in their spheres.

The arrangement of the typical appendages has been fully examined by Braun, Henslow, and others. The former has endeavoured to shew mathematically, not only that the spiral regulates the position of the appendages of the stem, but that each species is subject to fixed laws, by which the nature of the spires, and in many cases their number, is determined.

The part of the stem or branch from which a leaf originates, is called a node, the intervening space an internode. Leaves are said to be alternate, when each node produces a single leaf, and when the successive leaves occupy alternately different sides of the stem. When there is such an arrangement, a line commencing at the first leaf, passing round the stem, and touching the point of attachment of each succeeding leaf, forms a spiral, the cycle ending with the leaf placed directly above the one from which we set out. When two leaves originate from a node, and are placed face to face, they are called opposite, and such position has been explained by some, on the supposition of two spirals passing simultaneously up the stem. Three or more leaves springing from a node form a whorl; such position may be owing to the non-development of the internodes of an entire cycle, each spiral being thus reduced to a circle. In opposite and whorled leaves, we find not less evident traces of order as regards the individual leaves of successive nodes. In opposite leaves, for example, the pairs of leaves stand at right angles to each other; and in the whorled, the leaves of each often stand opposite to the spaces between those of the next.

Fig. 15.*

Fig. 16.†

The beauty and simplicity of such an arrangement as the spiral can be clearly seen and appreciated by examining a branch of an Araucaria, or the cone of any fir.‡

* Fig. 15. A stem with alternate leaves arranged in a quincuncial manner. The sixth leaf is directly above the first, and commences the second cycle, expressed by fraction $\frac{2}{5}$.

† Fig. 16. A stem with opposite leaves. The pairs are placed at right angles alternately.

‡ The spiral twisting of an entire organism, or of some of its parts, is worthy of notice here: for instance, the stems of twining plants, as honeysuckle, convolvulus, &c. The

In the spiral, the number of turns made round the stem in completing the cycle is different, and we cannot do better than introduce here the following demonstrations and examples, as given in Professor Balfour's "Class-Book of Botany."

Suppose that, commencing with a leaf No. 1, we reach leaf No. 8 directly above No. 1, after making three turns round the stem, the fraction indicating such an arrangement would be $\frac{3}{7}$. In another case we may reach No. 8 after one turn ; the fraction would then be $\frac{1}{7}$. The fractions mark the angular divergence between any two leaves of the cycle, as represented in the divided circles

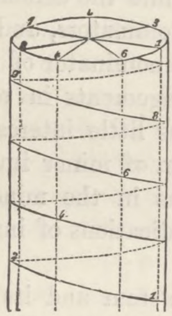


Fig. 17.

Fig. 18.

at the upper part of the stems. In *Fig.* 17, between 1 and 2, the angular divergence is obviously $\frac{3}{7}$ of a circle, or $\frac{3}{7}$ of $360° = 154\frac{2}{7}°$. In *Fig.* 18, the divergence is $\frac{1}{7}$ of the circle, or $\frac{1}{7}$ of $360° = 51\frac{3}{7}°$.

leaves of many plants while in the bud, of banana, for instance, and some modifications of leaves and branches, follow the same law, such as tendrils, the flower-stalk of Cyclamon, the seed-vessel of Streptocarpus, &c. Among the lower tribes we observe similar instances, as in the sea-weed Chorda filum; in species of Desmidium found in fresh water; the teeth surrounding the mouth of the capsule of some mosses, and in others besides. The "winding of leaves" has been recently examined by Wichura, "Flora, 1852."

The following are some of the usual modes of divergence of leaves, and of their modifications :—

Distichous; $\frac{1}{2}$, as in lime-tree, &c.
Tristichous; $\frac{1}{3}$, as in Cereus triangularis, &c.
Quincunx; $\frac{2}{5}$, as in apple, cherry, &c.
$\frac{3}{8}$, as in holly, laurel, &c.
$\frac{5}{13}$, as in wormwood, &c.
$\frac{3}{21}$, as in cones of Pinus Pinea, &c.
$\frac{13}{34}$, as in Plantago medica, &c.
$\frac{21}{55}$, as in cones of some pines.

All these fractions embrace common arrangements; each bears a constant relation to the other; the numerator of each fraction is equal to the sum of the numerators of the two preceding fractions, while the denominator is the sum of the two preceding denominators, and the numerator of each is likewise the denominator of the next but one preceding.* Such arrangements in regard to position and number may possess little interest in the estimation of some, and may seem of minor import, but they awaken profound reflections in the minds of all who are disposed to trace the indications of intelligence in the works of nature.

Organs of Reproduction.—The stem and its appendages present us with almost innumerable phases of departure from the primitive type, thus giving a variety of aspect to the vegetable world, pleasing to the eye and instructive to the mind. The production of flowers and fruit, which is the final effort of every plant, immeasurably enhances its value, and adds much to the variety and the pleasing effects produced by it. In order to the "herb yielding seed, and the fruit-tree yielding fruit after his kind," that is, fulfilling one of the very obvious ends of their existence, there must be superadded an endless diversity and combination of contrivances. These con-

* Balfour's Class-Book of Botany, p. 99.

trivances, while they enable the plant to fulfil its functions, are made by Him who accomplishes several ends by one and the same means, to minister to the pleasure of man by the æsthetic feelings stirred up. These parts were described by Linnæus, in one of his few poetical fits, as the "nuptial dress:"—they are "In glory garmented, each in its own."

Bracts are parts intervening between the ordinary leaves and the flower, properly so called. They usually have a flower in the angle formed between them and the stem. So closely do they resemble leaves in most plants that it is not easy to define the difference. In many cases they have the same colour as leaves, but differ from them in size and form. In other cases their colour is materially different ; in certain species of Salvia, for instance, they are as brilliant as the flower. There are plants in which they exceed the flower itself in size and beauty, as, for example, Euphorbia splendens. When very numerous, as in the daisy, the cup of the acorn, &c., it is very obvious that, like leaves, they obey the law of the spiral. It is worthy of notice, that in Marcgraavia and Norantea they resemble pitchers, just as leaves become transformed into similarly modified appendages. Bracts, therefore, present us with examples of transition between true leaves and the parts of the flower.

Inflorescence, or arrangement of flowers on the stem. There is evidently a plan running through all such arrangements, just as the spiral law regulates the position of the typical appendages. As we shall presently shew, flowers consist of parts essentially of the same nature as leaves, and flower-buds may, therefore, be expected to follow the same law of position as leaf-buds.

The Flower and its parts.—The idea that the leaf is the type of all the floral organs originated with Linnæus

A clearer enunciation of this theory, and a fuller development of the whole, were made by the poet Goethe. We now proceed to an examination of this interesting subject.

A complete flower, usually so called, consists of four series of organs, succeeding each other from below upwards, viz., calyx, corolla, stamens, and pistil. The two first of these, usually so ornamental, are not unfrequently absent; the two last are, properly speaking, the only essential parts of a flower. If all these organs are of the same nature as leaves, we ought to find similarity of general structure, and like obedience to the law of position.

Calyx.—This, which constitutes the outermost of the parts which enter into the formation of a complete flower, consists naturally of separate pieces, called *sepals;* these

FIG. 19.*

FIG. 20.†

have usually the appearance of leaves, and exactly resemble them in structure. In the common bugle (Ajuga reptans) we find a gradual transition from below upwards, from *leaf* to *bract,* the lower bracts being of the same colour and form as leaves, while further up they gradu-

* FIG. 19. Diagram of symmetrical pentamerous flower, shewing four whorls or concentric series of organs, viz. outer row of five sepals, the *calyx;* second row of five petals, the *corolla;* third row, the five *stamens;* fourth row, the five *pistils.* (Flower of a Dicotyledon.)

† FIG. 20. Diagram of the symmetrical trimerous flower of Fritillary, having three divisions of calyx, and three of corolla; six stamens in two rows; and a pistil composed of three united. (Flower of a Monocotyledon.)

ally assume a bluish purple tint, while their venation is also modified, in both which respects they resemble the *calyx*. But this is only one of the many instances in which we can trace upon the same plant a transition from leaf to bract, and from bract to sepal.

Corolla.—The term flower is, in common language, employed to express that part which is most brilliant in colour; this, in botanical language, is the corolla, and the pieces of it are called petals. In fuchsia the calyx and corolla are equally conspicuous in colour; nay, in some varieties the former is the more splendid of the two. In monocotyledons, the two whorls, that of the calyx and corolla, generally resemble each other both in form and colour; thus, in Herb Paris there is a striking similarity between them. Magnolia, certain species of water-lily, and other plants, present in the same flower a decided transition from calyx to corolla, and the converse. In general structure the two organs are little different. We have already seen that the transition from leaves to bracts, and from the latter to sepals, is obvious enough; and as the two first are evidently of the same nature, so it may be inferred that sepals and petals are really constructed after the leaf type; and the highest authorities are agreed on this point.

Stamens.—These, which form the third series of floral organs, from without inwards (see *Fig.* 19), present the greatest departure from the type of the leaf, there being a general diminution of superficial extent, with an increase of thickness at the extremity. A perfect stamen consists of two parts, anther and filament, the latter corresponding to the leaf-stalk, the former to the blade. The filament is no more essential to the anther than the stalk is to the blade of the leaf, and is often absent. In many double flowers we observe a series of changes, which illustrate the true nature of the stamen. It is ·learly demonstrable in some double roses, the stamen

Fig. 21.*

passing from its normal condition into a petal, and this again into a sepal. The common white water-lily presents us with the same transition as its natural structure.

Since, then, bracts are of the same nature as the leaf, and bracts are allied to sepals, and sepals to petals, and all this in more than one particular ; and as petals pass into stamens, and the converse, all may be regarded as formed after the same type.

The part of the stamen called anther corresponds to the blade of a leaf; its two halves represent the two portions of the leaf divided by the midrib, and the whole surrounded by cuticle, and containing cellular tissue or parenchima, some part of which becomes transformed into the pollen or fecundating powder of the plant, so essential to the formation of the seed.

Pistil.—This central organ of the flower more resembles the typical leaf than the stamen. It differs from the three outer whorls of the flower in this respect, that when simple it is generally the representative of a leaf folded upon itself, and with some of its parts adhering more or less together ; the same is true of its individual pieces when it is compound.† This folding and adhesion of the seed-vessel is not always complete, as we may

* Fig. 21. Transformations in the stamens of the rose. The complete stamen is altered, gradually passing through different states, until it becomes a petal, and the petal resembles a sepal with a midrib.

† Schleiden believes some pistils to be really hollow stems.

see in the common mignonette of gardens. The leaf-like structure of the seed-vessel or pistil, as its natural condition, is very obvious in many plants; for instance, in the pod of the pea or bean, and in that of hellebore and marsh-marigold. In some cases we see it reverting to the general type; for example, in the cherry with double flowers, the fruit of which is abortive, and in its stead we observe one or two green leaves, resembling in miniature those of the tree.


a—Fig. 22.*—*b*

In order to understand the nature of this part of the flower, let us imagine a leaf such as that of the cherry or laurel, to be so folded that the two edges are brought in contact, the two halves of the upper surface being opposed to each other, and the whole in a vertical position; the lower surface of such leaf will correspond to the outer surface of the pistil, and the upper to its lining or inner surface. Such, in fact, is the real nature of a simple leaf-pistil.

The seed.—We may now inquire into the nature of the seeds, called, technically, when young, ovules or little eggs. It is well known that the leaves of some plants bear buds on their edges; for example, Malaxis and Bryophyllum; the ovules are representatives of such buds. Suppose a leaf of one of these plants folded on itself, and the edges also folded inwards and adherent, we have in this way an exact representative of the seed vessel and seeds of not a few plants. Some abnormal cases illustrate the same truth; thus, Professor Henslow has shewn that in mignonette the ovules sometimes become transformed into small leaves attached to a short axis, precisely the structure of a bud. Whether, there-

* Fig. 22. Seed-vessel of double-flowering cherry converted into a small leaf, in two states; unfolded, *a*; folded, *b*.

fore, we adopt Schimper's view, that "ovules are buds of a higher order, their integuments leaves, and their stalk the axis," or Lindley's, that they are "leaf-buds in a particular state, and their integuments composed of scales or rudimentary leaves," we are still constrained to admit that they are formed after the same type as the other parts.*

But if the different series of organs which we have been describing as entering into the formation of a perfect flower, are really of the same nature as the leaves or typical appendages, they ought to have their position regulated by the same law. Such, in fact, is the case.

We have already had occasion to allude to the whorled arrangement of leaves on the stem, and in these instances we have a type of any of the four whorls of the flower already described. Farther, the relative position of the leaves in successive whorls, represents also that of the parts of the flower; for as the leaves in successive whorls are, generally speaking, alternate, the same holds in the flower. This comparison is admitted by all authorities.

The whorled arrangement of leaves is but a modification of the spiral, and the same law regulates the position and mutual relations of sepals, petals, stamens, and pistils. The parts of succeeding whorls, in both cases, occupy the same relative position as in whorls of leaves—that is, each is placed opposite the space between two in the next series; in other words, the parts of the flower alternate with each other. (See *Fig.* 19). But the law of the spiral extends also to the individual pieces of each whorl, though it is frequently not very obvious, and is

* It may be worthy of notice here, as connected with this subject, that in some plants called viviparous, we observe mixed up with the flowers and flower-buds small bulbs, which, when mature, drop off and take root; they are, in fact, miniature buds. Polygonum viviparum, Saxifraga cernua, and others are examples. In some of these the true flowers are reduced to two or three at the upper part of the stem.

liable to be overlooked by a careless observer. In some species of rock-rose, and in Polygala, as well as in many other plants besides, some of the sepals, or pieces of the calycine whorl, are lower or more external than the others, which are higher and within the former. This prevalence of the spiral is especially obvious in the pistil or central part of the flower. The common strawberry, when ripe, illustrates this ; the numerous small pistils (or seeds, as they are commonly but improperly called) dotted over its surface, will be found, on close examination, to follow the spiral arrangement. The soft, juicy part of the strawberry is just an enlarged fruit-stalk, axis, or stem (receptacle of botanists), and the numerous minute pistils or seed-vessels which it supports, are arranged according to the same law which regulates the position of leaves, of which they are homotypes.

Adolphe Brougniart long since showed, that what are called floral whorls are not strictly such in many cases, but merely a series of organs closely approximated, and occupying different heights on the short axis. This, as we have shown, is often sufficiently obvious as the natural condition of the parts, but it is at times more palpable in monstrous flowers.

We have stated that ovules are of the same nature as buds. Since these latter, growing usually in the angle between stem and leaves, necessarily follow the law of the spiral in regard to position, the same ought to be true of ovules, and examples of this are easily found. Even when the ovules or young seeds are very numerous in a seed-vessel, there is no confusion, but the utmost regularity in their arrangement. Thus in the pod of a pea, where they form two rows, corresponding to the infolded edges of the typical leaf, those on one side alternate with those on the other. In the seed-vessel of the wall-flower, where they are more numerous, they follow the same law.

The regularity is not less obvious when we examine cases in which they are more abundant still, as, for example, in the seed-vessel of the common foxglove. It is worthy of notice, as an illustration of the same law, that the two seeds usually found at the base of each scale in the cone of a fir, are often not exactly on the same level, one being generally a little higher than the other.

Not only are there relations of structure and position in the parts of the flowers, but we also observe relations in number.

The typical flower in plants, having the dicotyledonous structure of seed, has its parts regulated by the numbers four or five, or some multiples of them ; in flowers of monocotyledons, the number three, or some multiple of it, prevails.* The fundamental structure in both may be modified in three ways ; 1*st*, by lateral adhesion of the pieces of the same series, or of organs of different series ; 2*d*, by increase or diminution in the number of the parts ; 3*d*, by inequality of size and form, or union of the different parts, or peculiarities in the development of the axis which supports them. Some botanical authorities admit the existence of nine thousand genera, and about one hundred thousand species of the higher forms of plants.† The characters of the former being founded

* Linnæus, in classifying plants according to the number of stamens, attached, probably without being aware of the importance of the principle, a greater weight to numbers than has been assigned to them by more modern observers. In Geraniums we may often observe five stems, five leaves divided into five parts, five flower-stalks, five sepals, five petals, and the stamens in multiples of five. In the natural family Umbelliferæ (carrot and hemlock are examples), the number five prevails not only in the flower, but it also seems to regulate the inflorescence, five or some multiple of it occurring very frequently in that part. The common elder-tree belonging to the Honeysuckle family, has five leaflets on a common stalk, the inflorescence or flower-stem has five primary branches, each of these has in turn five secondary, and so on repeatedly ; five being also the typical number in the flower. In the true heaths, four is the typical number in the parts of the flower, but it (or its multiples) often appears also to regulate the number of leaves which appear together, as well as the number of flowers which are grouped together.

† These numbers are doubtless far above the mark, as regards plants actually discovered.

on differences in the organs of reproduction, there are therefore numerous modifications of the typical flower. All parts of the plant furnish characters of species, and there are therefore many thousand modifications of the typical plant. Amid so much variety, it is pleasing to contemplate the common plan which regulates all; and knowing that plan, we possess a key to explain those remarkable forms which are so common in the vegetable kingdom, whether the coronet-like flower of Napoleona imperialis, the irregular flower of Aristolochia, or of the Balsams, or that peculiar slipper-shaped corolla from which Calceolaria derives its name. The gaping flower of Mimulus, and the irregular mask-like flower of Linaria, are all referable to a common type. A knowledge of the typical flower in the Endogens enables us to ascertain the true nature of those modifications which render the grotesque flowers of the Orchids so remarkable; in some it resembles an insect, in others a spider, and in a third case, a helmet with the visor up, indeed there is scarcely a common insect or reptile to which some of them have not been likened.* The flowers of the bee and spider orchis, the toad-like Megaclinium Bufo, and the Caleana nigrita of Swan River, whose flowers capture insects, and all the anomalous Cape species, can be interpreted when we know the type.

Having gone over the organs of the plant individually, we are now to inquire whether there may not be indications of a unity running through all classes of plants.

Allusion has been made to two great classes of flowering plants called Monocotyledons and Dicotyledons, each characterized by peculiarities in the structure of seed, of stem, and of leaf (and also by a difference in the mode

* Lindley's Vegetable Kingdom, p. 176.

of germination of the seeds). Each also has, generally speaking, a certain number or its multiples regulating the number of parts in the flower. There seem, however, to be evidences that these two great classes, thus usually distinguished, really possess much that is common. According to Mohl, the structure of the stem of an Endogen and of an Exogen, during the first year of their growth, is altogether the same. Dutrochet indicates the Bryony as an example of such identity. As to the seed, Professor Lindley remarks,* "It is apparent that dicotyledons are not absolutely characterized by having two cotyledons, nor monocotyledons by having only one. The real distinction between them consists in the mode of germination, and in the cotyledons of dicotyledons being opposite or in whorls, while in the monocotyledons they are solitary or alternate."

The difference in the arrangement of the veins of the leaves in these two classes present not a few exceptions ; thus, on the one hand, among monocotyledons we have examples of netted venation, as in Arum, Calla, Lilium giganteum, &c., and on the other, examples of parallel venation among dicotyledons, as in Nerium. There seem, therefore, to be transitional forms between the two great classes into which the largest proportion of the highei plants has been divided by botanists.

There are indications, too, of a unity of structure running through all the organs of the individual plant. We think it of importance to illustrate this at considerable length.

It will not be reckoned by any scientific botanist, in the present day, as an excess of refinement to represent the developed organs of the plant as all formed after one or other of two different types or models, the Stem and the Leaf.

* Introduction to Botany, vol. ii. p. 267.

First, The more solid parts of the plant are composed of a number of stems, proceeding the one from the other in linear succession. Springing from the embryo, or seed, there is the axis mounting upward and becoming the aerial stem, and growing downward and becoming the root. From the former of these, or the ascending axis, there go off lateral stems, which we may call branches, and from these, other stems, which we may call branchlets. There proceed, in like manner, from the descending axis, or top root, lateral branches which also ramify through the soil. There are important differences between the aerial and the subterranean stems to fit them for their different functions.. Roots, for example, have no pith, no scales or leaves, and, in ordinary circumstances, no leaf-buds like the upward axis. Still the two are alike in the general character ; the branched plant is found to have a branched root. The tendencies of the underground ramification have not, so far as we know, been carefully determined ; but above ground, it is very evident that the stem, branch, and branchlet obey the same laws. "If a thousand branches from the same tree," says Lindley, "are compared together, they will be found to be formed upon the same uniform plan, and to accord in every essential particular. Each branch is also, under favorable circumstances, capable of itself becoming a separate individual, as is found by cuttings, buddings, graftings, and other horticultural processes. This being the case, it follows that what is proved of one branch is true of all the others." We have seen a pear-tree laid prostrate on the ground by storms, but, with its roots still fixed in the soil, sending out a branch from its side, which mounted upward, and took a form precisely like that of the parent tree.

The other typical or model form is the leaf. We have shewn that all the appendages of the plant are constructed on this type. "Linnæus had a presentiment of something of this kind, and, in his Prolepsis Plantarum, carried it out in such a way that, starting from the consideration of a perennial plant with regular periodicity of vegetation, as in our forest trees, he explained the collective floral plants, from the bracts onward, as the collective foliar produce of a five-year-old shoot, which, by anticipation and modification, was developed in one year. This view is, in the first instance, taken from the most limited point possible, from the examination of a plant of our climate; and secondly, imagined and carried out with great want of clearness."* The true doctrine was first propounded by C. F. Wolff (Theoria Generationis, 1764), but his treatise lay buried in neglect till the doctrine became established by the influence of others. It was first presented to the world by the great German poet, Goethe, who, though not learned in the artificial botany at that time taught in the schools, had a fine eye for the objective world. We are not willing, indeed, to admit that the form in which Goethe expounded the doctrine is in every respect correct. It is wrong to represent floral organs as metamorphosed leaves, for they never have been leaves in fact; the accurate statement is, that these organs and leaves are formed after the same general plan. Nor are we to represent nature as striving after a model form, which she fails to reach, in the various modifications of organs; for the modifications are as much an end and intended, as the parts which may be pointed to as patterns. Still, Goethe may be regarded as having seized the great law of vegetable morphology. His Versuch die Metamorphose der Pflanzen zu erklären, was published in 1790, and has furnished the foundation

* Schleiden's Principles of Scientific Botany, translated by Lankester.

to scientific botany. But as Goethe had no name among the initiated, little attention was paid by botanists generally to his speculations till long after, when they were mentioned by Jussieu, and brought into general notice by De Candolle, in his "Organographie," published in 1827. The doctrine, somewhat modified, is now acknowledged by the great doctors, and has been sanctioned by the great councils of science.

According to this idea, a plant is composed of two essentially distinct parts, the stem and leaf. The leaf is attached to the ascending stem, and besides its common form, it takes, while obeying the same fundamental laws, certain other forms, as scales, bracts, sepals, petals, stamens, and pistils. Schleiden, who has developed this view, gives, in his "Plant, a Biography," a picture of a typical plant constructed on this principle. This makes a plant a dual.

Fig. 23.*

* Fig. 23. The typical plant—1 to 7. Axis.

I. to VI. Appendages.—I. Cotyledon; II. Leaves; III. Calyx; IV. Corolla; V. Stamen; VI. Pistil.

II. Typical appendages. I. III. IV. V VI. Modified appendages.

b b, Buds composed of shortened axes, with rudimentary appendages.

But it appears to us possible to reduce a plant by a more enlarged conception of its nature to a unity, that is, to shew that there is a unity of plan running throughout the whole.*

Looking first at the ramification of the stems, we may observe a central stem, or central stems, sending out other stems at definite angles, and of a normal length, and altogether in so regular a manner that the whole plant is made to take a predetermined form. Looking next at the venation of the leaf we perceive (see *Figs.* 12, 24, 25, 26) that it too has a ramified character, that it has in the centre a main rib, or ribs, from which proceed other ribs or veins in so definite a manner that the whole skeleton assumes a regular shape. Now, we maintain that a number of correspondences can be detected between the ramification of the stems and the ramification of the leaf-veins.

In prosecuting this inquiry, let us first inspect, in a general way, the leaf of a tree, with its central vein, or veins, and its side veins. (See *Figs.* 12, 24, 25, 26.) On the most cursory inspection the impression will be left on the mind that the central vein, or midrib, as it is called, corresponds to the central stem or axis of the tree, and its side veins to the branches. Having seized the figure of the leaf-venation in the first instance, let us now look at the skeleton of the tree, say a tree stripped of its leaves in winter, and we may notice how like it is in its disc and the arrangement of its parts to the skeleton and outline of a leaf. We shall be particularly struck with this if we view the tree in the dim twilight,

* Dr. M'Cosh has here to express his obligations to Professor Balfour of Edinburgh who, without prematurely committing himself to these views, has kindly helped to give them publicity and bring them under discussion. See Transactions of Botanical Society of Edinburgh, July 1851, and Balfour's Class-Book of Botany, 2d edit. p. 113; see also Sectional Reports, for 1852 and 1854, of British Association for Promotion of Science.

or "pale moonlight," between us and a clear sky, as we may conceive Wordsworth to have viewed it.

> "Often have I stood,
> Foot-bound, uplooking at this lovely tree,
> Beneath a frosty moon."

We are quite aware that, in the tree, the branches go off all round the axis, and give to the whole figure a spherical form, whereas in the leaf the fibrous veins all lie in one plane. But then we have a transition from the one to the other, and a point of connexion in the branch, the branchlets of which—as, for example, visibly in the beech—often lie in one plane, and, if filled up, would make the figure bear a resemblance to the leaf. The principal difference between the tree and leaf may possibly be found to consist in this, that for special ends the cellular tissue which, in the tree and its branches, is collected into the pith and bark, (which are connected by the medullary rays,) is in the leaf spread out so as to fill up the interstices in the fibrous matter which forms the veins. The general impression produced by the first thoughtful survey of a morphological correspondence between stem ramification and leaf ramification will be confirmed by a more searching and scientific investigation. In maintaining this, we always assume that in the cases subjected to examination both stem and leaf are fully and fairly developed.

But here it will be necessary to have it settled, at the outset, that every species of plant tends, if allowed to grow freely and in favorable circumstances, to take a particular form, and that the same is also true of the leaf. This statement will be allowed, after a moment's recollection and thought, as to the leaf. The cherry leaf (*Fig.* 12) obviously assumes one shape, the beech leaf (*Fig.* 24) another shape, the lime leaf (*Fig.* 25) a third shape, and the poplar leaf (*Fig.* 26) yet a different shape. Every one who has used his eyes will remember that the oak leaf has its peculiar figure, and the thorn leaf its own conformation, and the birch leaf its specific outline, by which we at once recognise them and distinguish them the one from the other. A very little patient observation of trees growing freely—of lawn-trees, for example—may satisfy any one, that what is true of the leaf is also true of the tree. Every species of tree, according to naturalists, has its own habit; and this gives to it a peculiar physiognomy by which the practised eye will at once recognise it. We have often found it interesting, (when we had nothing else to interest us,) in passing along a road, to detect, by their configuration, the various species of trees which met the eye, and this when they were bared in winter, and there was no foliage to aid us. Towards this normal shape of its species every individual tree tends. No doubt it is greatly interfered with, and much thwarted in its efforts by prevailing winds which bend it, or violent storms which break it, by too much cold at one side, or too much sunshine at another side, by a niggard soil denying nourishment, or officious neighbours jostling it, by cattle browsing on it, or men cutting it; still we can see the native tendency in the most unfavourable circumstances, while, in more favoured positions, we see the tree growing up to its beau-ideal.

And here it may be laid down as a general rule, that every plant takes the fairest shape when allowed to assume its natural form. True, there are trees which have been rendered picturesque by being torn or twisted by the storm, or venerable by the marks of age; but being unaided by associated feelings produced by such causes, the plant is always injured when attempts are made by man to give it an artificial shape. Every tree should be allowed fairly to develop itself, protected only from rude winds, and interfering neighbours, and grazings of cattle, and prunings of man, who so often mars in attempting to mend. All ornamental pruning should aim, not at improving, but aiding nature—nay, not so much at aiding it, as cutting off unnatural additions and removing artificial imperfections. Thus left to their innate tendencies, all plants will grow into a form more or less beautiful. A tree growing freely and fairly in a lawn, where it has soil to feed it, and space to develop itself, and air to breathe in, and sun to warm it, and fences to shelter it, stands before us a most interesting object of contemplation. The parallel branches, and their spiral arrangement round the axis, their sweep of curve, and the methodical way in which they first lengthen and then shorten as they ascend the trunk, and the graceful rotundity and elegant outline of the whole between us and the sky, all combine to fix the eye, and unconsciously excite and engage the musing intellect. And there is another beauty produced by a number of differently-formed trees standing on the same lawn, and each shewing its separate mould and features. For as one star differeth from another in glory, and as one saint in heaven differeth from another in glory, so one tree differeth from another in glory. There is one glory of the oak, which looks as if it had faced a hundred storms, and having stood them all, were ready to face as many more ; another glory of the sycamore, that "spreads in gentle pomp it honeyed shade !" another glory of the birch, so graceful in the midst of its maiden tresses ; another glory of the elm, throwing out its wide arms as if rejoicing in its strength ; and another glory of the lime, with its sheltering shade inviting us to enter and to linger.

Each has its own glory, of which it would be shorn were it to make an ambitious attempt to usurp the glory of its neighbour.

It being allowed that there is a pattern form for the whole plant and for its leaf, we are now to trace certain interesting correspondences which we have noticed between the two.*

1. *In plants with woody structure, there seems to be a correspondence between the tree and leaf in this respect, that a leaf without a leaf-stalk implies a trunk naturally branched from the ground, and a leaf with a leaf-stalk implies that the species of tree on which it grows has naturally a bare stalk.*—In order to the settlement of this point, it is necessary to have it admitted that there are trees which are naturally feathered from the base, whereas there are others which have less or more of an unbranched trunk. Belonging to the former class we may name the greater number of our ornamental lawn shrubs, as the box, the holly, the laurels, bay and Portugal, the arbutus, the laurustinus, the privet, the snowberry. All of these cover the lawn from near the base, and it may be observed of the leaves of all of them, that they have no petiole, or a very short petiole. To this same class belong many of the common forest trees, such

FIG. 24.†

* Our observations have been extensive and varied, but they are limited when compared with the whole vegetable kingdom, and so we are prepared to expect that curious modifications and anomalies will cast up, which, while not setting aside these general views, will open new views, and enable science, in the end, to rise to a more thorough conception of the plant.

† FIG. 24. Beech leaf, as an example of leaf with little or no leaf-stalk; shewing nearly parallel veins; angle of venation, 45° to 50°; the midrib zigzag.

as the oak, the elm, the beech. The leaves of these trees have little or no leaf-stalk, and we are able, from a rather extensive observation, to affirm that these trees incline to send out branches from the base. At times, indeed, this tendency is interfered with. In fields, the lower branches are frequently eaten by cattle, and in thick woods they often fail from want of air. The lower branches of the young oak are studiously cut off by woodmen, in order to get a tall, unbranched trunk for timber. The beech is not unfrequently cut over before being planted out in lawns, and a whorl of branches is made, in consequence, to spring out some few feet above the ground. In England, the favorite elm is often pruned near the base, in order to lessen the shade upon the field or highway. But when allowed to grow unmolested, and in favourable circumstances, these trees are all bushy from the base. The very circumstance that the oak requires pruning in order to its having a bare trunk, proves that its own tendency is otherwise. The beech shews that it is naturally branched from the roots, by the closeness of the hedges which it forms. The pruned elm is ever displaying its native disposition, by the little branches that crop out from its trunk in spite of all the cutting to which it is subjected.

Other trees, again, have less or more of a bare trunk, and the leaves of these have less or more of a leaf-stalk. To this belong the cherry, (*Fig.* 12,) the lime, (*Fig.* 25,) the poplar, (*Fig.* 26,) the apple, the pear, the birch, the chestnut, the sycamore. These cannot be induced, except by constant cutting, to grow bushy, or to afford shelter, from their base in rows or fences. The thorn may seem to furnish a disproof, by its being so commonly employed in hedges. But every one who has bestowed the least attention upon the subject, knows that thorns need constant cutting to keep them from becoming bare near the root, and their native habits are seen when they are planted out in lawns, where they have invariably (as the beautiful thorns in Phœnix Park, Dublin, can testify) an unbranched trunk.

2. *There is a correspondence between the disposition and distribution of the branches, and the disposition and distribution of the leaf veins.*—Some trees, such as the beech, the poplar, the birch, the oak, have one main axis, from which there proceed comparatively small side branches, pretty equably along its length ; and it will be found in such cases that the leaf (see *Figs.* 12, 25) has one central vein, with pretty equally disposed veins on either side. Other trees again, incline rather to send off, at a particular height, for each species, a number of branches at once. This is the case with the lime, the common sycamore, and the horse-chestnut. The lime has a few feet of unbranched trunk, and at the place at which it begins to branch there will commonly be noticed a cluster of branches, which, as they droop down give to that tree its attractive shade, and, in correspondence with this, we may observe that the leaf has a petiole,

Fig. 25.*

* Lime leaf, as example of a leaf with a leaf-stalk, shewing a clustering or whorling of veins at the point at which the veins begin to come off, and a nearly parallel venation. The angles made by the lateral veins from the midrib are 42°, those made by the veins proceeding from these main lateral veins are 50°. The angle *a a* corresponds to the angle of the peduncle upon the branch.

at the top of which there is a clustering of lateral veins. The trunk of the sycamore, about eight or ten feet above the surface of the ground, commonly divides itself into four or five large branches, and, in precise analogy, we find a pretty long leaf-stalk dividing into five midribs. The horse-chestnut often sends off at the top of its bare trunk (as may be seen in hundreds of trees in Bushy Park) a still greater number of branches, and in correspondence with this its leaf is commonly divided into seven leaflets. This correspondence between branching and venation is very strikingly displayed in those plants which have triplet leaves, such as broom and laburnum; a careful observation of a number of such will satisfy any one that the axis, in the one a few inches, and in the other a few feet, above the ground, inclines to divide into three main branches. In some plants there is a whorling (approximately in the sense explained, p. 96) of leaves at the point at which they issue from the stem; this may be seen in rhododendrons, the common barberries, and azelias. In these plants the branches also go off in whorls, as any one may satisfy himself by the most cursory inspection.

This morphological correspondence may be seen in herbaceous plants as well as in plants with woody structure. We have the triplet leaf and triplet stalk in marsh-trefoil, in wood-sorrel, and clover, and the whorled stalks, with a clustering of leaves or midribs, in lady's-mantle, geranium, mallow, and lupin. In common lady's-mantle there are several midribs, and, in the mountain species, a whorling of leaves, and in both a tendency to whorl in the stalks.

So far as we have been able to generalize a very extensive series of facts before us, we are inclined to lay down the provisional law, that the whole leafage coming out at one place on the stem corresponds to the whole plant, and that the venation of each single leaf corresponds to the ramification of a branch. We state the general axiom in this form, because in many plants more leaves than one issue from one point, and in such cases it seems to be not the single leaf but the whole leafage which is the type of the tree.

3. *There is a correspondence between the angle at which the branch goes off and that at which the lateral veins go off.*—And here, again, it will be needful to have it admitted that there is a normal angle both for the lateral leaf veins and the lateral branches. So far as the lateral veins are concerned, it will be acknowledged, by every one who has ever looked with care at the form of a leaf, that there is a normal angle for every species of plant. An inspection of any leaf picked up at random will shew that the lateral veins run nearly parallel to each other (see cherry leaf, *Fig.* 12, beech leaf, *Fig.* 24, lime leaf, *Fig.* 25), and that in certain plants, as at the base of the poplar leaf, for example (see *Fig.* 26), the veins go off at a much more obtuse angle than in certain other plants, as, for instance, the lime (see *Fig.* 25). The leaves of the elm and hazel have some resemblance to each other, but may at once be distinguished by their angle of venation, which in the former is 55°, and in the latter 40°. It will not be so readily allowed that there is a normal angle at which the branch goes off in every species of tree. We have heard it maintained that a branch sets off from the axis as best it can, taking any empty space available to it, and in search of air to breathe in and sun to warm it. But a very little careful observation, with this special object in view, may satisfy any candid mind that this is not the case, and that the branches tend to go out very much parallel to each other,

and at a normal angle, for every species. Any one may see at a glance that the elm and oak branch goes off at a wider angle than that of the birch or beech. No doubt many external circumstances tend to interfere with this internal tendency. A branch will often be bent down by its own weight, or turned upward by another branch, or by want of room and air, or spoiled by cattle or children, or men, still the tendency will manifest itself, even when thwarted ; and in every open lawn, duly sheltered, there will be trees whose skeleton beautifully displays the native direction of the branches, which will be seen, like the leaf veins, to run very much parallel to each other, and within a few degrees—now on the one side and now on the other side—of an average or normal angle, which may be ascertained by a number of measurements.

When it is acknowledged that there is a normal angle both for vein and branch, what we may call the angle of venation and the angle of ramification, the question is started, and admits of being answered, Is there a correspondence between the two? We may satisfy ourselves that there is, in a general way, by a bare inspection, or by taking a leaf, abstracting its soft matter, and then looking through the skeleton venation upon the ramification of the branches, and comparing the two. Or the point may be settled more scientifically by using a goniometer, consisting of a graduated semicircle with a movable index, and measuring the angle both of vein and branch. The angle of the vein is easily ascertained, and the angle of the branch may also be obtained approximately by taking a series of measurements and striking the average. By such means it can be proven that there is a correspondence between the angle of venation and ramification of each species of plants. In most plants with woody structure the angle of both vein and branch ranges between 45° and 60°. In the greater number of herbaceous plants* the angle varies from 25° to 40°. But both in trees and herbaceous plants there are angles so acute as 10° or 15°, and so obtuse as 70° or 75°. So far as we have observed there are no normal angles more obtuse than the number last named, though branches are often bent down by their own weight, so as to stand perpendicular to the axis, or are even inclined at an acute angle to the part of the trunk below the point from which the branch springs.

For every species of plant which we have examined there is a definite normal angle or angles. We say angles, for the angles may differ at different parts of the venation and ramification of the same plant. Thus, in some plants the angle of venation is widest at the base, and gradually narrows as we ascend. Whenever this is the case in the leaf there is a similar narrowing in the angle of the ramification of the branches. It is seen in a marked manner in the poplar and the beech, and helps to give to the leaves and coma of these trees that rounded pyramidal form by which they are distinguished. More frequently there is a difference between the angle at

FIG. 26.†

* Dr. M'Cosh has here to express his obligation to a most excellent but extremely modest man, Mr. Mitchell, formerly schoolmaster at Edzell, now in the City Mission. Edinburgh, for help in applying his theory to herbaceous plants.

† FIG. 26. Poplar leaf, as an example of leaf with leaf-stalk. The primary angle of venation begins at 70°, and lessens as we ascend the midrib.

which the main lateral veins and main lateral branches go off from the midrib or axis, and that at which the lesser veins and branches go off either from the midrib or axis, or from the main lateral veins and branches. We may call the former of these, that is, the angle made by main veins and branches, the primary angle, and that made by lesser branches and veins, the secondary angle. In looking at the lime leaf, (*Fig.* 25,) we may notice that the main veins (primary) go off at a much more acute angle than certain smaller veins (secondary). Using this nomenclature, we have found that the primary angle of the venation of the leaf is the same with the primary angle of the ramification of the stem, and that the secondary angle of venation is the same as the secondary angle of ramification.

In measuring angles, then, it will be necessary to distinguish between the primary and secondary angles of ramification and venation. In applying this distinction to herbaceous plants, we found that the angle at which the peduncle, that is, the flower-stalk, goes off, corresponds not to the primary, but secondary, angle of venation. In following out this system, however, we often experience a difficulty in ascertaining whether we are measuring the angle of a true branch, or peduncle, as botanists do not seem to have laid down any rules to enable us to distinguish between these organs.

It appears, then, that on inspecting the ramification and venation of any given plant, we may observe a normal primary angle which is the same both for main lateral vein and main lateral branch, and also a secondary normal angle for the lesser veins, (whether proceeding from the lateral veins or from the midrib,) and for the lesser branches, including the peduncle. This secondary angle is in some few plants more acute than the primary.

Thus in the common dock the primary angle is 60°, and the secondary angle of flower-stalk and lesser veins about 40°. But in most plants the secondary angle is the more obtuse, and helps, when it is so, to give to the tree its outspreading appearance. Thus in the lime (see *Fig.* 25) this primary angle is 42°, and the secondary about 50°, and in the oak the primary is 50°, and the secondary angle about 65°. The following may serve as examples of the angles of venation and ramification in some of our common plants :*—

PLANTS WITH WOODY STRUCTURE.

	Deg.		Deg.
Alder,	50	Laurustinus,	50–55
Ash,	60	Lime,	42
Bay Laurel,	50–60	Small veins and branches,	50–55
Beech,	45–48	Maple,	40–45
Birch,	30–48	Lesser veins and branches,	55
Box,	60	Mountain Ash,	45
Cherry,	50	Oak, large branches,	50
Elm,	50–55	Smaller veins and branches,	65–70
Hazel,	42	Rhododendron,	60
Holly,	55	Rose,	60
Horse Chestnut,	50	Sycamore,	50–55
Laburnum,	60	Willow, angle varies in each species.	

HERBACEOUS PLANTS.

	Primary Angle. Deg.	Secondary Angle. Deg.
Chenopodium glaucum,	40	50
urbicum,	40	40
Geranium,	35	varies in each species, in some, 60
Geum intermedium,	30	30
montanum,	35–38	50
Ranunculus,	25–28	differs in each species.
Scrophularia aquatica,	40	50–60
nodosa,	40	50
Sinapsis nigra,	40–45	50–55
Valeriana officinalis,	30 (vein)	45

* We are willing to admit that in following out these views, anomalies will present

We have found that the angle of the peduncle seems specially to correspond to the angle made by a vein coming forth near the top of the main lateral veins. (See *a* in *Fig.* 25.) Let us here recall the doctrine previously enunciated, (see p. 95,) that the pistil is a leaf folded on itself, as may be seen very evidently in a pea-pod.* If we inspect the interior of such a pea-pod, we shall find the seed coming off very obviously from the top of a lateral vein. We now see that in the leaf a lesser vein, bearing seed in the pea-pod, corresponds in the ramification to the peduncle bearing the flower. This completes the correspondence between the leaf and the plant on which it grows.

4. *There is a correspondence between the curve of the vein and the curve of the corresponding branches.*— Here we must once more insist that every vein and every branch has its normal curve. We have not been able to express this curve in a mathematical formula, but the eye testifies that it has a mathematical regularity, and that there is a correspondence between the curve of the vein and that of the branch.

The parts whose disposition and direction we have been examining, are those which are chiefly instrumental in giving their normal figure to the plant and its leaf; and as the part in the leaf has a correspondence with the part in the branch, it follows that there may be a certain correspondence between the form assumed by the leaf and that towards which the whole tree tends. We use

themselves. Thus, in plants with decurrent leaves, such as thistles, the decurrency of the leaf seems often to make the angle of the vein wider than that of the branch. In the Lombardy poplar the angle of the branches seems to correspond not to the primary but secondary angle of venation. These anomalies will turn out to be as instructive as the more regular phenomena.

* Schleiden, it may be proper to mention, considers this to be a stem pistil. There is a point here, a transition point, at which the correspondence between leaf and branch becomes very close and visible.

the restricted language, *may be a certain correspondence*, for there are special circumstances which may modify the forms of leaf or plant, and make them differ from each other. Where the leaves are pinnate—that is, arranged like the barbs of a feather along a common axis, there is no resemblance between the leafage and whole plant.* This does not prove that leaf venation and branch are not homotypal, any more than the difference between the fore and hind limbs in animals shews that these two parts are not homotypal. And in not a few cases the general resemblance between plant and tree is very visible, as—to take the trees whose outline strikes the eye, and prints itself on the fancy in all our landscapes—in the swelling lime, and the spreading elm, and the heavy-topped oak; and trees which stand upon an unbranched stalk, as the sycamore, with sturdy ribs and swelling chest, and the birch and poplar, with their coma first rotund, and then tapering gracefully to a point. In not a few plants the correspondence becomes minutely, we had almost said ludicrously, exact, and may be detected in the most trivial particulars. Thus the stems of some trees, such as the thorn and laburnum, are not straight, and the branches have a twisted form; and in these plants the venation is not straight, and the leafage is not in one plane—in this respect very unlike the beech. But in the beech there is a no less curious correspondence, for the stems take a turn at every node at which they send off a branch, and the mid-

* We would not speak on this subject with confidence, but it seems to us that when the leaf is pinnate, the tree is *decomposite*—that is, instead of sending up one main axis (like the beech, the poplar, &c.) from bottom to top, it sends off in a scattered way, as it ascends branch after branch, till the axis is lost. We have noticed this in ash, mountain ash, walnut, Mahonias, Acacias, and also Ailanthus glandulosus, Gymnocladus Canadensis, Koelcreuteria, Sophora Japonica, and Robinias, (R. pseudo-acacia and R. viscosa,) &c. We have also noticed a frequent, though, we suspect, by no means invariable, connexion between the doubly pinnate leaf and the umbelliferous structure.

rib of the leaf has a similar zigzag appearance. (See *Fig.* 24.)

Such points as these should be carefully noticed and attended to by the landscape painter and by the pruner. When the commonwealth of taste is properly constituted, one of its first laws will be passed against the common mode of pruning, which cuts trees into all sorts of unnatural shapes, and in particular, pays no regard to each plant's peculiarity of beauty. We can excuse the old Scotch Earl who planted his trees in groups, to represent the position of the troops which gained a victory under him, for if he thereby spoiled the beauties of nature, he at least imparted some knowledge of military art; but those who, in ornamental lawns, form spherical yews and conical laurels—those who force plants to resemble beasts, birds, or fishes—those who give the oak or elm a bare stalk—those who cut over a poplar to make it bushy from the base—those who break off the triplet from the broom or laburnum, or deprive the lime, or the chestnut, or the sycamore of its whorl, should themselves, on the principle of exacting one member for another, be subjected to a similar pruning process, and this because of the offence which they commit against nature without and nature within them.

These observations apply to plants which have leaves veined, unfolded, and presenting a surface to the eye. We now turn to plants which have needle-shaped or linear leaves. Such leaves correspond, we believe, to the individual stems proceeding from the axis or branches. But our observations have been confined to the great family of the Coniferæ, so called because their seed-vessels are cone-shaped. In what follows, our illustrations are to be taken chiefly from pines and firs, the only portions of the large family of cone-bearers which we have had an opportunity of carefully inspecting.

It is obvious, on the most cursory observation, that a unity runs through the whole of the structure of each of this tribe of plants. We may notice first, how the appendages are regularly arranged in a series of whorls (using this phrase in the loose sense previously explained) along the whole axis. There is, first of all, a whorling in the arrangement of the cotyledons, or first springing leaves. Some botanists have represented the cotyledons of the Coniferæ as numerous ; others are inclined to think that there are only two cotyledons, and that each of these is cleft into a number of parts ; all agree that the parts are whorled. Looking to the axis above ground, we observe the same arrangement repeated in the branches, which come out at the nodes in a succession of whorls from the base to the top of the axis. Every node and internode of the pine is of the same construction as every other.

We may notice further, how the whole tree, composed of stem and branches, is made, by the evidently predetermined arrangement of these parts, to assume in its outline a most elegant figure. The form is that of the cone, rounded off gracefully at the base. We are aware that in many cases the lower branches, especially if eaten by cattle, fall off as the tree grows old, and show a bare trunk surmounted by a bushy top : thus, when the lower branches of the broad-topped stone pine fall away, we have that picturesque, umbrella-shaped figure, which so often appears in Italian scenery and Italian paintings. But, in its natural and normal shape, every cone-bearer seems to be feathered from near the root. It is interesting to notice, that if we were to intersect the tree horizontally at any one node, the part cut off above would always be a cone, somewhat similar in shape to the whole tree. This, no doubt, results from the nature of the cone as a mathematical figure; but on noticing the fact, we are the more impressed with the peculiar fitness of the pre-arrangement which makes stem and branches produce so perfect a figure. While the whole family affect this general form, we may observe that every species takes a shape of its own, so that we can at once determine what it is at a considerable distance. Some, like the common sprüce fir, have a sharp apex, and look as if they pointed to heaven; while others, like the stone pine, are broad and bushy, and look as if they delighted to embrace and shelter the earth. There is one beauty of the finely-proportioned cluster pine, another beauty of the sturdy Scotch fir, another beauty of the tapering Douglas fir, another beauty of the graceful Weymouth, another beauty of the shaggy Montezuma, and another beauty of the brawny Coulter pine, as he flings out his arms so powerfully. No attempt should be made, by cutting or bending, to make any one species take the form of any other; all such officious meddling, on the part of man, will only mar the beauty of the Divine workmanship. A lawn is fairest to look on when different species are planted on it, when each is allowed to grow naturally, and has room allotted to it to shew its peculiar type and beauty.

Turning now to the inspection of the seed-vessels, we find them, as their name (cones) denotes, moulded after the same form; nay, the very clusters or bunches of stamens (amenta) are made to assume a conical shape. It is evident that, in this tribe of plants, there is a significancy in this beautiful mathematical figure; and we are inclined to ask whether it was not some mystic perception of this which led the ancient Assyrians to assign so important a place to the cone in those sacred symbols which have become so familiar to us by the researches of Dr. Layard? But without insisting on this, we think we are justified in affirming that the circumstance that the cones, formed of scales, which are modified leaves, and amenta, which are also formed of modified leaves, taking the same shape as the tree, formed of branches, is another illustration of the tendency of leaf and branch to obey the same laws and follow the same dispositions.

Not only is there a general resemblance between cone and tree; we are inclined to think, from a pretty extensive observation, that the full-grown and expanded cone not unfrequently tends to take the shape of the particular species of tree on which it grows. It would require a series of measurements, such as we have not had it in our power to make, to establish this truth scientifically, but a general correspondence is often obvious to the eye. Thus, to take some of the species most marked in themselves, and best known among us. The common Norway spruce is tall in proportion to its width, and so also its cone. (See *Fig.* 27.) The same may be said of Abies Douglasii, which, moreover, has a sharp apex; the cone tends to assume the same shape. In striking contrast is the stone pine, (Pinus Pinea, see *Fig.* 28,) in which both cone and tree are wide in proportion to their height. The cluster pine (P. Pinaster) is beautifully proportioned in its length and breadth, both in

FIG. 27.*

* FIG. 27. Cone of Abies excelsa, bearing a resemblance to a tree, and shewing a set of spirals from right to left, and another set from left to right. These sets of spirals, crossing each other, produce on the surface of the cone rhomboidal figures.

tree and cone. (See *Fig.* 29.) Contrasted with this, both the tree and cone of Pinus pumila have a crushed ap-

FIG. 28.*

FIG. 29.†

pearance. Coulter's pine has heavy, wide-spreading branches, and its cone is of a rotund, bulky shape. The cone of the Labrador pine (P. Banksiana) is often bulged at one of the sides, and any of the trees which we have seen have a straggling, misshapen appearance.

We now proceed to give the result of a series of observations‡ in regard to the dispositions of the scales of the cone and the leaves of the tree.

(1.) The scales are arranged along the axis of the cone

* FIG. 28. Cone of Pinus Pinea; dumpy like the tree, shewing the two sets of spirals crossing each other, and producing rhomboidal figures, whose angles are approximately above and below 120° and 60° at each of the sides.

† FIG. 29. Cone of Pinus Pinaster, shewing the two sets of spirals, and rhomboids with definite angles.

‡ In making these observations, Dr. M'Cosh has examined, with more or less care, nearly every cone in the Museums of Kew, of the Linnæan Society, and of the Edin burgh Botanic Garden, all of which have been kindly thrown open to him.

in a spiral manner. As the basis of the whole, there seems to be a governing spiral—that is, the scales are attached to the axis in a regular spiral. This spiral is at times from right to left, and at other times from left to right, and we have not been able to discover any law determining which of these courses it should pursue ; it certainly is not determined by its position on the tree, or by the course of the sun in the heavens. The scales in this spiral being at equal distances, necessitate mathematically other three spirals, or four spirals in all—one of these, the governing spiral, and another, running in the same direction, and other two in the opposite direction. Sometimes all of these spirals can be noticed ; in all cases two are very visible, one from right to left, the other from left to right. (See *Figs.* 27, 28, 29.)

On comparing the cone with the branch, we find a disposition in the appendages of the latter similar to those of the former. The leaves on the young stem and the scars left when these leaves fall off, form invariably two sets of visible spirals, one from right to left, and the other from left to right.

(2.) The two sets of visible spirals form, by their intersection, a series of very beautiful and mathematically regular rhomboidal figures on the surface of the cone. (See *Figs.* 27, 28, 29.)

The elegance of the whole figure, with these spiral gyrations, which allure on the eye, and these well-defined lozenge shapes on the surface, form the ground, if we do not mistake, of children's predilection for cones. When they gather these so eagerly and industriously, when they play with them for such a length of time, it must be because of some unconscious perception of the visible harmonies—a perception which they could not of course scientifically expound, or even express to others. And it would be well for us in this, as in many other cases, not contemptuously to cast away the simple tastes of our childhood, but rather to cherish them, and put them meanwhile under the guidance of a matured understanding. A pine-cone will reward the study for hours together of the very highest intellect. Here, as in numerous other instances, science, in following up our spontaneous tastes, will unfold wonders on which the reason gazes with profound interest.

If we measure these rhomboidal figures on the surface of the cones of pines and firs, we find that the angles are definite, being approximately 120° above and below, and 60° at the sides. (See *Figs.* 27, 28, 29.) We use the language approximately, because there is often, as might be expected, a departure from the normal angle on the one side or the other, but the actual angles stick so closely, on the one side or other, to the numbers given, that we may regard these as the normal ones. The eye, or rather the intellect, feels a pleasure in contemplating such a figure, made up of two equilateral triangles, and in every respect so beautifully proportioned, and combining an easily observable unity with an easily observable variety.

On the stems likewise, the intersection of the two spirals formed by leaves, and the scars of fallen leaves, forms a series of rhomboids. We cannot speak so confidently of the angles of these rhomboids as of those of the cone, but we have found in many cases that when the leaves have fallen off and the scars are visible, the angles at two of the opposite corners are approximately 120°, and at the other two opposite corners 60°. But there is this difference between the rhomboids on the cone and the rhomboids on the stem, that whereas in the former the angle is 120° above and below, and 60° at the sides, in the latter the angle is 120° at the sides, and 60° above and below. We have found these numbers very often on the stem of a few years old ; as it becomes older the rhomboid is less elongated, but by this time the scars are beginning to disappear, being covered up with the bark.

This arrangement produces on the surface of the cone a series of quincunxes, a figure which has long been regarded as possessing many virtues. Virgil, in his Georgics, in giving directions for planting trees, says, "Indulge ordinibus," and recommends the quincunx.

> "Omnia sint paribus numeris dimensa viarum,
> Non animum modo uti pascat prospectus inanem,
> Sed quia non aliter vires dabit omnibus æquas
> Terra."
>
> VIRG. GEORG. II., 284–286.

Speaking of the same figure, Quintilian says, "Quid quincunce speciosius qui in quamcunque partem spectaveris rectus est." Sir Thomas Browne, in his ingenious though fanciful work, entitled "The Quincunx Mystically Considered," seems to have had pleasant glimpses of the truths to be discovered by the study of the cone-bearers, "Now, if for this order we affect coniferous and tapering trees, particularly the cypress, which grows in a conical figure, we have found a tree not only of great ornament, but, in its essentials of affinity unto this order, a solid rhombus, being made by the conversion of two equicrural cones, as Archimedes hath deponed. But these were the common trees about Babylon and the East, whereof the ark was made." "But," he adds, "the Firr and Pine Tree do naturally dictate this position ; the rhomboidal protuberances in pine-apples maintaining this quincuncial order into each other, and each rhombus in itself. Thus are also disposed the triangular foliations in the conical fruit of the Firr tree, orderly shadowing and protecting the winged seeds below them."

(3.) There is, we have said, a very visible set of spirals going from right to left, and another very visible set from left to right on the surface of the cone. In these sets there is a definite number of spirals. We propose, in the absence of an authorized word, calling the parts or numbers of a set of spirals, *threads*. The number of threads, in a set of spirals in all coniferæ, seems some one of the following numbers, 1, 2, 3, 5, 8, 13, 21, 34, &c., in which scale any two contiguous numbers added together gives the succeeding one. We have already fallen in with this remarkable series of numbers in leaf arrangement; it now casts up once more in a somewhat different, and probably a more fundamental relation. In the case before considered, these numbers were merely the more common ones; in the case now before us they seem to be invariable ones. On the supposition that the spiral, more or less modified, governs the arrangement of the appendages of all plants, we are inclined to look on this series as having a deep significancy in the morphology of the plant.

We have observed that there is a constant relation in the number of threads in the two sets of spirals. Whatever the number of threads in the one set of spirals—say that proceeding from right to left—the number in the other—those proceeding from left to right—is always one or other of the contiguous ones in the above scale. The number of spirals in the two intersecting sets are 1 and 2, or 2 and 3, or 5 and 8, or 8 and 13, or 13 and 21, or 21 and 34. Thus, if the number of threads in the one set of spirals—say that proceeding from right to left—is 5, the number in the other set—that proceeding from left to right—will be either 3 or 8. These numerical relations seem to regulate the sets of spirals in all coniferæ. In pines the number of threads in by far the greater number of species, is 5 and 8. In a few species the numbers are 3 and 5, and in a few others 8 and 13. In Araucauria imbricata the number of threads in the two sets respectively is 21 and 34.

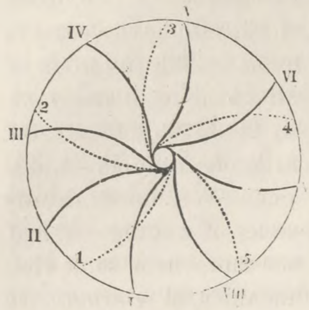


Fig. 30.*

In the disposition of the scars on the stems there are similar numerical relations. Thus the number of threads is one or other of the numbers in the scale, 1, 2, 3, 5, 8, &c., and the numbers of the two sets are always contiguous ones in this scale. Thus, if the number of threads in the one set of spirals is 3, the number in the other will either be 2 or 5. We have remarked, however, that the number of threads in the spirals of the branch is commonly less or lower in the scale than the number of threads in the spiral of the cone. In pines the common numbers for the cone are 5 and 8, whereas the numbers for the visible spirals on the stem are 5 and 3.

(4.) We have found in the cones of pines and firs, (so far as we have examined them,) that all the spirals in one of the sets, and this invariably the one which contains the greater number of threads, take approximately just one turn in going from the base to the top of the cone, that is, each goes round the axis once, and stops at the apex perpendicularly over the point from which it

* Fig. 30. Diagram shewing that two sets of spirals set out from the base of a cone, and that there is a relation between the number of spirals in the two sets. In the diagram the number proceeding from left to right is 5, and the number from right to left is 8.

started. Thus, if the spirals be 8 and 5, (as in *Fig.* 30,) then each of the 8 will be found to have taken one complete turn before it reaches the apex, and if the numbers be 13 and 8, the 13 will be found to have twisted themselves once round the axis. This seems to be the rule followed by the set of spirals containing the larger number. The other set appears also to have a rule. In cones with the ordinary relation between the height and width, that is, where the circumference is greater than the height, the number of turns made by the set of spirals of the lower number is 2, that is, the spirals go twice round the axis before reaching the apex. But in cones whose height is great in proportion to their width, whose length is greater than their circumference, as, for example, Pinus Strobus, Pinaster, excelsa, monticola, Lambertiana, filifolia, and Abies alba, excelsa, Douglasii, the number of turns taken by the spirals is 3.

Such co-ordinated facts as these may possess little interest to the mere technical naturalist, whose sole aim is to discover new genera and species, or the mere practical horticulturist or arboriculturist, whose object is to find plants of commercial value. But they tend to raise up profound reflections in the truly philosophical mind, and open up glimpses to the religious mind of the deep things of God. They shew that the plant, and all its members, had been before the mind of God prior to the time when He said, "Let the earth bring forth grass, the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself upon the earth, and it was so;" "and God saw that it was good." Mathematical figures, more or less modified to suit special ends, make their appearance everywhere among the members of the plant. The mathematical spiral regulates the arrangement of all the appendages of the plant.

Even the lines which man has not been able to express in mathematical formulæ, such as the curve of the veins and branches, and the outline of the coma of a tree, are evidently regulated by models in the mind of the Divine Architect. Numerical relations of a most interesting character cast up among every class of plants, and among all the organs of every plant. All appendicular organs, whether belonging to the nutritive or reproductive system, are homotypes. Nay, correspondences may be detected between the disposition and the distribution of branches and leaf veins, sufficient to entitle us to represent root, stem, and leaf, as homotypes, and to prove that there is a unity of composition in the structure of the whole plant.

SECT. II.—TRACES OF SPECIAL ADAPTATION IN THE ORGANS OF THE PLANT.

Our aim in this chapter is to shew that in the structure of the plant there are combined simplicity of general plan and variety of modification, the latter for special ends. Having endeavoured in the preceding section to demonstrate the first great truth, we are in this section to illustrate the second.

It is evident that stem and common leaves would not suffice to fit the plant for the discharge of all its functions. It needs, among others, organs or appendages for covering, for support, and for enabling it to propagate and perpetuate itself. To meet these wants members are found to spring up at the very place where they are needed, and at the very time when they are needed; and when they appear they come not as absolutely new organs, but after the old type, modified to serve the present purpose. Does the plant demand a covering?—

the leaf becomes a scale, or the cuticle produces hairs for that purpose. Is defence required against external attack ?—leaves or branches become sharpened or hardened at the point, and the whole plant, or the more assailable parts of it, are bristled all over with spines or prickles. That the species may live on in a new individual, the leaf takes a yet greater departure from its type, and becomes a stamen or pistil. The general plan of the Great Architect is kept up, and yet every several member fulfils a purpose. We cannot conceive of stronger or more convincing evidence of design being supplied to human intelligence.

1. ORGANS OF VEGETATION.

The general structure of the leaf has been already described ; we are now to contemplate some well-marked special modifications. The cuticle, or skin, shews numerous small openings, (the stomata of botanists ;) these, like the holes in a barn, keep up the communication between the air and the interior. In the leaves of aerial plants, which have the usual horizontal position, these pores are commonly abundant upon the lower surface, and upon that under surface the skin is also of a more delicate nature ; on the upper surface the stomata are usually less numerous, or even, in some cases, wanting, while the skin is tougher and denser. In leaves, again, which float on the surface of the water, the openings are confined to the upper surface, and in submerged leaves they are wanting altogether. The intervening portion of the leaf, already described, called parenchyma, presents some remarkable peculiarities in relation to the pores we have been describing. Next the upper surface of the leaf, it consists of compact oblong cells, placed perpendicularly and in close contact with each other, the layer nearest the lower surface is less dense, and numerous vacant spaces occur between the cells, permitting free communication, through the stomata or pores, between the atmosphere and the interior of the leaf. We have here, therefore, a striking example of harmony between the structure of this part of the plant and its function and position. The pores are exhaling and absorbing organs; where they are most

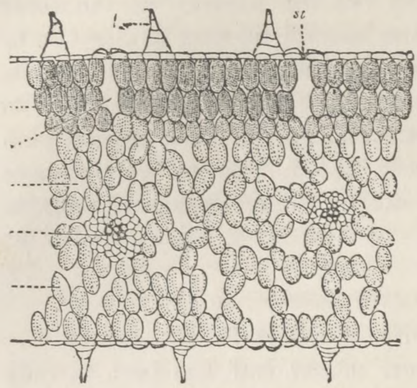


Fig. 31.*

abundant, there we find loose texture of the parenchyma, permitting free communication; where stomata are not needed, they are wanting; when they are required on a particular part of the leaf, there we find them. Many species of Utriculariæ—delicate water-plants—have numerous small sacs connected with the leaves, which are stated, about the flowering period, to become filled with air, and to buoy the plant near the surface of the water. In Pontederia crassipes and Trapa natans, some of the leaves have the stalk dilated into an air cavity, which acts as a float. The magnificent Victoria Regia presents several interesting features. It is an aquatic belonging to the water-lily family, and the fully developed leaf reaches a diameter of five feet or more. In order to give strength to such a large surface, the veins on the lower aspect of the leaf are of great depth, acting as so many

* Fig. 31. Perpendicular section of leaf, to shew different structures of upper and lower portions.

supporting girders. Between them are formed spaces in which air might accumulate and lead to a rupture of the parts; such an occurrence, however, is obviated by the perforations which constitute one of the pecularities of this remarkable plant. By transmitted light the leaf resembles a sieve, with numerous minute openings.

Stipules.—These appendages assume different forms, and vary in size and texture, according to the plant in which we examine them. They are, as already stated, formed after the leaf type, and although we cannot, in every case, point out the purposes served by their modified form, there are, nevertheless, instances in which we cannot doubt that they are present for a useful object. In Lathyrus aphaca they are of large size, and supply the place of the leaves, which are absent in the mature plant. In not a few plants they perform important functions as protecting organs, forming a covering to the young leaves; this is obvious enough in Magnolia, in the Indian-rubber fig, and in the submerged Potamogetons. When the leaves expand, these protective stipules fall off; their function being performed they are no longer needed, and so they disappear.

Covering of plants.—The varied aspect of the external surface of the different organs of plants, so important to the botanist in the distinction of species, and designated by the terms downy, silky, scaly, &c., is owing to the presence of certain minute appendages, the nature of which has been already described. (See p. 86.) In certain cases their presence has some relation to the habitat or dwelling-place of the plant. Those on the upper part of the pistil of hare-bell are well-known to act in collecting and retaining the pollen grains as they drop from the anther. There can be no doubt that in many cases the very minute fibrils on the underground parts of plants, which assist in the process of absorption, are really hairs, and of the same nature of those which cover aerial organs.

Armature.—Plants, like animals, have been provided with organs of defence, varying in strength and in the effects left by them from the simple and almost innocuous prickle of the rose to the formidable sting of Urtica urentissima, the wounds inflicted by which often lead to dangerous or even fatal results. We have shewn in last section that under the term Armature are comprehended modifications of several parts. The spines of the white Thorn and the black Thorn, of which every one has had experience, are branches turned into spear points, to repel all sensitive assailants. In Barberry certain leaves have been sharpened into prickles ; in Holly the leaves have had their secondary veins hardened and pointed effectually—as the mouth of any animal which may attempt to eat them will testify. In Robinia the stipules have undergone a change of condition, to fit them for a similar defensive function. The armature of Nettle and Loasa are modified hairs, as are also the prickles of the rose, and many other plants.

Supports.—This term comprises various modified organs, supplying instances of design as palpable as any furnished by the pillars and buttresses of human architecture. The native tendency of the stem is upwards, but there are multitudes of plants too weak to retain their vertical position ; and to aid them in their heavenward inclination various provisions have been made. At times the stem itself becomes twined round other plants ; this spiral twining may either be from right to left, as in the French bean, Dodder, Convolvulus, &c. ; or from left to right, as in the Honeysuckle and Hop. At other times the same end is accomplished by the superficial appendages of the stem, as, for instance, by the minute hooks on some species of Galium.

Tendrils, varying, as we have seen, in their nature in different plants, but all really referrible to a common type, possess the same properties as twining stems; they twist themselves round other plants, and thus support species too weak to stand in their own strength.

In Dischidia Rafflesiana the *pitcher*-shaped organs are leaves whose margins have become adherent. This plant is a climber, sometimes reaching the top of the loftiest trees, and generally the pitchers are confined to its upper part. It is stated that there, small roots are developed, and these, entering the pitchers, absorb the fluid which is accumulated from the fall of rain or dew; the long straggling stems are thus provided with a means of receiving nourishment at both extremities.

In human architecture we may discover contrivance in the means taken to retain the general symmetry of the entire edifice, while at the same time every part of it is devoted to a useful purpose; and surely the examples we have given indicate the same kind of lofty design, contriving to make organs conform themselves to a general type while they accomplish particular ends essential to the wellbeing of the plant. The cases brought forward belong to the nutritive system of plants; similar examples are furnished by the reproductive economy. But before proceeding to examine these,

Bracts may be alluded to, as forming an evident transition, as we have already shewn, from leaf to sepals, or divisions of the calyx. They are leaves specially modified, and may help the parts of the flower in the performance of their office. This may be laid down as a general rule, though we may not be able in every case to specify with precision their peculiar function. There are very numerous cases in which they serve as protecting organs. In Palms, and other plants, the large sheath which they form, called technically a *spathe*, encloses numerous flowers as yet in an early stage of development. In some Palms it is calculated that there may be thus protected no fewer than 200,000 flowers. In Narcissus, Allium, &c., the bract forms a protecting sheath to the flowers while in a young and tender state, and when these expand it shrivels and decays. In the daisy, and others of the family Compositæ, the numerous florets are protected by one or more series of overlapping bracts. The cup of the acorn is a protecting organ, formed also of numerous overlapping organs of the same nature. Where these parts present much resemblance to leaves, they often, as in Anemone and other plants, serve at first as protecting appendages, and subsequently they aid the leaves in their all-important functions.

II. REPRODUCTIVE SYSTEM.

Calyx.—It is admitted on all hands that the sepals, or pieces of the calyx, though not present in every instance, and therefore not absolutely essential in the economy of the flower, do, when present, perform some good offices. This is true, whether the pieces, in consequence of lateral adhesion, are made to take a tubular shape, or whether they have some other form. There can be no doubt that, in numerous instances, this part not only protects the more internal organs, but likewise assists the leaves in their function. The remarkable, and often very beautiful, hair-like appendages of the fruit (part of the calyx modified), in Composite plants, as the dandelion and others, assist in the dissemination of the fruit and seed: acted on by the wind, these pappose fruits are wafted to a distance from the parent plant, and, when they fall into a suitable soil, become the parents of fresh colonies.

Corolla.—The general office of this organ is very obvious. This whorl of petals serves, in most cases, to support and protect the more vital organs within ; such, at least, is one function which it evidently performs. It is all true, that we cannot in every instance state, with a well-founded confidence, what connexion there is between the form and colour of the individual piece or of the entire corolla, and its use in the economy of the plant. In not a few vegetable organisms, both calyx and corolla are wanting, and in such cases, at least, they cannot be essential organs ; but when present, we may believe that they serve a purpose. It is supposed by some that there is a relation between the colour of the petal and the measure of heat which it absorbs, and which the flower requires. Possibly there may also be a relation between the form of the corolla and the process of seed or fruit production in the species ; but science is not yet prepared to point it out. The brilliant apparatus of the flower acts, we are convinced, as an attraction to various kinds of insects, which, in the act of procuring food for themselves, assist also in scattering the fertilizing pollen, and bringing it into contact with the upper part of the seed-vessel. If we need to seek for any other final cause, we shall find it in the shapes and colours of flowers, as addressed to that love of the beautiful which is one of the most bountiful parts of the wonderful constitution of our nature.

Stamens.—These, with the pistil in the centre of the flower, are the most essential organs of all. Their all-important office is to produce the pollen or fecundating powder necessary to the formation of the seed.

We have pointed out, in last section, the homology of the stamen and its parts. Its departure from the general type is not so great as might at first appear, still it does deviate widely from the leaf, and all to accomplish the very special end allotted to it. The filament which supports the anther is (we have seen) no more essential to that anther than the stalk is to the leaf. This filament, however, does at times assume forms which act an important part in relation to other organs and the general mechanism of the plant. Thus in Kalmia, each anther is kept back by a little hood or hollow in the part of the corolla opposite to it. A slight force—the touch of an insect, for example—suffices to release the anther, when the elastic filament, acting as a spring, brings it forcibly in contact with the upper part of the pistil, the pollen meanwhile being freely emitted. The same object is secured by the elastic filaments of the common nettle, and the irritable filaments of the barberry. Without entering more minutely into the subject, it may be observed generally, that the application of a fertilizing matter being absolutely necessary to the propagation of the plant, it appears precisely where it is wanted; the parts which produce it protect it in the first place, and aid in the final application of it; while the whole apparatus is a special modification of the typical member.

Pistil.—The leaf type is here modified to form an all essential organ. Its functions are to receive and retain the pollen, and the top of the stigma is admirably fitted for such purposes. Another part of the same organ conducts the fecundating matter to the seed-buds or ovules, and affords also to these vital members protection—of a more temporary or permanent kind—till such time as they attain maturity, and reach a locality in which they may germinate into new life. In not a few cases the seed-vessels have appendages which act as wings, and waft them by the aid of the wind to distant localities. In other cases the appendages become floats or protectors, and give us nuts and capsules, which are conveyed by rivers and ocean currents to establish new colonies far from the parent stock. The hooks and other appendages of some fruits make them adhere to the coats of animals, and thus the plant, stationary itself, has its seed disseminated wide as the range of the animal, with its feet and wings. Other instances are not wanting of evident adaptations in the general structure of fruits, and in the properties of their elementary tissues. Thus the ripe fruits of some species of balsam, when touched, suddenly burst and scatter the seeds with considerable force; the squirting cucumber is a still more remarkable case of the same description.

Another final cause, different in kind, comes into view very prominently at this place. He who makes every organ subserve the welfare of the plant, has also made the plant, as a whole, and its individual parts, to promote an ulterior end. It seems very evident to us that certain modifications of the organ under consideration, and others contiguous, have a direct reference to the wants of man and the lower animals. We never can believe that the sugar, acids, oils, starch, and other products formed so abundantly in the fruits of different plants, were not meant to serve as food, and afford sentient gratification to the animal creation. The fruit, in its earlier stages, performs a necessary part in fertilization, at every period it yields support and protection to the young as well as the mature seeds, and when, in addition to these, it presents its beautiful forms and colours to the eye of man, and pleases all sentient creation with its perfumes, and gives satisfaction to the palate, and nourishment to the frame, we are sure that we have before us the modification of an organ for a twofold purpose, the one bearing directly on the economy of the plant itself, and another, and a further, having a respect to the wellbeing of the animal world.

And these ends, be it observed, are accomplished in conformity with the grand regulating principle of type or pattern. In a ripe cherry the kernel is the seed; the hard stone, so admirably fitted for protection, corresponds to the upper cuticle of the leaf—thus singularly transformed for a useful end; the skin of the fruit represents the cuticle of the lower surface of the leaf; the intervening delicious pulp is just an expansion of the cellular substance previously described as lying between the two cuticles; nay, the observant eye will discover that in the line on one side of the cherry, we have the united edges of the typical leaf.

Finally, in the *Seed* itself, that portable epitome of the entire vegetable organism, we find differences in the relative development of different parts, all in decided relation to some special function which has a respect to the continuance of the species, or the necessities of the animal creation. We have alluded to the adaptation of certain parts of fruits to the purpose of protecting the seed; but the seed itself has often an independent means of resisting injury in its hard integument or skin, modified for that purpose. The wing-like appendages of pine seeds, and the abundant hairy covering of those of willows, doubtless aid in their dissemination when they are committed to aerial currents. It may be added, that man finds in the covering of the seeds of the cotton plant an economic product of immense value for his clothing and comfort.

For the better comprehension of special modifications in the seed itself, we would refer to previous remarks,

(p. 82.) Generally speaking, we find two obvious contrasts in the relative development of the internal parts, viz., large cotyledons, and the albumen small or absent, (*Fig.* 8,) and small embryo with copious albumen. In the economy of each individual seed these differences are of vital importance. In germination the cotyledons in some cases (as Lupine) rise above ground, assume a green colour, and, for a time, perform the functions of leaves, finally giving place to the true leaves of the new plant, when these have attained sufficient size; or the cotyledons may remain under ground during the process of germination, as in the pea and bean, yielding up to the young plant the store of nourishment which they contain. Seeds with copious albumen and small embryo have, in like manner, in the former a temporary store of food for the latter.

But further, those parts of the seed which are of such importance in the early economy of the young plant, present also a new relation, viz., to the existence and well-being of man and numerous lower animals. Starch, oil, &c., are products yielded in abundance by seeds; and the hard albumen of some, as the ivory-nut, is turned to a useful purpose in the arts.

To sum up what we have said :—The stem bears up the whole plant, so that the influence of the sun and atmosphere may act through the leaves upon the fluids absorbed by the roots; which roots perform the functions of stays, enabling the whole vegetable organism to resist the action of such physical agents as wind. The law of the spiral, which regulates the arrangement of the appendages, seems to be admirably calculated to expose them to the influences needful in order to the growth of the whole plant. Certain of the special modifications are either absolutely necessary to the existence of the plant, or tend to its wellbeing, such as tendrils for support, scales and hairs for protection, spines and prickles as armature for defence. We also know that some of the varied modifications of the floral organs, namely, the stamens and pistils, are essential to the continuance of the race. It is very evident, too, that regularity in the arrangement of the flowers and of their parts will promote the function of fecundation, and tend to lessen risk of failure in this important end. Even the more common arrangements seem as if they were intended to promote the fertilization of the seed. Thus the stamens of the upper flowers of a spike, (wheat, for instance,) or of a raceme, (as common currant,) may not only fecundate the ovules in the flower to which they belong, but are also well placed to insure the fall of the pollen on those which stand below them. In the spikes of some species of carex or sedge, where the stamens and pistils are often in separate flowers, those at the apex of the spike have stamens only, and those further down pistils only. Again, when species of carex have some spikes with stamens only, and others with pistils only, the former often stand highest. These cases are so uniform and so numerous that we cannot regard them as mere accidental coincidences. There are, no doubt, exceptions, but in all such cases the same end is accomplished by the insects which frequent flowers in search of food, scattering and conveying from one flower to another the fecundating pollen. Again, the regular arrangement of the ovules in the interior of the seed-vessel, will be more likely to give each a better chance of receiving the influence of the matter conveyed by the minute tubes which pass down from the pollen, than indiscriminate jumbling of the whole.

Thus we observe in the vegetable kingdom that special ends are served both by the typical organs and their distribution, and also by the numerous deviations from the type, whatever be the nature and extent of these. It must, however, be frankly acknowledged that we cannot in every instance discover a final cause for every particular part of every plant, or, at all events, that our present knowledge does not entitle us to speak confidently on the subject. But this is not necessary in order to the validity of our argument. In a building we may be able to recognise design in its general style, although not in circumstances to point out the special purpose which every part of it was intended to serve. On the same principle we believe that we are entitled to say that we have discovered marks of design in the plant as a whole, and in its various modifications, even when we may not have arrived at a stage of knowledge which enables us to understand why an organ has assumed one particular form rather than another. It would be a very limited range of contemplation if our attention were confined to the function which individual parts are intended to perform in the vegetable economy. We cannot doubt that there is a relation between the existence of plants and the support of the animal world. In the grass of the field, and the valuable products yielded by fruits and seeds, we can see a provision made by the Creator for supplying the necessities of His creatures.

We go a step further, and affirm that plants were meant not only to furnish food to the animal creation, but were intended to afford them pleasure by their tastes and by their perfumes. It will surely not be affirmed that the organs of taste and of smell were given us merely as means of procuring food, or as sentinels, on guard at the outposts, to warn us of danger. Plants might have been less sapid or less odoriferous without any derangement of the functions which each part fulfils ; and there is surely some ground for concluding that He who planned and made them all superadded those qualities, and instituted a harmony between the sensate and the insensate, for the gratification of animal tastes. Not only so, we think there is good ground for affirming that not a few vegetable forms were meant to gratify the æsthetic feelings of man. We cannot declare with certainty that the forms assumed by the flower, by its calyx and corolla, are in every case necessary to the functions of the plant. We will not affirm that the beautifully rounded form of the peach, the delicacy of bloom on the surface, and the deliciousness of its flavour, are required in order to the production of the kernel and its hard protecting shell. We have no reason to think that the brilliant scales on the wings of the butterfly are necessary to its flight, for the insect, (as any one may observe) can fly after they are mostly all rubbed off, and some Lepidoptera have few or no scales at all ; and just as little ground have we for affirming that the plant could not fulfil its functions even though the flower had not been so ornamented.

Man has æsthetic tastes implanted in his nature ; these are gratified to the full by the lovely forms presented in the vegetable kingdom, and we are convinced that all this was arranged by Him who conferred on man his love of the beautiful, and supplied the objects by which that love is gratified.* And here we have to express our regret that philosophers have not been able to agree upon a theory of the beautiful. If there had been any acknowledged doctrine on this subject,

* Some insist that there is not only the beautiful in plants, (and in animals as well,) but also the grotesque. Granted, but surely we have here a further example of final cause in the relation between the grotesque in the plant and the sense of the ludicrous in man.

there would have been little difficulty in shewing that plants are fashioned in accordance with a very high style of beauty. In particular, we are as yet without any generally received principles in regard to what constitutes beauty of form. In such circumstances we can appeal to no admitted rules, but we can appeal to our own feelings, which declare that the plant, in its general form, and in its corolla, exhibits perfect models of beauty. Here we have an all-sufficient final cause superadded to all the other final causes, bearing more directly upon the economy of the plant, and coming in at the parts, such as the flower and fruit, where these others, to our eyes, might seem to fail.

7

CHAPTER III.

THE COLOURS OF PLANTS.

SECT. I.—THE RELATIONS OF FORM AND COLOUR IN THE FLOWER.

It is a very common impression that there is no rule, no law, for the distribution of colours in the vegetable kingdom.* We are convinced that this is a fundamental mistake. Little, it is true, has been done to establish scientific principles as to the colours of plants. Still, there is reason to believe that system prevails here as in every other department of nature. Laws in regard to the form, structure, number, and position of organs, are familiar to every botanist ; and it is surely not unreasonable to expect that order may also be found in the placing of colours. One of us has been able to furnish a contribution to this branch of inquiry, by discovering evidence of a very curious relation between the form and colour in the corolla in plants.†

In order that this may be understood, it will be necessary at this place to explain certain technical terms used

* We are great admirers of Mr. Ruskin's intuitional power, but the following statements in his Lamps of Architecture are too unguarded :—"The natural colour of objects never follows form, but is arranged on a different principle ;" and again, "Colour is simplified where form is rich, and *vice versa ;*" "In nature," he further says, the "boundaries of forms are elegant and precise ; those of colours, though subject to symmetry of a rude kind, are yet irregular—in blotches."

† See Dr. Dickie's Papers in Sectional Reports of Proceedings of British Association, 1854; and Annals of Natural History, Dec. 1854.

by botanists. The term *regular* is applied to every calyx or corolla in which each *sepal* or *petal* is of equal size and of similar form; in other words, in which all the divisions (whether they are free or adhere to each other by their edges*) are equally and uniformly developed. Every flower in which there is unequal or irregular development of sepals and of petals, is called irregular. It is to the very great difference in these respects that we owe the variety of aspect in the flowers of different species. As examples, the following familiar plants may be adduced;—the pansy has an irregular flower, that of wall-flower is regular; a primrose has a regular flower; a snapdragon presents an example of irregularity.

The following conclusions appear generally to hold good as to the relation of form and of colour in the flower.

1. *In regular corollas the colour is uniformly distributed whatever be the number of colours present.*—That is to say, the pieces of the corolla being all alike in size and form, have each an equal proportion of colour. The common primrose is an example where there is only one colour. In the Chinese primrose the same holds where two colours (the one the complement of the other) are present, the eye or centre being yellow, and the margin purple; these two colours in this regular flower are uniformly diffused, that is, each piece has an equal proportion of yellow and of purple respectively. In Myosotis, Anagallis, Erica, Gentiana, Pyrola, &c., we have uniform corolla with uniform distinction of colour. All Corollifloræ Exogens with regular flowers are examples; the same is true of certain Thalamifloræ, as Papaveraceæ, Cruciferæ,

* It may be necessary to explain that the terms free or adherent, refer to the condition of the mature flower, and not to the mode of development.

&c.; Calycifloral* Exogens with regular flowers, as Rosaceæ, Cactaceæ, &c., illustrate the same principle.

2. *Irregularity of corolla is associated with irregular distribution of colour, whether one or more colours are present.*—In irregular flowers where the number five prevails, the odd piece is most varied in form, size, and colour. When only one colour is present, it is usually more intense in the odd lobe of the corolla. When there are two colours, one of them is generally confined to the odd piece. Sometimes when only one colour is present, and of uniform intensity in all the pieces, the odd segment has spots or streaks of white. A few familiar instances may suffice.

Common Laburnum, ...	Four petals yellow; fifth, yellow, with purple veins.
Trifolium pratense, (common red-clover,)	Odd piece distinguished from the others by its darker purple veins.
Kennedia monophylla,.....	Four petals yellow; fifth, yellow eye and purple margin.
Swainsonia purpurea.......	Four petals yellow; fifth, white eye on purple ground.
Ajuga reptans, (common bugle,)	Four divisions purple; fifth, has yellow spot on inner surface.
Thymus Serpyllum, (wild thyme,)	Corolla generally red purple; two pale spots on the odd piece,
Galeopsis Tetrahit,.........	Four divisions generally yellow; fifth piece has purple spots on yellow ground.
Euphrasia officinalis, (common eyebright,)	Corolla purple generally; odd piece has yellow spot.

In those well-known annuals, Collinsia and Schizanthus, the prevailing colour is purple; the primary, yellow, appears in the odd lobe.

* Thalamifloræ comprehends plants in which there is no adhesion between the whorls of the flower. Calycifloræ comprehends those in which there is such adhesion. In Corollifloræ the petals are united by their edges forming a tubular flower, to the inside of which the stamens partially adhere.

In some genera with irregularity of flower often less marked than in previous examples, it is worthy of notice that the two divisions on each side of the odd lobe frequently partake of its characters as regards colour, half of each resembling the odd piece, as may be seen in Viola, Gloxinia, Achimenes, Rhododendron, and other plants.

3. *In certain Thalamiflorous Exogens with unequal corolla, arising chiefly from difference in size of the petals, the largest are most highly coloured.*—Common horse-chestnut may be mentioned as an example; on each petal there is usually a crimson spot at the lower part; the size of this spot and its intensity are in direct relation to the size of each petal, the two upper being largest, and the two lateral smaller, and the odd piece least of all.

4. *Different forms of corolla in the same inflorescence often present differences of colour, but all of the same form agree also in colour.*—The family of plants called Compositæ, comprehending Aster, Cineraria, Daisy, &c., &c., presents illustrations of this. When there are two colours, the flowers of the centre, usually of tubular form, have generally one colour of uniform intensity; those of the circumference, having a different form, agree together in colour also. Thus the common daisy has all the tubular flowers of the centre yellow, and all the ligulate (strap-like) flowers of the ray or circumference are white, variegated with purple. A yellow centre with a purple ray is a common association in Compositæ; for instance, in species of Aster, Rudbeckia, &c. These principles or laws prevail as well in monocotyledons as in dicotyledons. In the former, the calyx and corolla generally resemble each other in structure and shape, and in colour also. This very close resemblance between the two

whorls has given rise to the idea that there is only one series of external parts in monocotyledons. Relative position must, however, not be overlooked, and hence it is concluded that both calyx and corolla are present. In dicotyledons we generally find a greater contrast between calyx and corolla as regards colour. We may say therefore,—

5. *The law of the contrasts in the colour of the flower is simpler in monocotyledons than in dicotyledons.*— The flowers of dicotyledons may be symbolized by the square or pentagon, four and eight, five and ten being the prevalent numbers in the different whorls; whereas since three and six are generally found in the flowers of monocotyledons, the triangle may serve to symbolize such arrangement. Such comparison is not fanciful on our part, but an actual statement of the mode of illustration adopted by botanists. Thus, in a work by one of the highest authorities of the day,* a series of triangles is used for the purpose of demonstrating, more clearly than could be done by any other means, the true relations of the flower in the families of the grasses, palms, and orchids.

We may state in conclusion, therefore, that *simplicity of figure corresponds with simpler contrast of colour in the monocotyledons, while greater complexity of colour and greater complexity of structure are in direct relation in dicotyledons.*—In all these remarkable co-existences there is surely something more than mere casual coincidences. As the laws of the beautiful have not been detected and unfolded, it is not possible to demonstrate scientifically that the relations we have been treating of are in accordance with æsthetic principles. But the eye at once perceives in regard to some of these arrange-

* Lindley's Vegetable Kingdom, pp. 109, 169, 178.

ments, that they tend to enhance the beauty of the plant. Would not reason be offended if uniform flowers had not uniform colouring? Is there not a propriety, when in an irregular flower there is one petal standing by itself, that that petal should have more brilliant colours, that thus the flower may be tempered together, having more abundant honour in the parts which lacked, that there be no schism in the plant? We are persuaded that were we to put a flower without any colour into the hands of a skilful colourist, and ask him to put on the colours, he would do so on the very principles according to which plants are coloured in nature.

Proceeding on the principle that since plants of all epochs of the earth's history have been constructed on the same general plan, so the same associations of colour, and of colour and form, must have prevailed also, we may finally glance at a few conclusions to be derived from this source.

During the earlier geological periods, when Acrogenous Cryptogamia (Ferns, &c.) were abundant, the secondary and tertiary colours, as green, purple, russet, and citrine, probably prevailed.

During the reign of Gymnosperms, when Cycadeæ and Coniferæ were numerous, the secondary and tertiary colours must still have given a sombre aspect to the vegetable world.

From the commencement of the chalk formation there appears to have been a very marked and progressive increase of Angiospermous dicotyledons, which form the largest proportion of existing vegetation. Among them we find the floral organs with greater prominence in size, form, and colour; and such prominence of the "nuptial dress" of the plant is peculiarly a feature of species belonging to natural families which have attained their maximum in man's epoch, and are characteristic of it. Brougniart,* one of our highest authorities in this department, states that a remarkable character of the floras of the eocene, miocene, and pliocene epochs—which immediately preceded man's epoch—is the absence of the most numerous and most characteristic families of the Gamopetalæ.† Nothing announces the existence of Compositæ, Personatæ, Labiatæ, Solanaceæ, Boraginaceæ, &c.

Doubtless there were lovely flowers in former periods, "born to blush unseen," *at least by human beings*, but we miss those which are our special favourites, and whose cultivation is one of the characteristics of civilized man.

We cannot avoid thinking that there was design in all this, that the succession of created forms in the vegetable kingdom had a reference to the epoch of man; and that just about the time when there appeared an eye to receive and convey the impressions of beauty, and an intellect to derive satisfaction from the contemplation of such, then it was that the most highly adorned productions of Flora's kingdom were called into existence.

SECT. II.—ADAPTATION OF THE COLOURS OF PLANTS TO THE NATURAL TASTES OF MAN.

Artists lay it down as a maxim that a large portion of a painting should be of a neutral colour. Our natural tastes would not tolerate a scarlet or purple ground to a historical painting. In a skilful piece of art the more prominent figures are made to rise out of colours which attract no notice. It is the same in the beautiful canvas which is spread out before us in earth and sky. The ground colours of nature, if not all neutral, are at least

* Annales des Sciences Naturelles, 1849.

† In Gamopetalæ there is adhesion of petals; the flowers are tubular.

all soft and retiring. How grateful should we be that the sky is not usually dressed in red—that the clouds are not painted crimson—that the carpet of grass on which we tread is not yellow, and that the trees are not decked with orange leaves! The soil, in most places, is a sort of brown—the mature trunks of trees commonly take some kind of neutral hue—the true colour of the sky is a soft blue, except when coloured with gray clouds, and the foliage of vegetation is a refreshing green. It is out from the midst of these that the more regular and elegant forms, and the gayer colours of nature come forth to arrest the attention, to excite and dazzle us, not only by their own splendour, but by comparison and contrast.

All the gayer colours of the vegetable kingdom seem to be beautiful in themselves. The eye needs no associated object to lead it to detect a loveliness in the red rose, and the blue harebell, and the yellow primrose. But there are associations of colour in art which have a pleasing effect upon the mind. In our Schools of Design pains are taken to shew what colours may be placed in juxtaposition, and what colours may be kept at a distance from each other. In the construction of tapestry, and other kinds of higher needlework, in the manufacture of our finer texture of fabrics, and in the staining of glass for windows, strict attention is now paid to rules on this subject, prescribed by science and sanctioned by experience. We proceed to shew that in nature colours have been associated from the beginning, according to principles which have become known to man only at a comparatively late date in the history of human civilization and science. In order to explain this, it will be needful to begin with a few elementary statements in regard to light and colour.

According to the commonly adopted doctrine, there are three Primary Colours, Red, Yellow, and Blue. The combination of these, in certain proportions, yields White. The absence of them all is Black. These primaries, mixed together, two and two, produce what are called Secondary Colours, viz., Orange from the mixture of red and yellow, Green from the mixture of yellow and blue, and Purple from the mixture of red and blue. From the combination of the secondaries arise three Tertiary Colours :—Citrine from the mixture of orange and green, Olive from the mixture of green and purple, and Russet from the mixture of orange and purple.

There are certain other phrases which it may be needful to explain in their technical sense, as used by colourists. Tint is employed to denote the gradations of colour in lightness and shade ; Shade to express the gradations in depth from white down to black ; Hue is applied to the mixtures in compound colours. Thus we talk of a light tint of red where the red approaches to white, of a dark shade of purple where the purple inclines to black, and of hues of orange from the yellowest to the reddest, of hues of green from the yellowest to the bluest, and of hues of purple from the bluest to the reddest. When the orange has more than its proper proportion of red, we call it a red orange hue ; when in green the yellow prevails, we call it a yellow green ; and when in purple the blue predominates, we call it a blue purple. This is the common doctrine taught in schools of art ; it is correct enough for the purpose which we have at present in view, and the nomenclature enables us to express, in a rough way, the infinitely varied colours in nature.*

* Newton thought that there were seven simple primitive colours, red, orange, yellow green, blue, indigo, violet. Sir David Brewster has shewn that these can be reduced to three. Some scientific men seem to reckon all such classifications as in some respects

The language of music has been applied to colours; and colourists talk of the Melody of colours and the Harmony of colours. Colours are said to be in Melody when two contiguous tints, or shades, or hues, run insensibly into each other, as when red slides into pink and white, and purple deepens into dark purple or merges into red purple and red. Two different colours are said to be in Harmony when their association is felt to be pleasant to the eye.

Two colours are said to be Complementary when they together make up the white beam. Thus green and red are complementary, as also purple and yellow, orange and blue. The eye feels a pleasure in seeing colours in melody, or melting into each other. It also feels a pleasure in contemplating certain associations of different colours. In particular, the eye is pleased when complementary colours are beside each other, or under the view at the same time.* Complementary colours contrast the one with the other, but are always in harmony. It is necessary to add that white associates pleasantly with every other colour, as does also black.

The accompanying diagram (*Fig.* 32) is constructed with the view of shewing what colours are complementary to each other. In this figure we have the three primary colours, red, yellow, and blue, and the three secondaries, orange, green, and purple, with the hues of the secondaries on either side. We have also the tertiaries, citrine,

arbitrary, and speak of the solar light as composed of indeterminate numbers of differently colored rays. We have no opinion to offer on these points, or any other disputed point, in regard to the nature of colour. But as it is needful to use nomenclature of some description, we adopt the commonly received doctrine as expressing the actual facts very clearly, and with sufficient correctness for the purpose which we have in view.

* Divers explanations, physical and physiological, have been given of this. None of these seems to us to be altogether satisfactory, and it would be beyond our province to discuss them in such a treatise as this. It is enough for us that the fact be admitted, that the eye is gratified when it can simultaneously unite two complementary colours.

olive, and russet. The diagram is so constructed that the colours in corresponding segments of opposite circles are complementary, and so in harmony. Thus, red and

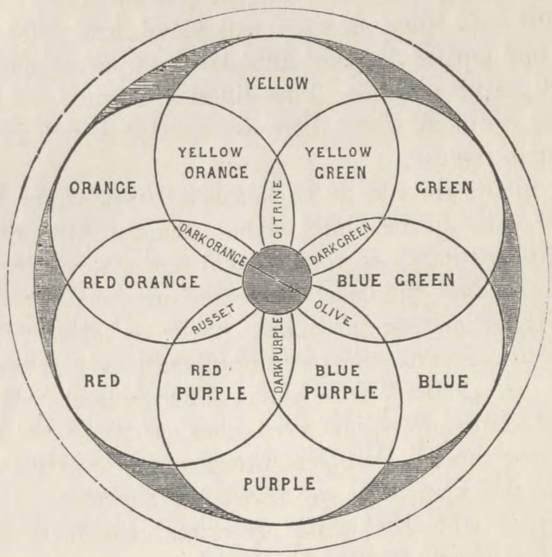


Fig. 32.

green, blue and orange, yellow and purple, are complementary. According to the hue of any particular secondary, so is also the hue of its complement. Thus a pure purple requires a yellow, but a red purple requires a yellow green, and a blue purple a yellow orange, as the complementary colour; and so of all the other secondaries. The tertiary citrine is in harmony with a dark purple, olive with a dark orange, and russet with a dark green.

These principles are taught now in every school of art, and are attended to in the manufacture of all our finer fabrics in which colour is an element of beauty, as in dresses, carpets, hangings, and furnishings of various descriptions. When two colours not in harmony might come in contact, the discord is avoided by placing a line of white or black between them. We are now to shew that these principles are also attended to in the colouring of certain departments of nature. Thus, to take up the three secondaries, green, purple, and orange.

1. *Green harmonizing with red and russet.*—The soft hue which the Author of nature has been pleased to give to the leaf of tree and herbage, is by far the most abundant colour in the vegetable kingdom. Now, wherever the flower of a plant is red, it associates agreeably with the leaf. The flowers of the rose, and of many pinks, geraniums, pelargoniums, mallows, lychnises, and dozens of others, contrast strikingly with the foliage of the plants on which they grow. The eye delights to see the fruit of the cherry, the rose, and the thorn, and the berry of the holly, the yew, the common barberry, the mountain ash, and unnumbered other plants, peeping forth from the green leaves. It often happens that according to the hue of the green so is the hue of the associated red. In a vast number of plants, the young stems and the petioles of the leaves, and in not a few cases the veins of the leaves, are red purple, contrasting with the leaves which are yellow green. The young cones of the larch, in spring, are of a reddish purple, harmonizing with the yellow green foliage. In other cases we find that it is a russet, that is, in harmony with a dark green. In the fir tribe and its allies, the leaves are dark green, and stems are russet. The same colours are the prevalent ones among rushes, and, indeed, in most of the juncous family of plants.

2. *Purple harmonizing with yellow and citron.*—This

is the second most prevalent harmony in the vegetable kingdom. So far as we have been able to observe, purple of various tints, shades, and hues, such as red purple where there is a preponderance of red, and blue purple where there is a preponderance of blue, is the most frequent colour of the petals of plants. In beautiful contrast we often find yellow in the centre of the flower. Thus, in the garden polyanthus, and in many varieties of auricula, the outer rim of the corolla is purple, and an inner circle is yellow. More frequently the complement is found in the yellow anthers or yellow pollen. It is a remarkable circumstance, that as the most frequent colour of petals is purple, so the most common colour of the pollen of plants is yellow. It is curious to notice, that according to the hue of the purple so is the hue of the associated yellow. Thus, in potato and bittersweet (Solanum dulcamara), the corolla is blue purple, and the anthers are red yellow, whereas in polyanthus the outer edge of the flower-cup is red purple, and the heart greenish yellow. In other plants the complementary is not yellow but citrine, a colour not uncommon in matured and decaying vegetation, where it contrasts with a dark purple. Purple and citrine are also commonly associated in the flowers of grasses. The newly-ripened cone of the cluster-pine is citrine ; when the scales open, the complementary purple is revealed on the base of each.

3. *Orange harmonizing with blue and olive.*—This harmony is less frequently met with in the vegetable kingdom, (it is very common in the sky.) Still, there are examples to be found. Thus in several species of Strelitzia, (as S. Reginæ, S. juncea, &c.,) the sepals are orange and the petals blue. A pure blue, however, is rarely to be met with in the flower of any of the

organs of plants. Most of the flowers called blue have more or less of a tinge of red. In such flowers the harmony is often very evident. Thus, the reddish-blue petals of blue lupines and Jacob's-ladders are associated with reddish-yellow anthers. In not a few composite plants, in some Hieraciums, for example, (such as Hieracium aurantiacum,) we may observe an orange disc surrounded by an olive involucre. The olive in some of these plants seems to be produced by purple spots on a green ground.

Not unfrequently the complementary colours may be found on the same organ. Thus, the side of a young branch exposed to the sun is often reddish purple, and the other side yellow green. But it is in the flower that we most frequently meet with the sister colours. They may be seen in many of the popular favourites, both among wild and garden plants. In the flower of the "forget-me-not," which ever greets the eye so cheerfully, there is a border of blue purple, and a centre or throat of orange yellow. In the pansy, so rich and soft that it has got the name of "heart's-ease," we have yellow and purple of various hues and degrees of intensity, brightened by a mixture of white. Eyebright has a purple and white corolla, with a sprinkling of yellow on its odd lobe In many of the universal favourites, harmony of colours adds at least to the effect produced by beauty of form. It is probably the elegant shape and the hanging posture of the flowers of foxglove which allure children to it, but the interest which they feel in it may be unconsciously increased by its purple and white petals, and its yellow anthers adorned with purple spots. The yellow Iris (I. pseudacorus) has a yellow flower lined with purple, and it has purple dots on the yellow anthers. In the daisy, described as "crimson-tipped" by Burns, there is the yellow disc harmonizing both with the white ray and the purple on its tips. These flowers are favourites with all classes—peer and peasant, old man and young maiden, countryman and townsman. They pleased us in our childhood, when we seized them and sought possession of them so eagerly, but found them fading like all earthly enjoyments, and they please us still in our advancing years, as we prefer lazily looking at them, and allowing them to grow where God has planted them, that they may gratify us and others as we pass on in the journey of life. That which has thus endeared them to multitudes is, we believe, to some extent at least, this very harmony of colours, which all feel, because it is intended —it is natural, that we should feel it, but which could not, till within these few years, have been scientifically expressed. We may also notice that yellow and purple are found in close contiguity on the flowers of many of the plants which man has domesticated, and which find a place in every garden, such as Chinese primrose, auricula, polyanthus, mimulus, calceolaria, Indian cress, snapdragon, and marigolds.

But we are not to suppose that the two colours are always to be found on the same organ, or that this harmony is confined to the inflorescence. On the contrary, it appears in a vast number of situations, and we have often found pleasure in detecting it under its various modifications. Frequently one of these colours is on one organ, and its complement on another organ. Very commonly (as we have seen) we have purple petals with yellow anthers or pollen, but at times there is a different order and relation of colours between these two organs. Thus, in several species of poppies (*e. g.* Papaver orientale) the petals are red orange, and the anthers olive. Usually the anthers, or at least the pollen, of plants is yellow ; but in the turn-cap lily, the decidedly red pollen is associated with the green filaments of the anthers, and in Hypericum Androsæmum, we meet with purple anthers, contrasting with the yellow filaments and yellow petals. In Amygdalis communis, the yellow anthers have their complements in the purple filaments. In wood-sage, the purple filaments contrast with the yellow petals.* In some syngenesius plants, there is one colour in the ray, and its complement in the disc ; thus, in Guillardia pinnatifida and Coreopsis Drummondii, the ray is yellow and the disc purple. Sometimes the one colour is in the calyx and its sister colour in the corolla. Thus, in evening primrose, (Oenothera macrocarpa, and also in O. tenuifolia,) the petals are yellow and the sepals purple. In some species of Ranunculus, (R. repens, R. bulbosa, R. Flammula,) the yellow flowers have their complement in purple on calyx, leaf-stalks, or leaf-sheaths on one or other, at times on all. In certain species of rushes, (*e. g.*, Juncus compressus,) the anthers and pollen are yellow, the ovary and stigma are purple, and the edge of the perianth is russet, and the centre dark green. In the paper reed of Egypt, we may observe that the sheaths at the base of the stalks are red purple, while the stalks themselves are yellow green. In some plants the stems and leaves have one of the hues of green, and the spines and prickles the corresponding hue of red. At times the leaf or stalk is one colour, and upon it there are spots of the complementary colour ; thus, on hemlock we may notice red purple spots on the yellow green

* It may be proper to allude here to Count Rumford's principle, that *two colours, to be in harmony, must both present the respective proportions of the coloured light necessary to form white.* In most of the instances we have adduced, it would not be easy to prove a conformity to this principle. But Chevreul, one of the highest authorities on this subject, considers Rumford's statement "as nothing more than an ingenious invention of fancy." (See Paper in Chem. Rep. of Cavendish Society, p. 189.)

stalks. Nay, we have observed that, if there be but a diseased spot or wart on a leaf produced by an insect, the colour of the spot will at times be complementary to that of the leaf, as may be seen in the little galls on the leaves of willows and roses. The scales of young cones are often purple, whereas the scales of the old cones, hanging on the same tree, are citrine. In Victoria regia, we may notice on the leaf (besides the beautiful mechanism by which it is supported) red purple ribs harmonizing with the prevailing yellow green, and in the expanding flower, the red purple calyx harmonizing with the yellow green at the edge of the sepals.*

* This frequent juxtaposition of complementary colours must have a physical as well as a final cause. If it be asked what this is, we are inclined to answer this question by asking another, the answer to which may possibly open up the way to an answer to the first question. When a beam of light falls on a green leaf, the green is said to be reflected and the red absorbed; but what, we ask, becomes of the red? When the beam falls on a purple petal, the purple is said to be reflected and the yellow absorbed; but what becomes of the yellow? Are the red and the yellow in these cases absolutely lost? If these constituents of the beam be lost, they are the only powers in nature which are so. In this world of ours nothing which has existed at any time is lost, even as nothing absolutely new comes into being. It is now a received doctrine, that the heat absorbed by plants in the geological era of the coal measures is laid up in fossil deposits, and may come forth in our epoch when the coal is ignited. May we not suppose, in like manner, that the red absorbed by the plant when the green is reflected by its leaves, will come forth sooner or later, in some form, in young stem, flower, or fruit; and that the yellow absorbed by the flower when the purple is reflected, will come out in the yellow pollen, or in some other form? We have thought at times that as the pure white beam, when it reaches the earth with its atmosphere, is divided into several rays, and that no one of these is lost, and as they all come forth sooner or later, we have thus a harmony of colours in nature. We have thus the brown earth, the ultimate recipient of the rays which have passed through the atmosphere, harmonizing with the blue sky, and ligneous substances become orange when ignited. But we throw out this view as a mere hypothesis in the absence of a better, and in order, if not to guide, at least to stir up inquiry; and we beg that it may be carefully separated from the co-ordinated facts presented in the text. In whatever way we may account for it, there is a most singular succession as well as co-existence of colours in the vegetable kingdom. Harmonious colours come out not only contemporaneously, but consecutively. In several species of Geum, (as G. urbanum and G. intermedium,) the petals are yellow and the pistils purple, but it is not till the yellow petals are falling off that the purple pistils appear. We have the same curious phenomenon in some species of Fragraria. In Cytisus Canariensis, the yellow corolla is followed by the purple pod. In some Cactaceæ, the yellow flower is succeeded by a purple fruit. In Taxodium sempervirens, the young shoots are yellow green, those of a year old are red purple, and those older still, citrine. Generally branches, when young, are green, as they advance they are purple, at a farther stage they are citrine, and finally

These harmonies are found in plants belonging to all the principal divisions of the vegetable kingdom. Thus, among the family of Mosses, the red or red purple teeth of the peristome are associated with the green or yellow green capsule; and the same is true of the different parts of their stems and leaves. Among Fungi, we have Boletus luridus and Boletus luteus with yellow and purple stems. In Lycopodiums, the most common colours are yellow and purple. Among Ferns, we have noticed Doodia aspera with its young fronds red purple and yellow green, and Dicksonia adiantoides with yellow green fronds and red purple stalks. Most exotic Orchideæ have yellow with purple spots, or yellowish green with red purple spots on calyx and corolla. In the flower of grasses, the prevailing colours are purple and citrine, russet and dark green. We have already detected this harmony among rushes, among herbaceous plants, among the cone-bearers, and trees generally.

It is a most interesting occupation to trace it at every season of the revolving year. In spring it is very obvious in the contrast between the yellow green leaf and the red purple of the stalk on which it grows; thus the young leaves of the primrose are yellow green, while the stalks are red purple. At the same season we may notice that the flower of Tussilago is yellow, while the involucre and scales of the stalks are purple. In the summer season the powerful beams of the sun bring forth this harmony in plants of every description. In

russet. Surely these successions are instructive. We have felt a deep interest in noticing how, in a vast number of plants, the colours which make up the full beam do some time or other, separately or in combination, make their appearance during the life or at the death of the plant. There are also curious cases, in which one colour appears in the outside, and its complement in the inside of the fruit. The inside of a nearly ripe fig is red-purple, the outside yellow-green: the same is true of the pericarp in some species of Pæony. The skin of the berry of Mahonias is blue, whereas the interior is orange.

autumn it is very strikingly exhibited in the contrast between the leafage and the berry, and other fruits. Nay, it is often very visible in the fruit itself. Thus in certain varieties of apple, hues of red and purple are associated with hues of green and yellow green, while in some varieties of pear, yellow green, red purple, and citrine occur together. The year dies (like the day) in glory amidst a magnificence of colouring in its phase, in which prevailing hues are greenish yellow and deep red purple, and citrine relieved by dark purple spots. In winter itself, we may see the harmony in those plants which (like friends in adversity) choose that season to shew their beauty ; thus the greenish yellow corolla of the arbutus harmonizes very beautifully with the red purple of the anthers, and also of the flower-stalks. The eye is refreshed in the depth of winter by seeing the red berries peeping forth from the midst of the green foliage of the yew and holly. Thus does the harmony run on till the returning sun of spring calls forth a new cycle.

We may discover in it, if we patiently seek for it, in every description of natural scene. In the grass of the fields we may observe it in the stems, which are often red purple in harmony with the yellow green leafage, and in the purple and citrine of the flowers. Nor can any one walk far in the fields without meeting plants which he has only to examine to discover that they illustrate this conjunction. If the bird's-foot (Lotus corniculatus) catch his eye, he may notice that its lively yellow corolla is relieved by purple on the outside of its large lobe. Or if he pick up the flower of purple clover, he will find that the anthers are yellow. If he carefully examine the common buttercups, he will find that as a set-off to the yellow flower there is purple on the calyx or some other organ. The yellow flower of silverweed (Potentilla anserina) has a visible contrast in the purple stalks and runners. He may notice how the yellow flower of common hawksbit (Hieracium Pilosella) has purplish tips and purple on the outside, and how numberless yellow syngenesious plants, such as dandelion and Apargia autumnalis, grow on purple stalks, and have purple spots on the involucre. Here and there he will discover Symphytum tuberosum, with dull yellow corolla and dull purple stem ; or self-heal, (Prunella vulgaris,) presenting its calyx with russet border and dark green centre, surmounted by blue purple corolla and whitish anthers. Possibly he may be so fortunate as to fall in with a rock rose, (Helianthemum vulgare,) with its yellow petals melodizing into crimson, and striped with purple. In our drier meads he cannot but notice yellow rattle, (Rhinanthus Crista-galli,) with yellow corolla tipped with purple, and Lathyrus pratensis, with purple veins in the large lobe of its yellow corolla ; and in our watery marshes the lousewort, (Pedicularis palustris,) with its purple petals and yellow anthers. In our pools he may meet with the Comarum palustre, with its dark red purple corolla and its yellow green heart. If he wander by our rivulets he may fall in with Geum rivale, with its purple petals, and its abundant and prominent yellow anthers, with its russet calyx, harmonizing with its dark green leaf. If he go forth into our wastes, he will meet with our sedges and rushes with their purple and citrine. In shady and moist places he may see the common loose-strife, (Lysimachia nemorum,) with yellow corolla, and stems and leaves tinged with purple. In our hedges he has the yellow green leaf of the thorn harmonizing with its red purple shoots, and growing up in the midst of them the purple vetch, (Vicia sepium,) with its purple corolla and yellow anthers ; while in the ditch there may be the lovely "forget-me-not," with its reddish blue and yellow orange. If he enter the wood he may see the common anemone, with its purple flowers and yellow anthers, or the leafage of the bush contrasted with its berries, or the cones of the fir and pine contrasted with one another, or with the foliage. If he betake himself to the sea-side, he will fall in with the sea sandwort, (Arenaria marina,) or the common sea-pink, (Statico Armeria,) both with purple corolla and prominent yellow anthers; or the common sea-radish, (Raphanus maritimus,) whose open yellow corolla harmonizes with the unexpanded flower-buds, which are purple.*

We are inclined to think, farther, that there is often a beautiful harmony in the way in which different plants are associated in nature. It is a curious circumstance that the colours of some sea-weeds are red of various hues, and of others are green of various hues, and as these grow together they help to embellish one another. We have heard skilful colourists declare that there is a harmony in the colours of the plants growing together in our finest meads, and our own eye testifies to the same effect. We are quite aware that in our cultivated fields there are often plants growing together with colours that are discordant. We could never discover any beauty in the yellow mustard growing among the green stalks of the farmer's grain. But in nature's own meads, in all places in which she not only grows but is allowed to sow her own plants, she commonly distributes her colours very gracefully. We are not prepared to give the full rationale of this. So far as the herbage is concerned, it may be partly accounted for by the circumstance that yellow and purple are the most common associations in the flower of grasses,

* We would refer to the Appendix for additional examples of harmonious colours in different plants.

and red purple and yellow green in the stalks and leafage. The green foliage, too, is everywhere relieved by red fruit and red flowers, such as wild roses, ragged robins, red campions, and geraniums. In the summer and early part of autumn, there will be buttercups still lingering, and bird's-foot, and divers syngenesious plants, such as ragweed and hawksbit, all yellow or yellow inclining to orange, and in contrast there will be purple clover and scabiouses, and self-heal, and harebell, and common bugle, and thistle, and knapweed, all purple or purple inclining to blue. We may notice, indeed, that in many of our fields some of these colours prevail to an unpleasant extent above the others. Thus in some spots there may be a disagreeable glare of yellow caused by ragwort and buttercup ; but we have noticed that if the progress of agricultural improvement does not interfere with the natural process, the thistles and knapweeds will soon so spread themselves as to restore the proper balance of colour. Nor let it be forgotten that nature lightens the whole scene, and heightens the effect of every other colour by her white flowers, by her daisies, her stitchworts, her chickweeds, her great white ox-eyes, her milfoils, and her meadowsweets. One reason why man loves and longs in these times to retreat from our best cultivated regions to the wilds of nature, is to be found in the circumstance that nature, in her own domains, mingles so gracefully her forms and colours.

We have thus a frequent harmony in the colouring of the individual plant, and a not unfrequent harmony in the colouring of plants growing contiguous to each other. When the plant is near, the eye will naturally fix itself on the complementary colours of the individual plant, and when we are looking at a lawn at some little distance, the eye will rather select the harmony presented by different plants. And here it is worthy of being mentioned, that colourists acknowledge that if there be complementary colours among objects before the eye, it will instinctively fix on them, to the neglect of adjacent colours.

Chevreul, who is the highest authority on the subject of simultaneous contrast of colours, recommends that in planting out flowers in gardens, attention be paid to the rules of complementary colours. "The principal rule to be observed in the arrangement of flowers, is to place the blue next the orange, and the violet next the yellow, while red and pink flowers are never seen to greater advantage than when surrounded by verdure and by white flowers ; the latter may also be advantageously dispersed among groups formed of blue and orange, and of violet and yellow flowers."* But this eminent chemist does not seem to have observed that plants in nature are arranged on these very principles. A skilful colourist, conducted into a garden, planted out on the plan recommended by Chevreul, would at once discover that there were plan and purpose in the distribution of the plants. But there are no less convincing proofs of design in the way in which colours are arranged on individual plants, and in which plants are distributed over our meadows and mountains.

Though it does not fall within our immediate subject, we may here be allowed, as an illustration of the general subject, to remark that traces of harmony of colours may likewise be found in the plumage of birds. The following seem to be the most common forms in which it presents itself. *First*, We often observe some dark colour, at times a black, but more commonly a dark blue,

* See Paper by Chevreul, p. 208, in Chemical Reports and Memoirs, 1848, of Works of Cavendish Society. The same views are more fully developed in Chevreul's great work, "De la loi du Contraste Simultané des Couleurs, (1839.)"

or very blue purple, in harmony with white. Sometimes the white is on the belly or breast, while the dark hue is on the back; at other times there are white spots relieving the dark shade all over the body. This is a common association in our birds of plainer plumage. It may be seen in many web-footed fowls, such as geese, divers, and gulls. The *second* most common harmony—if, indeed, it be the second and not the first—is between a sort of tawny hue, being a yellow, with more or less of red, and a dark blue, or rather dark blue purple. This collocation of colours is very frequent among raptorial birds, as, for example, many falcons and owls, and is found among wading birds and many species of thrushes. *Thirdly*, in our more ornamented birds we discover red associated with green. This congruity appears, and at once arrests the eye, in a great many parrots, in a number of todies, and in the Curucuis, a tribe of birds which live in low damp woods in the tropical parts of America and Asia, and feed on insects and berries.

These seem to be the more marked associations, but these three forms run into each other. Thus, some hornbills are dark blue and reddish yellow, but others have white instead of yellow. This is also the case with some of the raptorial birds. In the plumage of some fowls the reddish yellow seems to be a pure orange; this seems to be the case with some toucans—other toucans seem more nearly green and red. The same may be said of many solitary warblers, fly-catchers, and starlings. In some birds the red yellow is brightened into a scarlet, harmonizing with a greenish blue; this is a very common association among chatterers and finches. The scarlet ibis has the greater part of its plumage of the hue which its name denotes, but has a greenish blue on its wings. Among pheasants we often discover a red orange and a blue green, and the same colours, differently distributed, appear on our more ornamented ducks. In reviewing these associations we may notice that we have, on the one side, white rising into yellow orange and red, and on the other side blue sliding into purple or green.

We have not paid special attention to the subject, but similar harmonies prevail, we doubt not, in other departments of nature, as, for example, among insects. Any one may notice the yellow and purple on bees and wasps. The most cursory glance is sufficient to shew that many shells of mollusca are characterized by a yellow ground adorned with purple spots. In another department of nature it has been remarked by Field that the brown earth harmonizes agreeably with the blue sky.

Surrounded as we are by such harmonies, we are convinced that whenever the mind seeks for them it will discover them ; nay, the eye fixes on them when it is not designedly seeking for them, and rejoices in them when it can give no account of the cause of its joy. At the same time, the contemplative intellect experiences a farther pleasure, and a pleasure of its own, when it can scientifically explain to itself the source of all this enjoyment, and systematically look out for the pleasing associations of nature.

The heart, rightly tuned to the praise of its Maker, will experience a farther pleasure. Present to a skilful colourist an article of human workmanship, constructed according to the rules of simultaneous contrast in colouring, and he will at once say, Here are art and design. Place before him a piece of Gobelin tapestry, one of our finer carpets, or the stained glass of a window, and he will perceive at a glance that the associations of colour are not accidental, but that they are purposely suited to the physiological and psychical nature in man. We are convinced that there are equally clear proofs of contrivance in the colouring of natural objects, organic and inorganic. Indeed, colourists, long ago, observed that there was a beautiful harmony in the colours of nature; and within the last age, Field and Hay, and very possibly others, have stated what is the nature of this harmony, though they have not followed it into the various departments of natural history. He who can trace up all these adaptations to Him who causes His works to make sweet music by their harmony, has surely here a source of higher—we should rather say, of highest joy.

But the question is here started, Are there no colours associated in nature except harmonious ones? This is a question which we are not prepared dogmatically to answer, either in the negative or positive. One thing, however, seems to us very certain, that complementary colours appear so often in nature, and cast up, under such different modifications, and in such a variety of objects and situations, that their conjunction cannot be the result of mere chance. Besides the generalized facts of a positive character, we are prepared to say negatively that we have never observed in a corolla, or in any one organ of a plant, pure red and pure yellow, or blue and red, in contact with each other.* But in making these affirmations we are, at the same time, prepared to admit that there are colours in nature in juxtaposition which are not complementary. This, however, just raises the question, Can no colours be pleasantly associated except complementary colours? This question must be answered in the negative, and being so answered, a host of inquiries

* The same statement was made to us by Mr. Wood, an experienced flower painter, and lately assistant master in the Belfast School of Design. He farther informed us that he invariably found associations of harmonious colours in the different parts of plants, such as we have been describing.

come to be made as to what other associations are agreeable, and these should be followed by a series of investigations, having it for their end to discover how far all the non-complementary associations of nature can be described as pleasant. Chevreul tells us that we cannot prescribe arrangements of non-complementary colours, so as to please the eye, in as positive a manner as may be done with reference to the assortment of complementary colours. "This is the reason," he adds, "that in treating of the distribution of flowers in gardens I have only recommended an assortment of flowers whose colours are complementary, at the same time that I admit the existence of many other assortments productive of a very agreeable effect."* This whole subject is just opening upon us, and we must be satisfied for the present to substantiate a certain amount of truth, to acknowledge that there are unsolved points and difficulties, and trust that these may be cleared up by further investigation.

We must here state, however, that many of the seeming exceptions to these general views, are exceptions merely in appearance.

It not unfrequently happens, in the vegetable kingdom, that the discord between two contiguous colours is subdued by a patch of white, which, like innocence, (of which it has always been reckoned an emblem,) has never occasion to be ashamed of itself, for it may appear anywhere, and is in harmony with every object it can meet with. In Lycopsis arvensis, in harebell, and speedwells, the blue of the petals has no complementary orange, but then it is beautifully relieved by an adjacent white.

It may seem as if the leaves of plants were liable to be seen simultaneously with every other colour in the vege-

* See in works of Cavendish Society, Chemical Reports and Memoirs, 1848.—Paper by Chevreul, p. 219.

table kingdom, that there must be discord when the green leaf is perceived at the same time with the yellow and blue of the flower. Chevreul, in speaking of the artificial arrangement of flowers in a garden, lays down a rule which enables us to escape the difficulty. "I must, however, reply to the objection that might be made, that the green of the leaves, which serves, as it were, for a ground for the flowers, destroys the effect of the contrast of the latter. Such, however, is not the case; and to prove this, it is only necessary to fix on a screen of green silk two kinds of flowers, (in the manner pointed out in the paper,) and to look at them at a distance of ten paces. This admits of a very simple explanation, for as soon as the eye distinctly and simultaneously sees two colours, the attention is so riveted that contiguous objects, especially when on a receding plane, and where they are of a sombre colour, and present themselves in a confused manner to the sight, produce but a very feeble impression."*

Nor is it to be forgotten, that the coloured flowers of many plants are raised out from the midst of their leaves, and are so far above them that the petal and leaf do not come simultaneously into view in a marked manner. This is the case very obviously with harebell, dandelion, hyacinths, and many other plants. In such cases, it may be found either that the flower has a beauty of its own independent of any adjunct, or that it has a harmonizing concomitant in some other plant usually growing in the neighbourhood.

More important than any of these, we find that there is a physiological provision in the eye itself, which helps it to overcome any slight defects in the balancings of the colours in nature. Chevreul lays down the law, that in

* Chevreul's Paper on Chemical Reports, p. 207.

the case of the eye seeing at any time two colours which are in contact, they will appear as dissimilar as possible. In other words, on two colours being seen simultaneously, the complementary of the one will be added to the other. Thus, if a yellowish green leaf and a red flower be under the view at the same time, the yellow green will thereby be more inclined to green, and the red will acquire a slight tinge of blue, and the two will be brought more nearly into the complementary state. In this way the eye itself can rectify any slight defect in the harmonies of adjacent colours.

CHAPTER IV.

THE VERTEBRATE SKELETON.

SECT. I.—THE HOMOLOGIES AND HOMOTYPES OF THE VERTEBRATE SKELETON.

In the last age there raged a famous scientific controversy, which may be summarily represented as a dispute as to which of the two great principles which we are unfolding should be detected in the animal frame. The illustrious Cuvier, in building up the science of comparative anatomy, proceeded, in all his investigations, on the principle that every particular member of the body had a special or final cause. On the other hand, the great Geoffroy St. Hilaire, first the co-operator and then the rival of Cuvier, delighted to trace a unity of plan running through the bones of the skeleton. In 1830, this controversy came to a public explosion, which was viewed with intense anxiety by all interested in natural science, and in particular by the poet Goethe, who proclaimed it to be a far more important event than the French Revolution, which was ringing that same year in the ears of Europe. In conducting the dispute, extreme positions were taken by both sides. Attached to the principle of final cause, and having found how prolific it was, in his hands, of brilliant discoveries, Cuvier was not willing to admit the theory, (though he helped greatly to establish the fact,) that there is in the skeleton a general correspondence of parts, which can have no reference to the wellbeing of the animal, or the special functions of the organ. Geoffroy St. Hilaire, on the other hand, did not see that his doctrine of analogy was perfectly consistent with teleology, and he connected his theory of unity with the untenable doctrine of the transformation of species. This dispute should now be regarded as settled, by the establishment of both doctrines—both that of general homology and that of special teleology; and the former, we are convinced, will be found, when properly interpreted, to yield as rich a contribution to the cause of natural theology as the latter.

Any one may convince himself, very easily, that in a general sense there are model forms in the construction of the skeleton. He will see at a glance that every species of animal has its normal shape, and this is, to a considerable extent, determined by the length, thickness, and relative position of its bones. In the human frame, there are organs which have been used as standards of measurements, which they could not have been unless their size had been approximately definite. The length of the arm, from the elbow to the tip of the mid-finger, furnished the cubit to many nations of antiquity. The hand-breadth and the span were measures among the ancient Hebrews. In not a few countries the stretch of the arms, the pace, the palm, the breadth of the thumb, have been used to indicate linear measure. Among artists the human frame has long been known to have proportions in its members. The visible outline of the head in front is divided into four equal parts;—the first, from the top of the head to the setting of the hair; the second, from this to the root of the nose; the third, the nose; and the fourth, from the lower part of the nose to the chin. The height of the figure is found to be eight heads; the first reaching from summit of head to chin, the second from chin to breast, the third from breast to navel, the fourth from navel to top of thigh, the fifth to middle of thigh, the sixth to knee, the seventh to the calf of the leg, and the last to the heel. The body is thus divided into two equal parts—one from head to hip, the other from hip to heel. The length of the frame is also known to be equal to the line drawn from finger-tops to finger-tops of the outstretched arms.

But without dwelling longer on these general topics, we proceed to shew, in a scientific manner, that the vertebrate skeleton consists of a series of pieces constructed on a common plan; and in doing so, we shall largely avail ourselves of the masterly researches of Professor Owen, who has done so much towards the completion of this most interesting subject.

We know that the skeleton is not a peculiarly interesting object to an untutored eye. It has been associated, in the minds of many, with the grave's mouth and mortality. It possesses in itself no physical beauty; it is meant to be wrapt up from the view by a covering of flesh and muscles, which are made, for our gratification, to present themselves in full and rounded forms. Still, to minds which are fitted to penetrate beneath the surface, it has become an object of intense interest, and is felt to possess not a little beauty. The reason is, that there has been a perception of the unity of the structure along its whole length, and from the highest to the lowest animal in the class, and of the suitableness of the infinitely varied parts to their infinitely diversified functions.

Each of the series of parts which makes up the vertebrate skeleton is called a Vertebra. It will be sufficient for our purpose to indicate here the principal parts of the *typical vertebra*, without entering into those more minute details which are necessary for the purposes of the comparative anatomist; for these details we would refer to Professor Owen's paper on the Megatherium, in the Philosophical Transactions for 1850.

Typical Vertebra consists of a centre or body, around which are arranged other pieces, (called technically apophyses, or projecting parts,) so as to form two principal arches, one superior,* the other inferior. The upper arch gives protection to nervous matter, and is hence called neural: it is bounded on each side by two principal pieces, called neurapophyses, and is closed above by the neural spine, so called from its frequently pointed form; (it is, however, sometimes bifid.) The lower arch, called hæmal, protects blood-vessels, &c., (hence its name, from Greek, *haima*, blood;) it also consists of lateral pieces, called respectively pleurapophyses and hæmapophyses, and is closed by the hæmal spine, which, like the neural spine, is sometimes cleft. The body of the vertebra may be considered the foundation of the arches, and the neural and hæmal spines represent, in position, the keystones of each. Sometimes the upper arch comprehends a pair of bones, called diapophyses, and the lower an additional pair, called parapophyses.

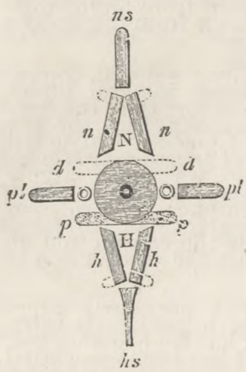


FIG. 33.†

* In the erect position of man, these are respectively posterior and anterior.

† FIG. 33. *Typical Vertebra; ns*, neural spine; *n*, neurapophysis; N, neural arch; *c*, centrum, or centre piece; *pl*, pleurapophysis; *h*, hæmapophysis; *hs*, hæmal spine; H hæmal arch; *d*, diapophysis; *p*, parapophysis.

Generally speaking, it is not difficult to demonstrate, that in the chain of bones extending from the head to the tail inclusive, we have a series of pieces partaking of the nature of the common typical structure just described. It is true that some present a near approach to the model, while in others the rea. nature of the parts is considerably masked, so that careful examination is necessary to show the relation. Knowing the type, however, we can explain all departures from it, whether owing to omission or contraction, adhesion or complication of pieces.

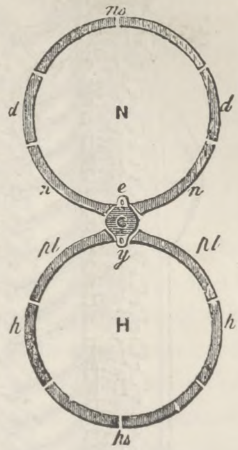
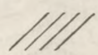
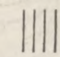
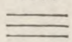


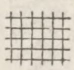
Fig. 34.*

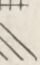
As there is a model vertebra, so there is an archetype skeleton, and we shall transfer to our pages the instructive diagram given by Professor Owen in his work on the "Homologies of the Vertebrate Skeleton." The elements of each vertebra are indicated by the peculiar shading,—

n, neurapophyses, . thus 

d, diapophyses, . . thus 

p, parapophyses, . . thus 

c, centre or body, . . thus 

pl, pleurapophyses, . thus 

ns, neural spine, and *hs*, hæmal spine, are left unshaded, the appendages are represented by dots.

* Fig. 34. The relations of the parts in *Fig.* 33 will be rendered more evident by comparing it with *Fig.* 34; the references are the same in both; *y*, hypapophysis; *e*, epapophysis.

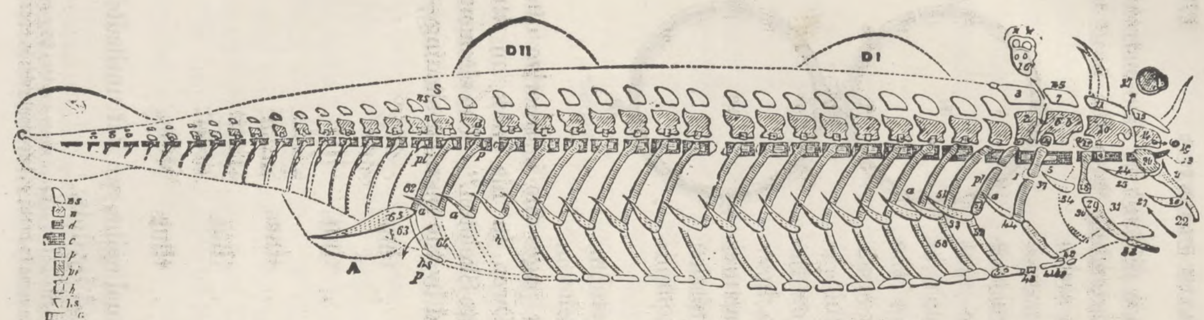


Fig. 35.*

* Fig. 35. Diagram of *Archetype skeleton* of vertebrate animals, according to Professor Owen :—2, exoccipital; 3, supraoccipital,—these form the neural arch of the occipital vertebra; the hæmal is formed by 51, scapula or shoulder-blade; 52, coracoid bone; 53 is the anterior limb, supported by this hæmal arch; 6, alisphenoid; 7, parietal, forming the neural arch of the parietal vertebra; the hæmal consists of the linear series immediately in front of the hæmal arch of the previous vertebra; 42 and 41 closing the arch below.

The neural arch of the frontal vertebra is formed by 10, orbitosphenoid; 11, frontal; the hæmal consists of 28 to 32.

The nasal vertebra has its neural arch formed by 14, 15; the hæmal consists of 20, 21, and 22.

The centre of these four vertebræ of the head are represented by the numbers 1, 5, 9, and 13.

62, 63, represent iliac and ischiac bones, forming the principal part of the pelvis, P; 64 is the pubic portion of the pelvis, being a hæmapophysis of one of the vertebræ of the loins; 65 is the hind limb; numbers 24 and 37, and pieces marked *a*, are lateral appendages; 16, the ear; 17, the eye; 19, the nasal organ. The hard appendages of certain animals are also given in outline; 15, horn of Rhinoceros; 11, horn of Ruminants; DI, DII, dorsal fins of fishes and whales; C, tail fin; A, anal fin of fishes. The arrow in front indicates the mouth, the one behind indicates the anal opening.

The skeleton of every vertebrate animal is constructed on this plan, a series of homotypal parts, each as represented in Fig. 33, typical vertebra.

The four anterior vertebræ constitute the skull or brain-case; the first is called *nasal*, because it supports and protects the organs of smell; the second is named the *frontal* vertebra, corresponding to the forehead; the third is the *parietal*, from Latin *paries*, a wall, because its elements chiefly form the sides of the skull; the fourth is denominated *occipital*, corresponding to the occiput, or hind-head. Succeeding these we observe a series of pieces forming the bony framework of the neck, chest, abdomen, loins, and tail.

Generally speaking, we observe the following peculiarities in these different regions respectively; in the head the neural arch is highly enlarged in order to protect the brain, in the neck and succeeding regions the same arch is only moderately developed in correspondence with the size of the spinal cord. In the trunk it is the hæmal arch which attains largest dimensions, its functions being to guard the larger blood-vessels and viscera. In the tail both arches are generally suppressed, and the body of the vertebra alone remains.

It is admitted that the bony framework of man deviates very considerably from the archetype, but as "more than ninety per cent. of the bones in the human skeleton have their homologues (or namesakes) recognised by common consent in skeletons of all vertebrata,"* if it can be shewn that the skeleton of man consists of a series of similar pieces, and may be referred to the archetype, it will be obviously unnecessary to occupy space in discussing the same points regarding animals lower in the scale; these last, however, will afford examples not a few under the special branch of our subject.

Since the day when Oken saw the bleached skull of a deer in the Hartz forest, and exclaimed, "It is a verte-

* Owen, Lecture at Royal Institution, January 1847.

bral column," the idea that the brain-case is really made up of vertebræ has been fully tested and matured by anatomists of the highest authority, among the most conspicuous of whom is our own countryman, Professor Owen. There has doubtless been difference of opinion as to the number of vertebræ composing the skull, but respecting its general construction there is agreement among the best authorities.

FIRST, OR NASAL VERTEBRA IN MAN.—The *centrum* or *body* is the bone called *vomer*; the *neurapophyses* are formed by the perpendicular plate of the ethmoid bone, which, in reality, consists of two pieces united together; the neural arch is thus obliterated; the *neural spine* is bifid, and is represented by the two nasal bones. The inferior arch of this vertebra is composed as follows:—the *pleurapophyses* are formed by the palate bones; the *hæmapophyses* are the bones of the upper jaw; the *hæmal* spine is divided, and consists of the intermaxillary bones which support the front or incisor teeth.

SECOND, OR FRONTAL VERTEBRA.—The *centrum* is formed by the presphenoid bone; the orbito-sphenoids are the *neurapophyses;* the frontal bone forming the expanded brow in the human head, is the flattened *neural spine;* in the inferior arch the ring of bone, called by osteologists the external auditory process, is the *pleurapophysis;* the lower jaw represents *hæmapophysis* and *hæmal spine.*

THIRD, OR PARIETAL VERTEBRA.—The *centre* is formed by the basisphenoid bone; the alisphenoids are *neurapophyses;* the parietal bones form the cleft and expanded *neural spine;* the styloid pieces of the temporal bone are *pleurapophyses;* the lesser cornua of the hyoid bone (lying in the upper and fore-part of the neck) are *hæma-*

pophyses; the body of the same bone forming the *hæmal spine*, and thus completing the arch.

Fourth, or occipital vertebra.—The basilar piece of anatomists is the *centre;* the sides which bound the opening in the occipital bone, through which the upper part of the spinal cord is continuous with a portion of the cerebral mass, constitute the *neurapophyses* surmounted by the expanded *neural spine.* The lower or hæmal arch of this vertebra is removed from its natural position in man, as in most vertebrata—the reason of this will be discussed in a subsequent paragraph. The scapulæ or shoulder-blades are the pleurapophyses; their appendages, called coracoid processes, constitute the hæmapophyses; and the hæmal spine is wanting.†

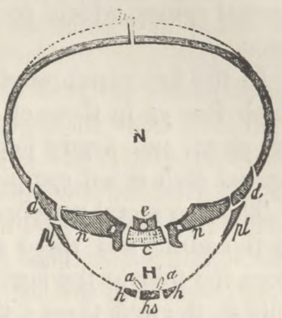


Fig. 36.*

The seven vertebræ of the neck are admitted to possess the general elements of the typical vertebra, the parts, however, are generally considerably modified in relation to the functions of that portion of the frame to which they belong.

The vertebræ of the back are twelve in number; the neural canal in each is sufficiently obvious, and of moderate size; the hæmal arch is highly enlarged; the ribs

* Fig. 36. Parietal segment, or vertebra of man. The neural arch is ample, (N,) to protect part of the brain: the hæmal (H) is contracted. In this case the diapophyses, *d*, are wedged between the neurapophyses, *n*, and the large neural spine, *ns; e* is a piece called epapophysis, which lies upon the centrum, *c; a, h,* and *hs* represent the parts of the hyoid bone suspended in the upper and fore-part of the neck, and closing the hæmal arch.

† In order to simplify the subject, we have omitted reference to diapophyses and parapophyses.

are the pleurapophyses, succeeded by the hæmapophyses, or cartilages of the ribs, and finally closed by the united hæmal spines, which constitute the sternum, or breast-bone.

In the five vertebræ of the loins, the elements are not so obvious as in those of the back. The pleurapophyses are short, and firmly joined to the central portion ; the hæmal arch is not completed by bony elements.

The five sacral vertebræ have their bodies firmly joined in the adult, and these same elements diminish in size from the first to the last. The neural arch is complete only in the first three ; the neural spines of the last two are absent. The hæmal arch of the first sacral vertebra is usually considered as formed of that part of the pelvis called ilium ; the portion called pubis is a hæmapophysis; the ischium is the hæmapophysis of the second sacral vertebra.

The four or five succeeding and terminal pieces of the back-bone in man, correspond to the tail in the lower animals, and for the most part consist of the centra only.

Such is a brief summary of the generally admitted views held respecting the nature of the human skeleton, (exclusive of the limbs, which will occupy attention in subsequent paragraphs ;) and as such have been, in many instances, arrived at by comparison with the bony frame-work of animals lower in the scale, it is unnecessary to allude to these under this department of our subject.

While, therefore, the entire skeleton in every vertebrate animal is constructed according to a common plan, and the series of vertebræ of which it consists may all be referred to one model, it appears to us that there is good reason for proceeding a step farther, and coming to the conclusion, that unity of form also prevails in the individual pieces of the typical vertebra and its appendages.

We may first allude to the appendages or limbs, as affording the most evident indications of such unity. If we take, as the typical form, a bone of the hand (metacarpal,) or of the foot (metatarsal,) we shall find that there is a striking resemblance to it in all the elements of every limb.* This typical bone may be described as having a nearly cylindrical shaft, dilated towards its two extremities. The large cannon bone in the foot of the horse (see *Fig.* 43) may serve to illustrate the form alluded to. Now, this is the prevailing shape in all the principal bones of the limbs. In man, for example, such general outline exists in the bones of the arm, fore-arm, hand and fingers; in thigh, leg, foot, and toes. The short and frequently irregular bones of the wrist and ankle present the greatest departure from the type; but in some animals the relation is obvious enough. Thus, in the common frog, certain of the ankle-bones (calcaneum and astragalus of anatomists) assume exactly the typical form.

In the individual pieces of the vertebra itself, we shall find evident traces of similarity to a typical form. The centrum, or body of the vertebra, presents a close approach to the model in the caudal part of the skeleton. This is evident in a great number of instances. One may suffice: the bones of the tail, in the young African elephant, consist of centrum only, and each very much resembles in form a metacarpal or metatarsal bone.

* It is a fact worthy of notice here, that the same form of an organ appears in plants. For example, the stalk which supports the leaflets of species of Æsculus, the horse-chestnut, exactly resembles a bone of the hand or foot; and in the manna-ash, we have four or more pieces of like shape forming the main stalk of the compound leaf, separating at the joints, and resembling a series of phalanges, as in a finger or toe. The same general outline is often visible in the bole of well-developed trees.

The elements of the inferior or hæmal arch present very clear examples of conformity to the type. Pleurapophyses or ribs are not always curved and *flat* bones, such as we see in Mammalia generally, and in the New Zealand bird called Apteryx. In not a few instances, especially certain aquatic birds, (the guillemot, for example,) the ribs are narrow and cylindrical, and bear considerable resemblance to the lengthened bones of the fingers which form the framework of the bat's wing. The numerous ribs of the boa and other serpents, differ from the model only in being curved. The shoulder or scapular is a pleurapophysis, (sometimes with conjoined hæmapophysis.) In man and mammalia generally it is broad and flat, but in many birds it is long and narrow, exactly like a rib ; and since, in some aquatic birds, the ordinary ribs very much resemble the model shape, we have thus transitional forms conducting us to the original type. The pelvis, intended to support and protect important viscera, and give attachment to powerful muscles, shews also striking departure from the model. But in the frog, the iliac bones (pleurapophyses) very much resemble the typical form. We have evident examples of likeness to our assumed model in the other elements of the lower arch, viz., the rib and its cartilage, (pleurapophysis and hæmapophysis.) Mere curvature of the parts, so as to assist in the formation of an arch, cannot be considered as very materially affecting the conclusion to be drawn. As regards the hæmal spine, it would not be easy to recognize any conformity to a primary shape in the sternum or breast-bone of man or of a bird; but in many animals, such as the lion, elephant, walrus, greyhound, &c., this part of the skeleton consists of a linear series of pieces, exactly resembling the typical form.

In the elements of the superior or neural arch, the departure from the model is generally greater and more constant than it is in the lower or hæmal arch. The flat bones of the skull deviate widely from the type, but not more so than the shoulder blade or the pelvis, both of which, as we have seen, present transitional forms. The very important functions of the brain-case, as a protector of the important parts within, necessarily imply a great and constant deviation from the model form. If we examine the principal element of the neural arch (neurapophysis) of any large vertebra, as in the baleen-whale, or in the finner, we see that, after all, it may be referred to the same general form which ribs assume, and they, as we have seen, can be traced to a model bone. The neural spine is indirectly referable to the same type, and by similar steps. We observe it in the dorsal region of ruminants, and other animals attaining great length, and resembling a rib, being, however, straight. There is but little difference in form between the longer neural spines of the dorsal vertebræ in the horse, and the first rib of the same animal.

On the whole, we think there are evident traces of community of form in the parts of the typical vertebra. The subject is interesting, and merits attention and further investigation by those favourably situated for opportunity of examining and studying the forms and transitions in an extensive series of skeletons.

There are not only proofs of general order as regards reference to a typical bone, vertebra, and archetype skeleton, but there are some well-established facts respecting the *number* of the vertebræ themselves. Those entering into the formation of the brain-case in mammalia are four, those of the neck are seven, except in the case of the three-toed sloth, which has nine, and the manati, in which only six are said to exist.*

The dorsal vertebræ are usually considered as characterized by the presence of long, arched, more or less moveable, pleurapophyses or ribs, and, taking such as a mark of distinction, we find that their number varies in different cases.

In most carnivorous or flesh-eating animals, the number of vertebræ of back and loins together is very constant, though the exact number of those called dorsal presents variations, as the following examples will shew: †—

	BACK.	LOINS.	TOTAL.
American Black Bear, . .	14	6	20
Dog, ...	13	7	20
Panther, ...	13	7	20
Spotted Hyæna, . . .	15	5	20
Glutton, ...	15	5	20

According to Professor Owen, all mammiferous animals, called Artiodactyles, as the ox, &c., having either two or four toes, agree in having nineteen vertebræ between the neck and the sacrum; this is remarkable when compared with the odd-toed group, usually called Perissodactyles, which present great irregularity in the number of the corresponding vertebræ, there being, for example, twenty-two in Rhinoceros; twenty-three in Tapir and the Palæotherium; and twenty-nine in Hyrax.

DIVERGING APPENDAGES OR LIMBS.

These constitute the limbs of animals, which are just lateral appendages of the typical vertebra. The simplest

* According to Maclise, some of the monkey tribe have only five or six neck vertebræ, and occasionally also in man the same occurs.—(Medical Times and Gazette, January, 1854.)

† Coote on Homologies of Human Skeleton, p. 26.

example of such appendage is very evident on examining the skeleton of a bird. Attached to its ribs or pleurapophyses, there are seen short flat pieces, which, being directed backwards, overlap the external surface of the next rib behind. (See *a*, *Fig.* 37; also *a* and 65, *Fig.* 35.) Similar appendages are found, less perfectly developed, in certain reptiles. They also occur in the abdominal parts of the most bony fishes, in which their length is such that they reach even to the skin. They are considered as parts of the primitive segment or vertebra, though less constant than the arches which support them. Now, the simplest form of limb is, in its nature, but very little removed from such diverging appendage; in some of the lower vertebrata, as Protopterus, the limbs are reduced to an unbranched ray.

Through various species of Amphiuma, and in Proteus, we observe greater complexity, (though still of low type compared with the extremities of man,) and this goes on step by step in different animals, till we reach the arrangements which characterize the higher forms. The Protopterus, whose simple limbs afford proof of their identity with the diverging appendages of the typical vertebra, present also proofs that the fore and hind limbs are homotypes, both being in that animal precisely of the same simple nature. But even in the higher animals, man

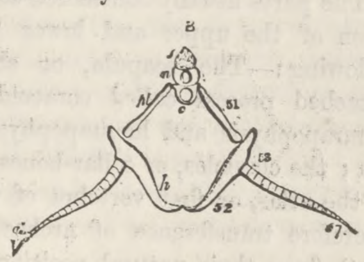


FIG. 37.*

* FIG. 37. Occipital vertebra of Protopterus. The hæmal arch is large, consisting of *pl.* pleurapophysis; *h.* hæmapophysis; hæmal spine is wanting. The long, simple, jointed ray, *a*, 57, is the diverging appendage or rudimentary limb.

for example, the resemblance is sufficiently obvious; the arm and thigh, fore-arm and leg, wrist and ankle-joint, hand and foot, are the corresponding parts of each limb; these members are therefore homotypes. But under whatever forms the limbs exist, they are supported by inverted arches, the presence of which is more constant than that of the appendages which they support, and for an obvious reason—the arch is required to protect certain important organs which are always present, as the brain and spinal cord, heart and lungs; the appendage of the arch comes in as a secondary instrument, necessary, doubtless, in the economy of the animal; but yet less important in a general sense than the other organs just mentioned.

The parts usually considered as entering into the formation of the upper and lower limbs in man, are the following:—The scapula, or shoulder-blade, and the attached process called coracoid, represent respectively pleurapophysis and hæmapophysis of the occipital vertebra; the clavicles, or collar-bones, are the hæmapophyses of the atlas, or first vertebra of the neck; there is here, therefore transference of arches (which are also imperfect) from their natural position;—the end of this we shall afterwards examine. Then follows the arm-bone, next the two bones of the fore-arm, called radius and ulna; then the carpus, or wrist, composed of eight bones apparently, but really of ten in two rows; connected to certain of these, we observe five bones of the hand called metacarpus, then follow those of the fingers, styled phalanges, each digit having three, excepting the thumb which has two.

The pelvic portion of the skeleton has been already noticed; it is in like manner an arch supporting diverging appendages, the lower limbs. Each of these consists, first, of thigh-bone, succeeded by the leg-bones, called tibia and fibula; then follows those of the ankle, the tarsus of anatomists, consisting apparently of seven bones in two rows, which, however, really represent ten primitively distinct pieces. Then follow five metatarsals, or bones of the foot, and connected with their lower ends are the toes, each, with the exception of the great toe having three bones.

Now, whatever be the functions of the extremities in any of the higher vertebrata, we find all, whether fore or hind limbs, constructed on the same plan as that just described, five being the typical number of digits. It may be remarked how different is the relative development of the digits, of thumb, index, middle, ring, and little fingers, styled, respectively, 1st, 2d, 3d, 4th, and 5th in the human hand.* The first digit has only two joints; the fifth has the usual number, viz., three, but the whole being short; the second comes next in length, then the fourth; and the third is the most highly developed of all. These peculiarities have distinct reference to the general permanence of these digits respectively, and throw light on certain modifications observed in animals lower in the scale.

In the typical limb, the shortening of the thumb and little finger, or the first and fifth digits, is a step towards their disappearance,† the 2d, 3d, and 4th being more permanent; the two last reaching the ground in the ox, and the longest of the two, namely, the 3d, is the only one which serves as a point of support in the horse. Professor Owen remarks, that "a perfect and beautiful

* The same numbers are used to represent the toes; great toe, number 1; little toe number 5.

† A similer law reigns in certain plants. In Cruciferæ, (cabbage tribe,) the stamens are usually six, four of these being longer than the other two. In *Cardamine hirsuta* there are usually only four, the two shorter being absent.

parallelism reigns in the order in which the toes successively disappear in the hind-foot with that of the fore-foot."*

Commencing with man as possessing the typical number, and descending to the lower animals, we find that that digit, (the first, or thumb, viz.,) whose uses, *par excellence*, characterize him, is one of the first which disappears. Departure from the typical five is a characteristic of mammalia lower in the scale, hence the tetra-, tri-, di-, and mono-dactyle limbs common among them.† Descending lower in the scale to fishes, we find the limbs presenting often (with a nearer approach to the simpler diverging appendages) a less subordination to the typical number, there being usually an excess. This, however, as Professor Owen remarks respecting the pectoral fin of the skate and its numerous digits, is not an example of complex deviation, "true complexity not being shewn in the number, but in the variety and co-ordination of the parts." In a word, all diverging appendages or limbs are constructed on a common plan; we shall afterwards examine their numerously diversified modifications for special ends. We also observe in them evident traces of order as regards a law of number, and a general rule in accordance with which they are present or absent, as the necessities of the animal require them or not.

SECT. II.—SPECIAL ADAPTATIONS IN THE STRUCTURE OF THE SKELETON.

The subject here opened to us is of vast extent, and even not yet thoroughly exhausted by all that has been done in human and comparative anatomy. It must be

* On Limbs, p. 23.

† This has reference to digits which attain functional size.

acknowledged that the relation between special modifications or departures from the general plan, and final ends of such, have not been determined as to every part of the animal frame. Nevertheless, so many striking examples present themselves to the careful and unprejudiced observer, that it may be considered a legitimate conclusion that there is such a general relation, although the cautious reasoner may hesitate to give a positive decision in every instance which may come under his notice.

We can indicate only some of the more obvious cases illustrative of the coincidence between the principle of order and that of special adaptation. We may appropriately open this part of our subject by glancing at the modifications observed in the vertebrate series in man.

In the cranial vertebræ we observe two remarkable contrasts in the development of the neural arches; which are more or less extended according to the purpose which they serve in reference to the particular part of the brain over which they are situated. The great size of the nervous centre, that is, the brain, requires a corresponding enlargement in certain neural arches, and this is found to be actually provided. Each vertebra gives protection to corresponding parts of the nervous matter; thus, the cerebellum is protected by the occipital, the mesencephalon (or middle portion)* by the parietal, and the prosencephalon (fore-part of cerebral mass) by the frontal vertebra. In all of these the neural arch is ample, in distinct relation to the size of the part requiring defence. The less development, or rather nearly complete obliteration, of the neural arch in the first or nasal vertebra, is commensurate in man (and other ani-

* Comprehending also Pons Varolii, Corpora quadrigemina, pituitary body, and third ventricle.

mals besides) with the small size of the remaining portion of the brain mass represented by the olfactory ganglia.

It is by means of the first and second vertebræ of the neck that free rotation of the head is effected. The anterior part of the first (forming a portion of its centre) is excavated, in order to receive the tooth-like projection of the second, or *axis*, which is so called because there rises from the upper part of its body a piece, round which the first, or *atlas*, plays as on a pivot, giving rise to the lateral movements of the head. The base of this pivot is in reality the body of this second vertebra; its apex, however, is formed of part of the body of the first, removed from its natural position, and united to that of the second. Now, we do not consider it any strained inference when we affirm, that there is here presented to us a notable instance of special adaptation for a particular function.

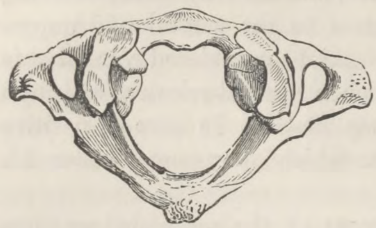


FIG. 38.*

FIG. 39.†

Generally speaking, the hæmal arch is imperfect in the vertebræ of the neck, because the large size of its elements (viz., pleurapophyses, hæmapophyses, and hæmal

* FIG. 38 represents the first neck-vertebra in man: it is called *atlas*, as supporting the head. A strong ligamentous band stretches across the large central opening, and divides it into two. The tooth-like projection of *Fig.* 39 is received into the fore-part of this divided ring, the posterior allows passage to the spinal cord.

† FIG. 39 is the axis or second vertebra of the neck in man. The apex of the tooth-like projection is part of the *centre* or body of the atlas, joined to the body or *centre* of the axis.

spines) would have interfered with free motion in this region of the body. Nevertheless, certain parts which, on a cursory glance, appear to be absent, are in reality present, but are specially modified by decrease and coalescence; thus, the portion of a cervical vertebra projecting outwards on each side, and hence called by anatomists the transverse process, in reality consists of diapophysis, parapophysis, and a short pleurapophysis or rib, firmly joined, but together forming a hole or short canal and a groove, to give protection and support to a blood-vessel and nerve respectively. The excessive development of the hæmal arch in the dorsal vertebræ, is a provision for the large and important organs to be protected—the heart, lungs, &c. The elastic and moveable ribs (pleurapophyses) and their cartilages (hæmapophyses,) are admirably adapted to the exhalation and inhalation of atmospheric air during the act of breathing.

The vertebræ of the loins are large and strong, thus affording a firm basis of support to the superincumbent column; the hæmal arch is not completed by bony elements, but by soft elastic walls, which yield to the varying expansion of the viscera within.

The union of the sacral vertebræ gives additional strength to this portion of the column, supporting, as it does, the elastic spine above it. The excessive development of that part of the hæmal arch—the pelvis of anatomists—is obviously intended to support and protect the larger viscera, and to present a surface of attachment for powerful muscles. The united bodies of the coccygeal series, forming a partial concave floor to the pelvis, afford additional support to the organs protected by this last. In short, while the skeleton of man consists throughout of a series of parts all formed on one model, yet there is a wide range of difference in most of them, and the special modifications have in all cases a very decided, and, in most instances, a very obvious relation to the development of different organs, without which our goodly frame could not perform its functions, or even continue to exist.

We may now examine some of the special modifications of vertebral elements, as exemplified by animals lower in the scale; from a multitude of instances, our limits constrain us to select only a few. Whether we examine fishes, reptiles, birds, or mammals, we shall find obvious illustrations of departure from the model or type in accordance with some function necessary to the very existence of the animal.

In Ophidia, or serpents, certain elements of the two anterior cranial vertebræ are freely moveable on each other, instead of being closely joined together, as is usually the case; strength and firmness are here sacrificed to mobility and expansile power of the parts, and why? The arrangement has a clear and express relation to the mode of feeding; serpents often swallow very large prey entire; but this they could not do were the parts firmly banded together. As it is, the mouth is capable of great extension, and the prey is taken in with ease.

In fishes there exists a remarkable concentration of important organs in the fore-part of the body. The head contains, not merely the brain and organs of the senses, but, in addition, the heart and gills; we find, accordingly, that the hæmal arches are commensurate in size with the presence of the important parts which they support and protect. In the words of Professor Owen, "Brain and sense-organs, jaws and tongue, heart and gills, arms and legs, may all belong to the head; and the disproportionate size of the head, and its firm attachment to the trunk, required by these functions, are precisely the conditions most favourable for facilitating the course of the fish through its native element."

In the whale, the vertebræ of the neck are joined into one solid column. By this arrangement, greater protection is afforded to the nervous cord, as this large and heavy animal ploughs its way with rapidity through the water. Flexibility in the neck, not needed in this case for other purposes, would have been an inconvenience.

The three-toed sloth presents an example the very converse of the last; the additional vertebræ (we have already alluded to it as an example of departure from the typical number) in the neck of this animal are admitted to have a relation to its habits; in the words of Professor Bell, "the object of the increased number of vertebræ is evidently to allow of a more extensive rotation of the head; for, as each of the bones turns, to a small extent, upon the succeeding one, it is clear that the degree of rotation of the extreme point will be in proportion to the number of pieces in the whole series."* But, in addition, as this animal spends its whole life on trees, clinging to the branches with its powerful limbs, and feeding on the twigs of its arboreal dwelling-place, the length of its neck gives it an advantage in better enabling it to reach the tender and extreme branches.

In carnivorous animals, having four limbs fitted for seizing and holding their living prey, and a mouth armed with strong teeth for tearing it, the neural spines and transverse process of certain neck-vertebræ are highly developed, so as to become commensurate with the power of the oblique muscles of the head, which are in them of great strength, to enable them to perform their important functions. In other words, the levers supplied by certain elements of the neck vertebræ are in direct pro-

* Cyclopædia of Anatomy and Physiology, Article *Edentata.*

portion to the active organs of motion, that is, the muscles, which require them as mechanical powers.

In birds, the fore-limbs are used in flight, and the function of the arm is transferred to the neck, that of prehension to the beak, which supplies the place of the hand. The neck is the only flexible part of the vertebral series, and motive power is abundantly provided for on the same principle as we have seen it to be in the sloth. It is curious to notice that there is a departure from the number seven, so constant in mammals; the vertebræ ranging from nine in the sparrow to twenty-three in the swan. The mode of connexion of the vertebræ is also such as to admit of the utmost freedom of motion.

In the dorsal portion of the vertebral series, we may also note a few striking adjustments. In certain mammalia, as the ox, deer, camel, &c., owing to the weight of the horns and antlers, or length of the neck, continued muscular exertion would be necessary, in order to retain the head in its natural position. Such disadvantages is obtained by the presence of the part called pax-wax, or ligament of the neck—composed of yellow elastic fibres—which acts as a natural spring, and obviates the need of constant voluntary muscular effort. Accordingly, we find that certain neural spines in the back (as well as in the neck) are greatly elongated, to give attachment to the remarkable organ referred to. In the aurochs, for example, some of the dorsal vertebræ have neural spines which are actually longer than some of the ribs. Such modifications are, indeed, generally observed in browsing animals.

As in the fish, excessive development of certain parts of the skull is a provision for the forward position of the heart and gills, so in air-breathing animals the lower arches of certain other vertebræ are highly developed, forming the ample thorax or chest, for the protection of their heart and lungs. In the neck of the bird we have seen that flexibility is necessary; in the back, firmness is the essential requisite, and we observe there union of vertebræ. Further, the hæmapophyses, which in man and others are cartilaginous, become in the bird converted into bone, and the united hæmal spines from the keel of the sternum or breast-bone, the extent of the surface presented by which is directly as the development of the powerful muscles which are attached, and directly also, of necessity, as the powers of flight. In the ostrich, and cursorial birds generally, which cannot fly, the hæmal spines do not form any crest. In birds, we also observe union between the vertebræ of the loins, an arrangement admirably calculated to give firm support during the powerful and rapid movements in flight

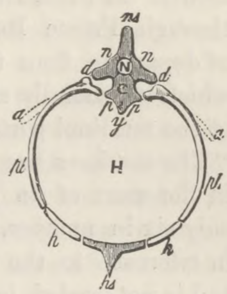


Fig. 40.*

Coalescence of the remaining vertebræ, in the adult human subject we have seen to be the usual arrangement, and this—together with size particularly in the sacrum—appears to have relation to the erect posture of the body. In many mammalia, the sacrum is proportionally narrower than in man, and coalescence of vertebræ is not the law; but in certain species, which have the faculty of assuming the erect or semi-erect posture, as some monkeys, bears, and certain rodents, the sacral portion of the skeleton is proportionally stronger than in others which have no such

* Fig. 40. Thoracic segment or vertebra of raven. The hæmal arch is ample in accordance with its functions as a protector of heart, lungs, &c., and as furnishing surfaces for attachment of powerful muscles. References are same as in preceding figures.

faculty. The permanently separate condition of the sacral elements in the beaver is an arrangement admirably suited to its peculiar habits, "using, as it does, not only its long and powerful tail, but even the whole posterior half of the trunk, as an organ of propulsion through the water."*

In man, as we have already seen, the terminal portion of the spine, forming the coccyx, consists of a few small pieces, reduced to little more than the centrum or body of the vertebra. But in many of the lower animals, the tail performs important functions, and attains higher development. Sir John Richardson, in his account of a journey through Prince Rupert's Land, mentions a curious case of departure from the usual type in the bovine family, which is generally characterized by the high development of the terminal portion of the vertebral series. He says, "The musk-ox has the peculiarity, in the bovine tribe, in the want of an evident tail; the caudal vertebræ are only six in number, being very flat, and nearly as short, in reference to the pelvis, as in the human species. A tail is not needed by this animal, as, in its elevated summer haunts, moschetos and other winged pests are comparatively few, while its closer woolly and shaggy hair furnishes its body with sufficient protection from their assaults."

The special modifications of the elements of the caudal portion are numerous, and have an obvious reference to final cause or end to be served. In the human coccyx there is no hæmal arch. In the tails of not a few animals, lower in the scale, it is distinctly formed of hæmapophyses and hæmal spine. The prehensile tails of the spider monkeys, the powerful oar-acting tail of the beaver, and the supporting pillar-like organ in the kan-

* Coote on Homologies of Skeleton, p. 61.

garoo, present individual peculiarities of the vertebral elements admirably suited to the different uses of the part. In the kangaroo the lower surface of the tail is subject to pressure, and the same is true of the prehensile tails in Phalangista and the opossum, and in all these the hæmal arch is well developed, in order to protect the blood-vessels. "In Petaurus, Phascogale, and Dasyurus, the tail acts as a balancing pole, or serves, from the long and thick hair with which it is clothed, as a portable blanket, to keep the nose and extremities warm during sleep. The hæmal arches in the tails of these are not so largely developed as in the kangaroo &c., their mechanical office of defending the blood-vessels of the tail from pressure not being required."*

It is admitted that the typical structure may be departed from by excess in the number of the elements; if it can be shewn that such departure has decided relation to the habits and wellbeing of an animal, it appears to us a powerful argument in favour of combined order and adaptation; we may here adduce a few examples.

Seals and penguins are not fitted for general sojourn and progression on the land, nevertheless they do occasionally frequent the shore, but their movements, under such circumstances, are peculiar. One of the highest authorities to which we can refer, specially alludes to these animals, and to modifications in certain vertebræ related to the habit in question. In the Greenland seal, Professor Owen describes processes superadded to the lower surface of the lumbar vertebræ, (hypapophyses,) "indicating great development of anterior vertebral muscles, relating to peculiar gasteropod progression on land. In penguins, similar hypapophyses attain their maximum

* Owen, in Proceedings of Zoological Society, 1838.

of development, and have an analogous function to that in the seals, extending the surface of attachment of the powerful muscles on the ventral aspect of the vertebral column, which act in the shuffling gasteropodal movements."*

In the armadillo, whose bony armour (giving to the animal its name) is of considerable weight in proportion to the size, and serves as a defence against its powerful foes, we find two additional spines (metapophyses) developed, one on each side of the neural spine, upon the principle that three points are better fitted than one to support a superincumbent weight. Certain serpents feed upon the eggs of birds; their teeth are few and feeble—for if the shell of the egg had been broken in the mouth, the want of flexible lips would have occasioned loss of the nutritious contents. Besides, these serpents follow the law of their congeners; loose attachment of cranial elements, as we have shewn, enables them to take their food entire. The egg, being thus received, is ripped open as it passes along the gullet, and this is effected by a contrivance no less remarkable for its simplicity than for its efficiency. Sharp projections (hypapophyses) from certain vertebræ of the neck, perforate the tube of the gullet, are capped by hard enamel, and effectually perform their proper office.

We shall close this part of our subject by alluding to two notable instances of special modifications pervading almost the whole skeleton in serpents and tortoises. In the former we find a long series of vertebræ, some of whose elements supply the place of limbs, which are generally wanting, or, if present, as in boa, so rudimentary as to be incapable of performing their usual functions. The pleurapophyses have free motion, and act as

* Professor Owen, in Philosophical Transactions, 1851.

efficient organs in progression on a hard surface, by means of the large scuta or shield-like scales covering the belly of the animal. These scuta form a number of movable broad surfaces, bearing the same relation to the ends of the ribs which hoofs do to the ends of the toes. In pelagic serpents which swim by lateral motion of the tail, the pleurapophyses are more freely movable in a lateral than in a backward direction, progress in the water being accomplished by rapid lateral curvatures of the tail and body. The neural spines of the dorsal vertebræ are small, those of the caudal portion large and compressed, and gradually lessening in size to the point of the tail—a peculiarity of these vertebral elements in strict harmony with the general compressed state of the body, and that of the short but strong and flat tail, which acts as an oar for propelling, as well as a rudder for guiding.*

The spinal column of the Ophidia shews the maximum of number of the different vertebræ, and of flexibility as a whole. In the words of Professor Owen, "At first view, the principle of vegetative repetition seems to have exhausted itself, in the long succession of incomplete vertebræ which support the trunk of the great constrictors; but by the endless combinations and adjustments of the inflections of their long spine, the absence of locomotive extremities is so compensated that the degraded and mutilated serpent can overreach and overcome animals of far higher organization than itself; it can outswim the fish, outrun the rat, outclimb the monkey, and outwrestle the tiger; crushing the carcase of the great Carnivore in the embrace of its redoubled coils, and proving the simple vertebral column to be more effectual in the struggle than the most strongly-developed fore-limbs,

* Dr. Cantor, Transactions of the Zoological Society.

with all their requisite rotatory mechanism for the effective varied application of the heavy and formidably armed paws."*

As the serpent shews us the highest possible flexibility, so does the tortoise exhibit the greatest rigidity and inflexibility of vertebral elements, intended also to accomplish an end necessary to the wellbeing of the animal. The carapace or upper arch, and plastron or floor, of the turtle's or tortoise's shell may be compared to the skull; to use the expression of Professor Owen, it is actually "an abdominal skull, formed of the centra of back, loins, and pelvis united together, their pleurapophyses, hæmapophyses, and other elements, being expanded and laterally adherent; appendages of the skin—the dermal bones—are connate with some of the vertebral elements, the whole forming a defence to a well-developed system of hæmal organs, heart, lungs, and alimentary canal."

DIVERGING APPENDAGES OR LIMBS.

These assume various forms, from the simple structure which we have noticed in the thorax of the bird up to the perfectly developed limbs of man. Among them remarkable modifications present themselves, having evident reference to the uses of the member, whether for grasping, supporting the body, flying, swimming, leaping, or burrowing.† The inference from all these adapta-

* Owen on Nature of Limbs, p. 96.

† In a former paragraph (p. 185) we have shewn evident traces of community of form in the elements of the vertebra and its appendages; in reference to the modifications of the latter, it will be necessary here to allude to the very ingenious but, we think, overstrained, views of M. Gervais—(Ann. des. Sc. Naturelles, 1853.) According to Duges, there is an arithmetical progression in the number of the parts from arm to fingers, and from thigh to toes, viz., arm and thigh, each of one piece, leg and fore-arm, each of two pieces; in wrist and ankle, hand and foot, fingers and toes, the number five prevails we have therefore the progression, 1, 2. 5. M. Gervais thinks he finds proof that in

tions of means to end cannot be explained away by affirming that the animal, finding that it has an organ suited to a certain purpose, uses it for that purpose. For in the first place, the creature is compelled to a certain mode of life by its instincts, which are altogether different from its limbs or any of its organs ; and, secondly, its limbs are suited to its other organs, and all its organs are suited to one another. There is in all this no wisdom or foresight on the part of the animal, but there are arrangements made for its welfare by a Power above it, causing independent organs and instincts to concur and co-operate.

It may be laid down as the common rule that the pectoral and ventral limbs are appendages of the fourth and twenty-six segments of the vetebral series.* The occipital is always the fourth vertebra, the pelvic may be less constant in its position. But displacement of vertebral appendages from their typical position in the skeleton is not uncommon, and will generally be found to be a provision for some peculiarity of function. In most fishes, the pectoral fins, which are its arms, occupy the typical position, being in connexion with the occipital vertebra, whereas in man, and many other animals, the same limbs are removed from their natural position, and are attached to the upper part of the chest. These different dispositions are admitted to be, in the one case as in the other, admirably adapted to the necessities of the animal. Professor Owen, referring to such modifications, remarks, "Wherever either arch with its appendages may be situated, it is in its best possible place

limbs of vertebrata the number five prevails even in the arm and fore-arm, thigh and leg, and that therefore there is union of bones in these parts. If this view should prove to be correct, such union may be considered as a special modification of the type in relation to the functions of the parts.

* We adopt here the views of Professor Owen.

in relation to the exigencies and sphere of life of the species."*

We may next examine some of the principal modifications of the diverging appendages themselves, and of their elements, traces of a general plan having already been pointed out, and proofs adduced that law and order prevail also in departures from the type. Although the limbs of animals are diverging appendages of the typical vertebra, all such appendages do not necessarily perform the functions of limbs. Their simplest and most rudimentary condition has been already alluded to as they are seen in the thorax of the bird, where they appear to serve merely the purpose of giving additional strength and firmness to the ribs, (pleurapophyses,) from which they originate.

In the head of the fish we observe them offering greater advance in development, and in beautiful harmony with their proper function. Those of the third or parietal vertebra constitute the parts called, technically *branchiostegals*, which, in most fishes, support a flap, whose function is to assist in protecting the gills, and regulating the admission of fresh currents of water to these important organs. The diverging appendages of the second cranial vertebra are modified to form the opercular bones which together constitute the framework of the gill-covers, by the movements of which the amount and direction of the respiratory currents are principally determined. The corresponding part in the anterior segment of the head consists of two pieces called *pterygoids*, the outer of which serves as a means of connexion between the hæmal arches of the first and second vertebræ. How different, then, the forms and uses of corresponding appendages in the head of the fish, for, in

* Owen on Limbs, p. 81.

contrast with those just mentioned, we observe the appendages of the fourth or occipital vertebra forming the pectoral fins, which correspond to the upper limbs in man, and perform an important, though not the principal part in aquatic progression. The beautiful harmony which subsists between the uses of the pectoral fins and their peculiar structure, has been so frequently and fully discussed in works of Natural Theology,* that it would be needless to go over the same ground here. In the frog-fishes, which have the power of moving on the ground when left by the receding tide, in the expanded pectorals of the flying-fish, acting as parachutes during its powerful aërial leaps, in those of the climbing perches of the tropics, and in the ordinary forms presented by the fins of most fishes, we observe modifications of parts constructed after the same model, but each in striking unison with the habits of the animal. In the fish, then, the fore-limbs (pectoral fins) are the diverging appendages of the occipital vertebra, and occupy their natural position as such, (that is, are placed far forwards,) being attached to the hind-head. In other vertebrata, the arch which supports them is transferred from its normal place to the upper part of the trunk, and this transference, and the structure of each piece, are admitted on all hands to be in complete harmony with the function of the limbs, and necessary to the comfort and wellbeing of the animals.

In birds, for example, the parts supporting the anterior limbs are modified, so as to fit the diverging appendage, to become an organ of flight. It has been already mentioned, that the scapula and coracoid are respectively pleurapophysis and hæmapophysis of the occipital vertebra, and the clavicles or collar-bones the hæmapophyses of the atlas, or first cervical vertebra. The relation of

* See Paley; also Bell on the Hand, Roget's Bridgewater Treatise, &c.

these to the appendages which they support are such, that the two can only be instructively studied together. This is specially true of birds. The great strength of the *coracoid* qualifies it for its main function, namely, to give attachment to the limbs, and afford a strong basis of support in flight during the quick and powerful strokes of the wings.

The function of the pectoral wings in the bird being peculiar, we find corresponding modification in the hard parts. Appendages of the skin, the feathers namely, serve the purpose of resistance to the air in flight, and so the full development of digits, with freedom of motion in the other bones of the limb, is not needed. The fore-arm and the wrist-joint are so constructed, that free motion is sacrificed to firmness, and the bony framework of the hand is rudimentary; nevertheless, the parts are not so obscured that we cannot indicate their relations, for in every case the general type still prevails, and each finger corresponding to the second, third, and fourth of the archetype, is clearly visible.* The diverging appendages, suspended to the pelvic arch, and forming the lower limbs, are equally in harmony with their function in different birds: this is more specially observable in the metatarsal portion and toes. The part commonly called leg in the bird, consists generally of three metatarsal bones, which, in the adult, are so firmly united as to give the appearance of one only. There is also, in most instances, another, which is, however, small, and whose function is to support the inner toe. The position of this inner digit has an express adaptation to the habits of the bird; being on a level with the other toes in perching birds, and therefore admirably fitted to give

* We may refer here to a former paragraph (p. 191) respecting the relative lengths of the digits and their permanence.

increased power of grasping; whereas it is removed higher and higher in different waders, and is finally absent in cursorial birds, as the emeu and others. Still greater reduction in the number of the toes takes place in the ostrich, the third and fourth alone remaining. There is final cause in all this; "whilst unity of design is clearly manifested, the wisdom of the Designer is displayed by the greater strength which results from the minor degree of subdivision of the part which takes the largest share in the support and propulsion of the body."†

FIG. 41.*

Among mammalia we find instruments for support, grasping, climbing, running, leaping, burrowing, flying, swimming, and diving. Now, it is distinctly observable, that whatever be the function of the limbs, all are constructed after the same plan, but varied to suit the end which is required by the instincts of the animal and its allotted sphere. It has been already stated that the arms and legs of man are homotypes, and that the individual parts which form them are also homotypes; yet while so far corresponding to each other, the two series are made to differ in order to suit them to their several uses. The harmonies of structure and function in each of the limbs of man, as well as in other animals, have been so fully discussed in different works, that it is unnecessary for us to enlarge much on the subject here.

The fore-limbs of that expert tunnel-maker, the mole, are admirably suited to its habits. The bones of the arm,

* FIG. 41. Foot of Ostrich, consisting only of digits 3 and 4.
† Owen on Limbs, p. 105.

fore-arm, wrist, hand, and fingers, are of great strength in proportion to the size of the animal; the whole limb is short and broad; the fingers are armed with strong nails; and the general conformation is such that the action of the powerful muscles renders the hand a most effectual instrument for burrowing in the soil, through which, as Professor Owen remarks, the animal may be said to swim.

The chief part of the bat's wing consists of a highly developed hand. The junction of the arm-bone with the shoulder-blade is in harmony with its function, being such as to permit upward and downward motion chiefly. It is interesting to observe that the collar-bone is longer and broader in those whose flight is more powerful, such as the insect-eating species, than in those which subsist on fruit, and which, consequently, do not need swiftness in pursuit of food. The arm-bone is long and slender in all bats, the fore-arm is also long, and the two bones which form it are incapable of rotation on each other, as such movement would have lessened the impulse of the wing. The bones of the hand and fingers, excepting those of the thumb, are of great length, in order to add to the superficial extent of the part, which is, in fact, a highly developed hand, the long fingers being connected by a web to the very tips. The small, but free, thumb, with its well-developed nail, enables the animal to cling easily to perpendicular surfaces as well as to climb them.

When we examine animals remarkable for their powers of progression on a hard surface, we meet with singular deviations from the typical limb, in respect not only of the number, but also the union of parts; in every instance structure and functions are clearly in harmony with the kind of life for which the animal is intended.

In the ox, the parts called, in common language, the knee and the leg, do not, in fact, correspond to these portions of the typical member. The so-called fore-knee is the wrist, with the bones considerably modified; the so-called fore-leg is, in reality, part of a hand composed of two metacarpal bones firmly united together in the adult state, corresponding to the third and fourth, and together forming the cannon-bone. On either side are the rudiments of the second and fifth digits; the thumb has disappeared, and those which attain functional size, in other words, which reach the ground, are the third and fourth. "The rudiments of the second and fifth digits are not without their use. When the elk or bison treads on swampy ground, the hoofs expand, the false hoofs are pushed out, and the resisting surface is increased as the foot sinks; but when it is lifted up the small hoofs collapse to the sides of the large ones, which contract, and, by their diminution of size, the act of withdrawal is facilitated. In ruminants, confined to arid deserts, we should hardly expect to meet with the mechanism which seems expressly adapted to the marsh and the swamp, and, in fact, every trace of the second and fifth digits has disappeared from the foot of the camel and dromedary."†

IV III

Fig. 42*.

In the horse, there is still farther reduction in number, only a single digit, the third, reaching to the ground and serving for support. The perfect adaptation of the limbs

* Fig. 42. Foot of the ox. At the upper part are seen the bones of the ankle, viz. *b*, the cuboid; *ce*, ectocuneiform; *s*, scaphoid; *a*, astragalus; *cl*, calcaneum; succeeding which is the cannon-bone, composed of the third and fourth metatarsal joined together. III. and IV. are digits; II. and V. are digits in a rudimentary condition; 66 and 67 are bones of the leg.

† Owen on Limbs, p. 34.

of the animal to its habits and power of rapid progression is so generally admitted, and has been so frequently discussed,* that it would be a work of supererogation to go over the same ground here. Suffice it to say, the principle of reduction in number of the parts, which we have already seen to be associated with swiftness of progression in the foot of the ostrich, is carried out fully in that of the horse: "he paweth in the valley, and rejoiceth in his strength."

FIG. 43.‡

In conclusion it may be added, that there is distinct evidence of arrangement in the height of the limbs in most mammalia, and this is true of both fore and hind extremities: *their length is equal to that of the head and neck together;*"† the browsing species, therefore, can easily reach the herbage necessary for their subsistence. Bimanous and Quadramanous animals (man and the apes) are exceptions; but then they have limbs whose digits are fitted to procure food. Certain others may be noted as exceptions, namely, bats, which feed on wing, and the elephant, whose short neck and prominent tusks would prevent browsing, but in compensation, it is provided with that "grotesque hand," the trunk, which is merely a nasal apparatus, having superadded to its ordinary function that of sensation and prehension.

* See Bell on the Hand, etc.

† Straus-Durckheim, Théologie de la Nature, vol. i. p. 226.

‡ FIG. 43. Hind-foot of the horse. The letters at the upper part represent the bones of the ankle; *a*, astragalus; *cl*, heel-bone or calcaneum, the prominent part of which is the "hock;" *s*, scaphoid bone; *b*, cuboid; *ce*, ectocuneiform; *cm*, mesocuneiform. The long bone which succeeds these, and joined to *ce*, is that called cannon-bone, and corresponds to the third metatarsal bone; to its lower end are attached the three bones (phalanges) of the third toe; the last of the three, marked III., is expanded to sustain the hoof. The bones marked II. and IV., situated on each side, are called by veterinarians *splint-bones;* they are the rudiments of the second and fourth metatarsal bone. The cannon-bone has been already referred to as presenting the model after which all the pieces of the typical vertebra are constructed.

CHAPTER V.

TEETH.

SECT. I.—TRACES OF ORDER IN THE FORM AND STRUCTURE OF TEETH.

THE upper and lower jaws alone support teeth in the higher vertebrata. We have already seen that the former corresponds to the hæmapophyses and divided hæmal spine of first or nasal vertebra, and that the lower jaw is the hæmapophysis and hæmal spine of the second or frontal vertebra. The teeth, supported by these vertebral elements, are generally distinguishable, in the higher vertebrata, into three series, viz., incisors, canines, and molars.

The incisor or cutting teeth occupy the fore-part of the maxillæ, those of the upper jaw being supported by the intermaxillaries, (or premaxillaries,) which correspond to the divided hæmal spine of the arch to which they belong. Generally speaking, the teeth occupying this position are chisel-shaped. The tusks, called also canines, form the first of the series supported by the maxillary bones, properly so called : these teeth are generally conical in form, and in animals lower than man, project beyond the other teeth. The molars, as their name indicates, are generally characterized by a broad flat surface, fitted for bruising.

Such may be regarded as the special characteristics of these three kinds of teeth, nevertheless there seems to be a common type embracing all, and there are transitional forms. The incisors are sometimes conical, like the canines: this is very obvious in the great polar bear, as well as certain other carnivora; and in the elephant, the same teeth constitute the tusks. In the insect-eating bat, the projections of the molars are conical; in the dolphin and others of the whale order, all the teeth are conical. There appear, therefore, to be clear indications that the cone may be considered the typical form of tooth.

As is remarked, however, by Professor Owen, "shape and size are the least constant of dental characters in the mammalia, and the homologous teeth are determined, like other parts, by their relative position, by their connexions, and by their development." We have already stated by what mark, founded on position, the incisors may be invariably distinguished, and that the canines succeed them in order from before backwards. The mode of development of the remaining teeth enables us to determine their homologies. In most mammalia there are two sets of teeth, the milk or deciduous, and those which succeed them, called permanent. Now, some of the milk-molars are directly succeeded by permanent teeth, which displace them vertically; others, which appear as the animal advances in age, do not displace predecessors; and hence a distinction of the molars into *premolars* or false molars, and *true molars.* The second set of premolars occupy the place of others which preceded them; the true molars are situated more posteriorly, and have had no predecessors.

Investigations of anatomists have shewn that, in reference to number, the teeth follow a type, and the typical dental formula is thus indicated:

$$\text{Incisors, } \frac{3-3}{3-3}, \text{ canines, } \frac{1-1}{1-1}, \text{ premolars, } \frac{4-4}{4-4}, \text{ molars, } \frac{3-3}{3-3}.$$

The figures above and below the lines express the respective numbers of teeth on each side in upper and lower jaw.

A common plan also prevails in the general structure of the teeth. Three distinct substances, differing in hardness and in microscopical characters, enter into their formation. A perfect mammalian tooth may be considered as formed principally of hard *dentine* or ivory in the centre, still harder enamel on the crown, and most external of all, a layer of *cement*, which is softer than the other two.

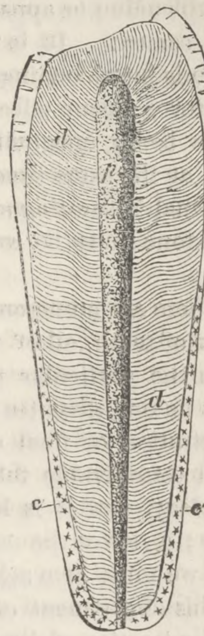


Fig. 44.*

Fig. 44. Longitudinal section of human incisor, magnified. *p*, pulp cavity; *d*, dentine or ivory; *e*, enamel; *c*, cement.

SECT. II.—TRACES OF SPECIAL ADAPTATION IN THE NUMBER, FORM, AND STRUCTURE OF TEETH.

In these organs, of so much importance in the animal economy, and of such scientific interest to the zoologist and palæontologist, we find numerous examples of modifications in respect of structure, form, and number, all for the fulfilling of useful ends.

Remarkable complex modifications occur when the substances of which the teeth consist, instead of being simply superposed, and shewing a comparatively regular surface, present infoldings of the surface, and consequent interblending or apparent mixture of the dentine, enamel, and cement. It is obvious that in all cases in which there is interblending of parts differing in hardness, by whatever means effected, a rough surface is kept up by their being unequally worn away; a most admirable, and, at the same time, simple contrivance for forming an effectual triturating surface, on the same principle that a millstone must be rough in order to perform its office fully.

There are numerous and remarkable special modifications of teeth, all of which are so obviously in harmony with the particular purpose they are intended to serve, that no one disputes the propriety of adducing such in illustration of final cause. These have been discussed with considerable fulness by different writers on natural theology, and it is less necessary to enter into details here; a few of the more prominent examples may suffice, and we must here acknowledge the valuable contribution to this department of the history of the teeth embodied in the treatise of the Hunterian Professor.*

Among bats we find three varieties in the kind of food; some subsist on insects which they capture during flight; others feed on soft vegetable food, such as fruits; and a few suck the blood of animals, whose skin they puncture during sleep. The insectivorous bats have all the teeth characterized by the presence of numerous sharp conical points well fitted for capturing and retaining their living prey. In frugivorous species the molars are well developed, and are suited by their blunt tuber-

* Owen's Odontography.

cular crowns to reduce the vegetable matter to the state of pulp. In true bloodsucking species, the vampyres, the upper incisor teeth, and canines, are well fitted to puncture the skin, while the molars are deficient in number, the blood on which they feed requiring no trituration.

The Rodentia, or gnawing animals, (rat, hare, &c.,) present a peculiar arrangement (one of their leading characters) in the front or incisor teeth, which are in continual requisition for gnawing or cutting hard vegetable matter. The front part of the incisors, and it only has a thick layer of enamel, the consequence of which arrangement is, that the softer dentine behind being continually worn away, a sharp chisel-shaped edge is always kept up. But since both, though thus unequally, are also liable to wear away, an arrangement is added in no less beautiful harmony with instinct and habits; the teeth are continually growing from the base during the lifetime of the animal. The modifications of the molar teeth are not less remarkable; in all of them we find peculiar interblending of the cement, enamel, and dentine, so that a rough surface is secured by unequal abrasion. Still farther their mode of implantation has direct relation to differences in the kind of food which the animal is led to seek and is able to digest. The rats which subsist on mixed food, are less liable to the general wearing of the molars, "and no more dental matter is produced than is necessary for the firm implantation of the tooth in the jaw."* Those Rodentia which feed on hard vegetable substances have molars which are liable to continual abrasion, but which are also continually growing at the base during most of the animal's life; in some, as in the Capybara, this renewal of the molars continues during the whole life. Professor Owen describes an additional

* Owen's Odontography, p. 401.

arrangement in these permanently-growing molars, "they are curved, and the pressure during mastication is thus not directly transmitted to the formative pulp."*

In carnivorous animals, certain teeth are admirably fitted for seizing, holding, and destroying the living prey, and others for dividing it afterwards. The incisors are of the typical number, and therefore more numerous than in many other mammalia, and they often present a transition in general form towards the canines. These latter are large, sharply conical, and of great strength. Some of the molar teeth present remarkable modifications. The fourth premolar in the upper, and the first molar in the lower jaw, are large and sharp-edged, so that when they are moved in opposition to each other, they cut like the blades of scissors; their function is sectorial, and they are admirably fitted to divide flesh. The concurrence of independent circumstances is seen in this, that the instincts of these animals lead them to eat flesh, the teeth are exactly suited to such food, their stomach is able to digest it, and the structure of their limbs enables them to seize and hold it. The hyæna obtains its food from the harder parts left by other carnivora, the bones of animals forming its chief sustenance; and the teeth are modified in harmony with its habits, presenting a remarkable deviation from the usual typical form in the carnivorous division to which the animal belongs. Certain of the premolars in upper and lower jaws are large and conical, and have at the base, near the line of the gum, a thick belt or ridge, which serves to protect that part during the process of crushing the hard bones. Professor Owen states that such a tooth, when shewn to an experienced engineer, was declared by him to be a perfect model of a hammer for stone-breaking.

* Owen's Odontography, p. 402.

In true vegetable-feeding, hoofed mammalia, we find remarkable interblending of dentine, enamel, and cement, in the molars, the proportions of each in different cases varying, as well as the pattern presented by the crown of the teeth. A general idea of such arrangement, and of its consequences, (roughness of surface,) may be obtained by inspection of the old molar teeth of an ox or sheep. In such animals also, owing to the peculiar mechanism of the joint of the lower jaw, there is very free motion in various directions, and thus the whole triturating surface of the teeth, so well adapted to their function, is readily available.

In the elephant, several curious modifications may be observed in the large molar teeth. Each is composed of a number of connected plates, having the usual arrangement of dentine, enamel, and cement substances, the latter being at first the binding material by which the plates are tied together. "The formation of each grinder begins with the summit of the anterior plate, and the rest are completed in succession; the tooth is gradually advanced in position as its growth proceeds, and in the existing Indian elephant, the anterior plates are brought into use before the posterior are formed."* In all elephants, the molars succeed each other from behind forwards, moving in a curve, the young growing tooth being nearly at right angles to the one already in use. Professor Owen's statement is so much to the point that we shall quote it entire, "The jaw is not encumbered with the whole weight of the massive tooth at once, but it is formed by degrees as wanted; the subdivision of the crown into a number of successive plates, and of these into subcylindrical processes, presenting the conditions most favourable to progressive formation. Subdivision

* Cyclopædia of Anatomy Art. *Teeth.*

of the tooth gives another advantage, each part, like a simple tooth, has dentine, enamel, and cement. The different parts of the tooth, as they come forwards, have, of course, from differences of attrition, different kinds of surface, the anterior portion for crushing branches, the middle, with its transverse ridges, for reducing these to smaller fragments, and the posterior tubercles of enamel grind it to a pulp."

Such special modifications of masticating organs, according to the gnawing, flesh-eating, or vegetable-grinding habits in different animals, are sufficiently obvious, but not more so than the peculiarities of organs fitted for mixed food, as in human beings. In his dentition, man presents a character intermediate between the carnivorous and the herbivorous type; "the presence of canines, and the absence of complex structure, arising from interblending of vertical plates of the different dentinal tissues in the molars, would prove that the food could not have been the coarse, uncooked vegetable substances for which complex molars are adapted; and, on the other hand, the feeble development of the canines, and the absence of molars of the sectorial shape, and opposed like scissors' blades, would equally shew that the species had been unfitted for obtaining habitual sustenance from the raw, quivering fibre of recently killed animals."* How evident, therefore, the relation between the kind of food which man naturally makes choice of, and the organs which bruise and prepare it for the act of digestion in the stomach; there is assuredly no mere accidental coincidence in all these arrangements.

The Ophidia, (or serpent order,) as has been already stated, take in their prey entire, and their teeth are generally simply conical, and fitted for retention. The poison

* Owen's Odontography, p. 471.

fangs of certain species are particularly worthy of notice, and certain non-venomous species are instructive as presenting a transitional form. Some of the teeth in the upper jaw, in certain kinds of serpents, present a longitudinal groove which serves to conduct an acrid, but not deadly saliva, into the wounds which they inflict. The true venomous fang, such as that of the rattlesnake, is just a flat tooth folded on itself, and the edges united; the hollow or canal which traverses it is in communication with the poison-gland at its base, the muscles covering which being in powerful action during attack, compress the gland, and squeeze its deadly contents into the wound inflicted by the fang. When not in use, these formidable weapons are retracted and concealed in a fold of the gum, with their points directed backwards; the relation of tooth, jaw, and other parts, is sufficient to uncover the recumbent fang, and bring it into use when required.

In fishes, special adjustments are as numerous and remarkable as in higher vertebrata. Those that feed on worms, and similar soft food, have teeth which are simply conical, and differing in number and size according to the minor modifications of habit; the barbel and others present such a form of dental apparatus, well fitted for simple capture and retention of the food. The wolf-fish, again, has a dental furniture suited for bruising the shells of the mollusca on which it feeds; the thin membranous stomach of that species shews that the pavement of bruising teeth, with which its mouth is lined, serves for the effectual comminution of its prey, rendering the presence of a gizzard unnecessary. The fishes which feed on the coral-building animals have parrot-like jaws in front, for breaking off the calcareous polypidoms, and on the pharyngeal bones behind, an apparatus to crush and prepare for digestion in the stomach. The pharyngeal teeth of the wrasse are each in the form of an arch of greath strength, admirably fitted for the process of crushing, "if the engineer would study the model of a dome of unusual strength, and so supported as to relieve from its pressure the floor of a vaulted chamber beneath, let him make a vertical section of one of the crushing pharyngeal teeth of a wrasse."* In the carnivorous Sphyraena, whose teeth are liable to injury during efforts to secure its living prey, these formidable organs are continually replaced, the alternate teeth being shed cotemporaneously, by which provision is made for having a series of offensive weapons always ready for use.

The position of teeth, also, in this class, is in strict conformity with the habits and general organization. Those of flat fishes (flounders, &c.) are unequally distributed, being most numerous on the side next the under surface of the animal; in other words that side of the jaws next the ground, (in the usual position of such fishes,) being the one nearest their food, which is under them.

It appears, then, that in these instruments, as in every other part of the animal frame, while a general plan subordinates the whole, there is, at the same time, a vast number and variety of modifications, each in beautiful harmony with the instincts and habits of the animal, with all its organs, and with the place and part assigned to it by its great Author.

* Owen's Odontography, p. 788.

CHAPTER VI.

MOLLUSCA.

SECT. I.—TYPICAL FORMS OF MOLLUSCA.

WE have, in the preceding pages, been directing attention to animals possessed of an internal skeleton formed of parts constructed according to a common plan. We pass to the examination of others generally characterized by the absence of such a framework, but often presenting hard parts on the outside, constituting exoskeleton.

It is admitted that there are three types of invertebrata: the molluscan, as the oyster, etc.; the articulate, such as insects and crabs; and the radiate, comprehending the star-fishes, etc.

Although much remains to be done in reducing these departments of the animal kingdom to the same philosophical order which the department of the vertebrata has attained, we shall find no lack of examples for illustrating the argument, some of the more obvious and prominent of which may now be examined. We begin with mollusca.

The investigations of observers on the Continent and in our own country, have demonstrated that in the earlier periods of life, the mollusca present symmetry of parts in reference to a vertical and longitudinal plane. An examination of the history of development in the mollusc has shown that in early life there is a short compressed body, destitute of any lateral appendages, and presenting no repetition of segments.

In the skeleton of the vertebrata, it is necessary to observe the relations of its parts to the neural and hæmal organs, which are protected by it. The superior and inferior region of the molluscan animal must also be determined in order that the relations of parts in the archetype may be understood.

In vertebrata, the dorsal or superior aspect of the body corresponds to the position of the central mass of the nervous system, the hæmal being inferior. There is some difference of opinion as to the relations of the parts in the mollusca.* Adopting the view that the neural side is also the lower or ventral, and the hæmal the

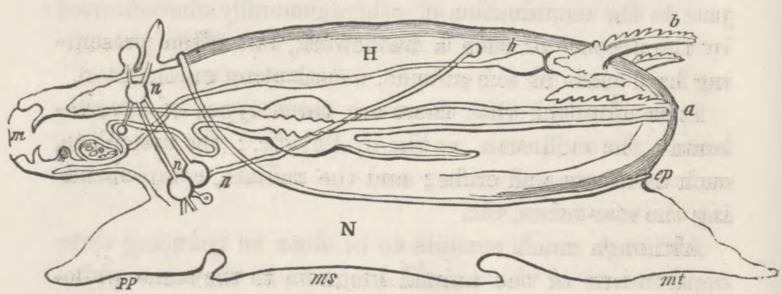


Fig. 45.†

superior, we proceed to examine the archetype, our materials being chiefly drawn from the admirable treatise of Professor Huxley on this subject.‡

* Professor Allman on the Homologies of the Tunicata and Polyzoa. Transactions Royal Irish Academy, 1852.

† Fig. 45. Ideal archetype, or common plan of the mollusca. *m*, the mouth; *a*, the anal aperture, or extremity of the intestine; H, hæmal region; *h*, the heart; *b*, branchiæ or gills; N, neural region; *n*, *n*, *n*, ganglia or nervous centres; *ep*, epipodium or upper foot; *pp*, propodium, anterior part of foot; *ms*, mesopodium, middle part; *mt*, metapodium, posterior part; *pp*, *ms*, and *mt*, together constitute the foot in general language.

‡ Transactions Royal Society, 1853; see also Knight's English Cyclopædia, Art. *Mollusca*.

The archetype mollusc is supposed to be bilaterally symmetrical; the relations of the different parts will be understood from the accompanyng figure. The hæmal region (H) corresponds to that where the heart (*h*) is situated; the opposite is termed neural, and the great nervous centres (*n n n*) are usually placed in it. The anterior part of the body is marked by the position of the mouth, (*m*,) the posterior by the opposite opening of the alimentary canal or anus (*a*.) The lower or neural surface is usually called the foot, because generally employed as an organ of progression. The foot may be divided into three portions, the propodium (*pp*) or fore-foot; the mesopodium (*ms*) or middle foot; and the metapodium (*mt*) or hind foot. The upper part of the foot, or middle region of the body, sometimes is prolonged into a fold or enlargement on each side below the point of junction of the hæmal and neural regions; this prolongation is called epipodium, (*ep*.) On the lateral and superior part of the head are two pairs of appendages, the eyes and tentacles. The part usually called mantle or pallium in mollusca, consists of a free fold of the skin either behind or in front of the anus. In the figure the branchiæ or gills (*b*) lie behind the heart, (*h*.)

There are two principal modifications of this common plan depending mainly on the relative development of certain parts of the hæmal region. The portion of it in front of the anus is called abdomen, that behind it is called post-abdomen. Excessive development of the former, accompa-

FIG. 46.*

* FIG. 46. Neural modification of archetype mollusc. The mouth, stomach, and alimentary canal are shaded. Here the part of the hæmal region above, or in front of the canal opening, is highly developed; the alimentary canal having a concavity toward the neural surface

nied by a bend of the intestine into it, (the concave part of which is directed downwards, or towards the neural surface,) constitutes a neural flexure. When the post-abdomen becomes developed in the same way, the open part of the intestinal bend will be directed towards the hæmal surface, giving rise to a hæmal flexure.

Fig. 47. *

Professor Huxley considers, therefore, that there are two primary modifications of the molluscan archetype, which may be termed the Neural and Hæmal plans.

The presence or absence of a shell is of minor importance, and does not affect the relations of the archetype ; all mollusca, therefore, may be referred to the same common typical form.

The cuttle-fish, with its formidable prehensile arms and beak ; the singular Clio ; the sluggish oyster ; the more active pecten or clam ; the destructive teredo or ship-worm ; those expert tunnel-makers and borers, species of Pholas and others ; the slug and garden snail ; the pearl oyster ;—in a word, the almost endless forms of this great division of the Invertebrate sub-kingdom, may all be considered as framed after the same model, and we shall find that certain modifications of it have undoubtedly reference to the habits and mode of life of the animals.

* Fig. 47. Hæmal modifications of archetype mollusc. Shews excessive development of post-abdomen, the part behind or below the anus. The alimentary canal has a flexure toward the hæmal region; in the fig. the heart is seen in the concavity of the flexure.

SECT. II.—MODIFICATIONS OF THE ARCHETYPE MOLLUSC.

Cephalopoda, or cuttle-fishes. These remarkable animals are usually placed in the foremost ranks of the molluscan type, and they present several interesting points of structure. The appendages, (whose position has given rise to the name Cephalopoda, or head-footed,) provided with a greater or less number of discs, each acting as a sucker, enabling them to retain their living prey and resist its struggles; their formidable beak-like jaws, by which they tear their prey in pieces; their bag, from which they explode an inky cloud, under cover of which they escape from their pursuers; their funnel, which serves as a discharge-pipe for water which has been in contact with the gills, and which, by the force of its escape, assists in aquatic progression; their highly-developed and curiously-constructed eyes—all give them a high degree of prominence in the estimation of the naturalist. They are pre-eminently the Felidæ of the ocean: lying in wait for living prey; lurking in secrecy to spring on it; feeding chiefly in the twilight or at night; while their strength and rapidity of movement render them formidable enemies to many of their fellow-inhabitants of the ocean. They are, moreover, the chameleons of the deep, having the power of rapidly changing the colour of their skin as emergencies require. What special modifications do they present, as departures from the model? and what relations do such bear to the habits of these animals? These are questions which may be now briefly examined, so far as the results arrived at by observers enable us to speak.

It is admitted that the development of all animals is subject to strict law, and the results of inquiries in this direction enable us to indicate the real nature of parts whose homology, in reference to the archetype, may seem difficult to solve in the fully matured condition.

It has been already stated that the Cephalopods are so named from the position of certain organs, which, although chiefly employed for prehension and retention of prey, are nevertheless also capable of being used as means of progression on a hard surface. Designations of parts are not always in strict accordance with their true nature, but it so happens in this particular instance, that the term Cephalopod is homologically correct, for the appendages which surround the fore-part of the animal in reality correspond to the lower surface or foot, being actually lateral appendages of that part. These organs vary in number; in some species there are eight, in others ten. In the well-known Argonaut, two of the appendages are webbed, so as to present considerable extent of surface. These were described by Aristotle as the sails of the animal, which, in fine weather, and when floating on the surface, it expanded and raised to catch the wind—a description which, as it is now well known, does not indicate the true use of these parts; for their function is to form the shell, and progression is accomplished by the forcible ejection of water from the funnel, the animal being urged on its course by the recoil.

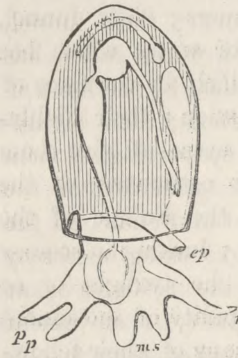


FIG. 48. *

* FIG. 48. Plan of cuttle-fish, to shew its relation to the archetype. *pp*, *ms*, *mt*, the parts of the foot modified to form the arms which surround the head; *ep*, epipodium forming the funnel through which water is discharged. The alimentary canal and heart will be seen in the middle of the shaded part of this figure.

In those with ten appendages, two are longer than the others, and serve as anchors to moor the body, or are darted out to capture prey beyond reach of the shorter arms.

Allusion has been made to the functions assigned to the funnel; this part, so necessary in the economy of the animal, may be also referred to its corresponding part in the archetype. It is derived from the epipodium, upper foot, (*Fig.* 48. *ep*,) the posterior part only is considered by Professor Huxley as contributing to the formation of this important organ. "The mouth is thrust back between the halves of the mesopodium, the propodium and mesopodium forming a continuous sheath—bearing tentacles—around the oral aperture. The two halves of the epipodium united form the funnel."*

Pteropoda.—The animals so denominated are generally of small size, but this is compensated for by their numbers. In the tropics, as well as in the Arctic seas, they abound, and, with other marine invertebrata, serve to stock the pasture-grounds of the great whales. The peculiar appendages, or lateral flaps, from which they derive their name, (*Pteropoda*, wing-footed,) are the principal means of progression by which they flit hither and thither—whence they have been appropriately called the moths and butterflies of the ocean. As littoral productions they are not generally known, excepting from the shells of some which are occasionally cast up; but in the open sea, far from land, they are sufficiently familiar to the observant navigator.

In these interesting molluscs, the parts called fore, middle, and hind foot, are generally in a rudimentary condition, and the epipodium or upper foot forms the wing-like appendages so necessary in the act of progres-

* Knight's English Cyclopædia, Art. *Mollusca.*

sion, and giving such a marked character to these animals. Cleodora, Euribia, Clio, Pneumodermon, and others, present each peculiar but minor modifications of the epipodium, doubtless in harmony with the habits of the respective species, but, nevertheless, essentially of the same nature, and performing the same general function.

The epipodium, which is but a narrow band in the archetype, appears, therefore, to attain its maximum of development in certain Pteropods, and forming wing-like appendages copiously traversed by strong muscular fibres, is admirably fitted to be employed as oars, and the testimony of observers confirms such idea respecting its use. —There are other mollusca not far removed in appearance from those just described, which also deserve to be noticed here as examples illustrative of the argument. They have been called *Heteropoda*. Like the *Pteropoda*, they are constituted for free progression in the water. The relations of their parts have been very fully examined by Professor Huxley in the Essay already quoted. The body in one genus, namely, Firola, is clear as crystal, so that all its internal organs can be distinctly seen, and the author quoted describes it "as hardly distinguishable in the water, except by the incessant flapping of its flattened ventral appendage." The shape of this organ, by which the animal makes progression in the water, is that of a cheese-cutter; it is a modification of the propodium or fore-foot of the archetype, the other parts remaining rudimentary. In another genus, viz., Atlanta, progression in the water is accomplished by means of an appendage similar to that of Firola, and a modification of the same part, thus remarkably constituted to serve an important end in the economy of the animal. But Atlanta has the power of attaching itself to marine plants by means of a sucking disc placed behind the propodium;

this part is the mesopodium, which thus presents a modification different from that of the propodium, the one as well as the other, however, being admirably suited to its function. Moreover, the metapodium, or tail, as it is sometimes called, bears on its surface the hard body called operculum, which serves as a lid to close the mouth of the shell when the animal retreats into that appendage.

In Aplysia, or sea-hare, the epipodium is highly developed for a special purpose, namely, to assist in locomotion. Professor Huxley describes a tropical Aplysia as flying through the water in precisely the same way as a Pteropod would do. In Natica, we observe the mesopodium modified, to serve as a disc for locomotion by creeping; the metapodium bearing the operculum or lid which closes the mouth of the shell when the animal takes refuge in it.

Among Bivalves, as they are called, from the form of the protecting shell, we find numerous modifications of the neural surface in evident relation to the wants of the animal. In the oyster, destined to sedentary life, it is small; in Solen or razor-fish it is large, constituting the foot, which the animal employs as an effective means of burying itself in the loose sand. According to the views of some, the same part is actually so modified in its form, and in the nature of its constituent tissues, that it may be used as an instrument for perforating wood and rock. Whatever be the form or function of this necessary organ of the bivalve mollusc, it is supposed to correspond to the metapodium of the archetype.

Certain *Gasteropodous* mollusca are, when young, protected by a shell resembling that of the nautilus in miniature. At this stage they do not possess the power of creeping, but swim freely in the water—a provision which secures their wide distribution, and gives rise to fresh colonies at a distance from the parent. At this early period of life they are provided with two wing-like appendages fringed with cilia; these are employed as oars, by which they move from place to place. The appendages in question are believed to correspond to the anterior part of the epipodium. This peculiar modification is, however, only a temporary arrangement; a time arrives when it is no longer needed; it then disappears, and the adult animal accomplishes progression on hard surfaces by means of the foot proper. The ciliated epipodium is provided for a temporary purpose, and when that is accomplished it disappears, to be superseded by another part.

It is therefore admitted, that all mollusca present traces of a common plan; and although in every instance it may not be possible to indicate with clearness and precision the special ends of the many modifications of the archetype, still, arguing from what we do know, it is not unreasonable to conclude that we have here independent members in harmony with each other, and conspiring to promote the wellbeing of the animal in its destined sphere of life.

CHAPTER VII.

ARTICULATA.

SECT. I.—HOMOTYPAL RINGS AND APPENDAGES.

We now pass to the Articulate type of the Invertebrata, comprehending crabs, barnacles, insects, spiders, and others.* These agree in one obvious character—their body consists of a series of similar or homotypal rings, which present almost endless variety in size, form, and other particulars, according to the habits of the species. The rings are generally, in the higher kinds at least, of more or less hard texture, giving support to appendages, and serving as points of attachment to numerous muscles, as well as protecting various important organs concerned in the function of sensation, motion, circulation, &c. They present us with examples of a highly-developed outside covering, technically called exoskeleton, the character of which varies as there is necessity in different parts, for variety of motion, for solidity, or for simple protection.

The endless diversity in form, and the exquisite beauty of colour and sculpture, exhibited by certain of the Articulata, have rendered them favourite objects of study, and their history has been in general very thoroughly

* It is not our intention to discuss here all the classes of the Articulate type; a selection will suffice for our purpose.

investigated by observers in different countries. The fertile results which have accrued from such inquiries present admirable examples of what may be expected from the patient labours of ardent naturalists, guided by careful attention to philosophical methods of investigation.

We have stated that all the pieces in the linear series of which an articulate animal is made up, are homotypal, that is, constructed on the same plan. This unity of composition is not necessarily coincident with any law of number, viewing the Articulata as a whole; but in the higher types, at least, the number of similar pieces of which the body consists is usually uniform.

We may here introduce the general law announced by M. Audoin, in 1820, that the similarity or difference between the segments, the union or the separation of the pieces of which they consist, the excessive development of some and the rudimentary conditions of others, occasion all those differences observed in the entire series of articulated animals. It is well established that a common type determines the general organization of the animals in question, and we may now examine the structure of the typical ring or segment.

Milne Edwards, in his history of the Crustacea, has demonstrated very clearly the composition of this part. It may be described as consisting of two arches, a superior and an inferior. The former consists of four pieces, arranged in pairs on each side of the middle line. The two upper, occupying a position on each side of this middle line, are called tergal,

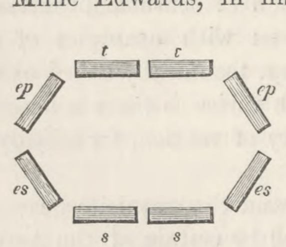


Fig. 49*

* Fig. 49. Plan of ring of Articulate animal. *t*, tergals; *ep*, epimerals; *s*, sternals; *es* episternals.

because forming the back, (from *tergum*, back;) those on each side are called epimerals, or flank pieces. The lower arch has similar composition: the middle pieces are called sternal, because corresponding in position to the breast-bone (sternum) in Vertebrata; the lateral pieces are called episternals. Instead of the technical terms epimeral and episternal, we may use the terms upper and lower flanks. In all this we find some resemblance to the neural and hæmal arches in the vertebrate segment, with this difference, that the body of the vertebra serves at once as a foundation and line of demarcation between the two arches, each of which is complete and independent. The typical segment in the Articulata may be compared to a segment of a tunnel, not merely arched in the roof, but having also a concave floor. A series of such rings constitutes the external framework of the animals under discussion, and protects the nervous centres, which are placed near to the floor, and also the hæmal organs, which lie beneath the roof, and therefore differ in their position from that in the Vertebrata.

The division of the body, in crabs and insects, into three regions—head, thorax, and abdomen, is generally obvious enough. There may exist difference of opinion regarding the number of segments or rings entering into the formation of each of these, and respecting the number of pieces constituting the typical ring; but it is generally admitted as an established truth, that the entire body is made up of a number of similar pieces.

In *Crustacea*, (crabs, &c.,) Milne Edwards and others believe each region to be made up of seven segments, making, therefore, twenty-one in all. In insects, the head is supposed to consist of five, the thorax of three, and the abdomen of eleven.* Erichson, in his Entomo-

* Newport, Art. *Insecta*, Cyclopædia of Anatomy and Physiology.

graphien, has demonstrated that the thoracic portion of the body in crabs, insects, and spiders, is made up of three segments.* But, as we have said, whatever difference of opinion exists regarding the entire number in any one region, or in the whole body, it is universally admitted that a uniform plan regulates the construction of the entire framework; "the different forms of the body are invariably the result, not of the introduction of new elements, but of the greater or less extent to which the primary parts are developed."†

We have seen that in the vertebrata the typical vertebra supports appendages; so the typical ring in the articulate invertebrata also gives attachment to lateral appendages. Their form and function vary according to the part of the body which supports them. They differ also in different species, and even at various periods of the life of the same individual, but they all possess certain common characters.

M. Audoin, long ago, demonstrated that the appendages in question belong either to the upper or lower arch of each ring of the body, the first constitute the wings of insects, and the second their legs; the same applies to those of crabs and spiders, which, however, want the upper appendages. They are, therefore, arranged in pairs on either side of the middle line, and each ring supports either two or four such appendages. Those of the inferior arch are the more important, and are of more universal occurrence than the others.

In Crustacea the complete appendage is constituted by three distinct portions, which it will be necessary briefly

* In Dana's Crustacea of the U. S. Exploring Expedition, there are some peculiar and important views as to the organization of the different groups, and the number of rings in the different regions (head, &c.,) of the body; as well as the mean normal length of rings. It is, however, unnecessary for our purpose to discuss the subject.

† Newport, in Cyclopædia of Anatomy and Physiology.

to describe. The first and most essential of these is the *stem*, which gives support to the other two; it is formed of a number of pieces attached in linear series. The second part is called *palp*, and is generally attached near the base of the stem. The third is called by M. Edwards the fouet, or *flabellum;* it also originates from the stem, but at a point more external than the *palp*. In conclusion, it may be remarked that attention to the number of appendages in any part sometimes affords a good criterion for deciding its composition, where, owing to adhesion or other circumstances, the number of rings may be obscured

Fig. 50.*

Modifications or departures from the general plan may arise from several causes;—as from soldering of two or more of the elementary pieces; from confused development of parts whose presence may be indicated by the existence of special centres during the process of hardening; from wasting of one or more of the elements of the typical segment; the abortion of certain parts of the same; unequal development; overlapping of neighbouring parts; disappearance of typical parts; and, lastly, from multiplication by repetition of similar parts.†

SECT. II.—SPECIAL MODIFICATIONS OF RINGS AND APPENDAGES.

Crustacea.—In the higher forms, usually called Decapods, (ten-footed,) from the number of their chief loco-

* Fig. 50. Appendages of Crustacean, showing its essential parts; *a*, stem; *b*, palp; *c*, flabellum.

† M. Edwards, Annals des Sciences Naturelles, 1851.

motive members, we observe three principal modifications in the general form of the body. First, there is the Brachyura or short-tailed crabs, (as the common crab,) in which the abdominal part of the body is of small size, and usually folded beneath the thorax, (so called,) which part is generally very highly developed. The second form comprehends the Anomoura, in which the abdominal portion of the body is soft and defenceless, as in the hermit crabs. Under the third head are included all those called Macroura, (long-tailed,) the posterior extremity of the body being well-developed; the lobster may be cited as an example. Details regarding the real nature of the departures from the archetype in each of these three forms are unnecessary for our purpose; it is enough to say that in every case, the structure, habits, and instincts of the animals are all in beautiful harmony with each other.

Where, as in the first of these, the thorax is well developed, and usually of great strength, the ambulatory appendages, in five pairs, are generally of large size, and constitute very efficient organs for progression as well as other purposes. The great strength of the general framework is in admirable harmony with its function as a supporter of the powerful limbs, and the protector of important internal organs. But, since the relations of the segments, and of the appendages which they support, are so intimate, the special modifications and functions of each are best studied in conjunction.

The tabular view which we here submit, of some of the segments and their appendages, will afford an idea of the deviations from the common plan which occur in different parts of the body of the same individual, and shew how each deviation has reference to some peculiar function of the part. There is an absence of the centralization and specialization which characterize animals higher in the scale; all the segments and their appendages together constitute the individual, and each performs its respective function in order to contribute to the wellbeing of the whole. The following table represents the general arrangement of most of the rings and appendages in one of the higher crustacea, a lobster, for example:—

Rings.	Appendages.	Functions.
1	Eyes.	Vision.
2	1st, pair of Antennæ,	Touch, &c.*
3	2d, do. do.	
4	Mandibles.	Capture and division of food, &c.
5	1st, Maxillæ,	
6	2d, do.	
7	1st, Feet-jaws,	
8	2d, do.	
9	3d, do.	
0	Limbs,	For progression.
11, 12, 13, 14	do.	

Then follow appendages of abdominal rings, varying in use.

The individual is thus made up of a number of organs, each of which fulfils a special office; by this division of labour each most effectively performs its part in the general economy, and the wellbeing of the whole is amply provided for.

The typical appendages of the first and second rings are modified for the purposes of vision, touch, hearing, &c.; then follow organs surrounding the mouth, and which are employed by the animal when food is required; the flabellum of the second pair of foot-jaws assists in respiration; the thoracic appendages are limbs for locomotion, and sometimes for prehension; those of the abdomen are either for locomotion or respiration, or are concerned in the function of reproduction. It is to be observed that

* One or both of these are now believed to perform the function of smelling.

each appendage presents special modifications not only in its general form, but also in the number of the elements of which it consists, but in every instance the departure from the typical appendage has a decided relation to its use and the comfort of the animal.

In Crustacea of lower organization, the king-crab, for example, the appendages of the head and thorax closely surround the mouth; they are nearly all of the same form, and act not only as limbs for motion, but also as instruments for the capture of the food, and farther, their bases act as jaws for dividing that food.

The mandibles correspond to the *stem* of the typical appendage, strengthened and usually toothed. In Chelura terebrans, whose habits of boring render it so destructive to wooden piles, the jaws present a file-like surface, admirably fitted to reduce to powder any such structure.

Generally speaking, it may be observed that the appendages of the fourth to the ninth segments inclusive have forms and dimensions varying in harmony with their uses. In the words of M. Edwards, "they are so much the shorter and flatter as they are more peculiarly apportioned to the oral apparatus, a disposition which is nowhere more conspicuously displayed than among the short-tailed Decapods, (common crab, for instance,) in which they resemble horny laminæ, armed with teeth of various sizes, and supporting a jointed *palp* as well as a flabellum."*

In the thoracic portion of the body, some of the more anterior appendages or limbs are, in the higher crustacea, of large size and peculiar organization, constituting the *pincers*, which are very formidable instruments for offence and defence, and are sometimes used for other purposes. One

* Cyclopædia of Anatomy, Art. *Crustacea.*

of the most striking examples of such modification in harmony with function, occurs in the large land-crab (Birgus Latro) of the Keeling Islands. We shall quote the description given by Mr. Darwin :—" The first pair of legs end in strong and heavy pincers, the last pair are fitted with weaker and narrower. The animal tears off the cocoa-nut husk, fibre by fibre, and always from that end under which the three eye-holes are situated ; when this is completed, the crab commences hammering with its heavy claws on one of the eye-holes till an opening is made, then, turning round its body by the aid of its posterior and narrow pincers, it extracts the contents—a curious instance of instinct and adaptation of structure between two objects so remote from each other as a crab and a cocoa-nut. The strength of the fore-pincers is great : an individual was confined in a tin box, the lid secured with twine, but the crab turned down the edges and escaped ; it actually punched many small holes quite through the tin."*

In the species of Portunus of our own seas, the last joint of some of the thoracic members is flattened, and the limb serves as a paddle for swimming, or is used by the animal as a means of scuttling itself in soft sand.

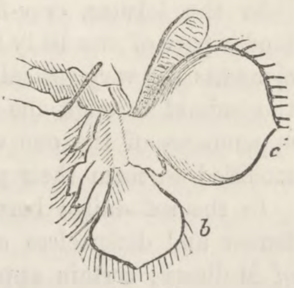


Fig. 51.†

In many Crustacea, certain appendages are modified to serve as apparatus for respiration, acting, in fact, as branchiæ or gills. Those called Branchiopods (gill-

* Darwin, Journal of a Naturalist, p. 463.

† Fig. 51. Transformation of appendage of abdomen in a Branchiopodous (gill-footed) Crustacean. *b*, flabellum ; *c*, palp, which act as respiratory organs.

footed) receive their name from this peculiarity; the whole of the thoracic appendages are in the form of lamellæ, and the parts corresponding to palp and flabellum are membranous vesicles highly vascular, and fitted to expose the circulating fluid to the action of the air contained in the surrounding water.

In certain others, the Amphipods, for example, localization of function is more complete, the *flabellum* alone acting as a gill. In those called Isopods, the members for locomotion have no other function superadded, respiration being performed by the first five pairs of abdominal appendages, which appear to have no other use.

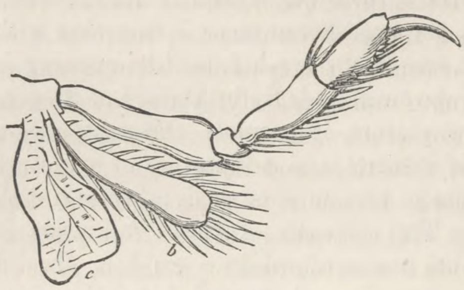


Fig. 52.*

In the lobster, cray-fish and others, in which the hinder part of the body is well developed, certain of its elements are very specially fitted for the progression of the animal through the water. The last ring, and the appendages of the one which precedes it, are specially modified to form their powerful tail fin.

In the soft-tailed hermit crabs, which protect their tender and defenceless abdomen in empty spiral shells of Mollusca, certain appendages are modified to act as hooks by which the animal holds fast to the inside of its borrowed habitation; and it is a curious circumstance, that some of these hooks are wanting on one side, since

* Fig. 52. Appendage of Amphipodous Crustacean, the flabellum, *c*, alone serving as a gill for respiration.

they would be useless or even an encumbrance to the animal, owing to the curve of its body corresponding to that of the shell in which it lives. The instincts of the hermit crab lead it to seek in an empty shell that protection which is wanting in the texture of its own body. The means by which it holds fast are also admirably fitted by form and position, to the exigency of the case.

Not a few of the Crustacea are parasites, that is, they attach themselves to other animals, and feed on their juices ; those called fish-lice are examples. Such habits require special peculiarities of organization, and we are constrained to admire the wisdom which foresaw and provided for all the necessities of these singular beings. The mouth apparatus in some is fitted at once for piercing and sucking the juices of the foster-parent ; and certain of the appendages in other species, corresponding to those already alluded to under the name of foot-jaws, are constructed in such a way that they enable the little animal to keep fast hold of its foster-parent.

In the curious Lerneadæ, whose grotesque forms have puzzled not a few observers, the young are furnished with a well-developed eye, and are provided with two large pairs of appendages, which serve as oars. Their peculiar instincts lead them to fasten themselves to various fishes, some selecting one part of the fish, others a different part. Some after they become fixed, the eye, no longer of any use, is lost, the oar-like appendages either disappear, or undergo a change of form suited to the new mode of life ; in a word, there are several independent successional arrangements concurring to one end. Certain parts are necessary to the existence and comfort of the animal, and such are provided, and everything is in conformity with the position which it occupies in the economy of nature.

Barnacles.—These remarkable animals, in some one or other of their forms, are doubtless familiar to our readers. Many of them are attached, by more or less flexible stalks, to sea-weeds, to drift-wood, even to quills shed by sea-birds, or they adhere in countless multitudes to the bottoms of ships which enter our harbours from some warmer region ; so abundant are they, in fact, as sometimes to impede the motion of the vessel in the water. Other kinds contribute to the formation of that white line which marks the limit of high-water on our rocky shores, or give a continuous covering to the exposed parts of marine piles or stakes of salmon-nets. Others invariably attach themselves to corals ; not a few find a suitable dwelling-place in the thick skin of whales, and

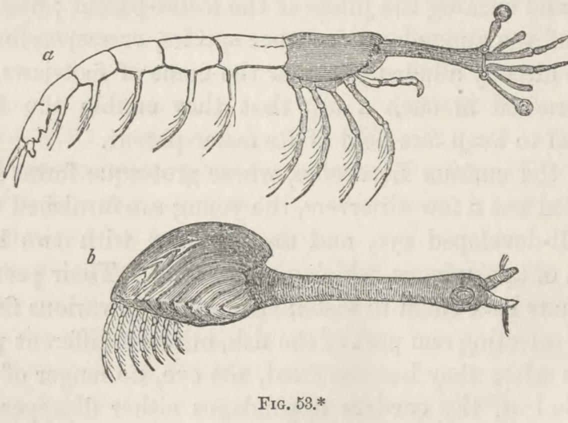


FIG. 53.*

certain others in the shell of the sea-turtle, and some bury themselves in sponges. All these curious animals are

* FIG. 53. *a*, A Stomapod Crustacean of the genus Leucifer. The abdominal portion is not shaded. The shaded part corresponds with the next, *b*.

b, Cirriped, or Barnacle—a mature individual. All the parts correspond to shaded portion of *a*; the eyes and antennæ, which are distinct in early life, are also represented here, for the sake of comparison.

constructed on the same general plan as the Crustacea we have been examining, and are, in fact, so nearly allied, that naturalists justly include them in that class. (*Fig.* 53.)

The archetype has undergone remarkable transformations in the barnacles, in order to fit them—and how admirably are they fitted—to that particular part which the Creator has assigned them in the economy of nature.

In the earlier periods of their life, barnacles are free; that is, unattached, are possessed of efficient locomotive members, and furnished with organs of vision; in this condition they very much resemble some of the simpler forms of Crustacea. Peculiar instincts lead to the choice of a proper habitat, whether a floating body, or a rock, a sponge, a whale, or a turtle; how admirable, therefore, the harmony between the structure and the instinct! The voluntary roving animal becomes fixed to some object, and, after various transformations of its organs, the adult state is finally assumed, and the change of form is commensurate with that of its mode of life. The fixed state of the full-grown animal renders several conditions necessary to its existence and comfort. Having no power of movement from one place to another, the barnacle is incapable of voluntarily avoiding injury from without. The animals require means of attachment, a shell for protection, and provision for the supply of their wants. All these points have been attended to in their structure, and there is remarkable concurrence of arrangements tending to the well-being of the entire organism.

The masterly researches of Mr. Darwin, forming two volumes recently published by the Ray Society, have fully elucidated the remarkable modifications of the Crustacean type met with in the animals under discussion. Comparison of the following table with that already given, will show the relation between a barnacle and a crab :—

Rings.	Appendages.
No. 1,	Eyes, } quite distinct in early stages.
2 & 3,	Antennæ, } quite distinct in early stages.
4,	Mandibles.
5 & 6,	Maxillæ.
7 & 8,	Generally coalesce or disappear.
9, 10, 11, 12, 13, 14,	Six pairs of limbs.
15, 16, 17,	form three small abdominal segments; the last four are wanting.

The appendages of the third ring, or the second pair of antennæ, are the primary means of attachment, the union being subsequently consummated by a cementing material, which at first issues from these appendages, and finally also, in some, through special openings in the head. Such, then, is the simple means by which the attachment of the barnacle is provided for. In connection with this part of their history, allusion may be made to the habits of a species not uncommon on some of our coasts. In Lepas fascicularis, the cement is very copiously given out, and forms a vesicular ball, which acts as a float. Mr. Darwin states that sometimes several individuals have their stalks imbedded in the same ball, which swims like a cork on the water. As this species grows into a

Fig. 54.*

* Fig. 54. Lepas fascicularis, with its stalk (together with three others, the stalks of which are alone seen) imbedded in a vesicular ball (constituting a float) of their own formation, of which a slice has been cut off to shew the internal structure.

bulky animal, we here see a beautiful and unique contrivance in the cement formed into a vesicular membraneous mass, serving as a buoy to float the individuals, which, when young and light, were supported on the small objects to which they originally had been cemented in the usual manner. We have seen a cluster composed of at least a dozen large specimens, any one of which, without the float, would have been sufficient to sink the small quill-feather of a sea-gull to which they were attached. It will be remembered that the position and production of this singular contrivance depend on modifications relating to certain appendages of the body.

As regards means of protection, we may quote Mr. Darwin, who states, "In the mature animal, the whole external covering, whether shell and operculum, or capitulum and stalk, is formed of the third segment of the head."* It consists of distinct plates, which overlap each other, and are capable of various movements, in which respect it differs from that of all crustaceans, and farther, is never moulted or cast off, as is the case in them.

But the animal requires, also, means for procuring food; this is provided for, in all common barnacles, by a special modification of the thoracic limbs, which form six pairs, and are admirably suited to their intended use. (See *Fig.* 53, *b.*) Each is two-oared and many-jointed; "they have a peculiar character, different from the limbs of other crustaceans, not being natatory, ambulatory, nor branchial, but 'captorial,' or fitted for sweeping the water, and thus catching prey."† Mr. Hancock describes these appendages as acting like a *prehensile net.* Is it possible to conceive any better example of parts constructed according to a general model, and yet harmo-

* Darwin, loc. cit. vol. ii., p. 13. † Ibid., vol. ii., p. 14.

niously combined and modified in distinct relation to a special purpose, than that found in the barnacle? Assuredly the lately-developed principle of homology does not set aside, but corroborates the old-established principle of final cause; and it appears to us that the more intimate our acquaintance with the one, so much clearer will be our idea and appreciation of the other.

Insects—The busy bee, that master architect and builder of its class; the industrious ants, from some of which man might derive useful lessons in social economy, division of labour, and persevering toil; the locusts, those rovers and depredators, the Goths and Vandals of the winged articulata; the painted butterflies, sipping the nectar which Flora provides so bountifully; the mailed beetles, the athletes of the insect world—notable as swimmers and divers, as sappers and miners, indeed, as adepts in various departments of nature's economy too numerous to be mentioned here;—all these now invite our attention. The field is so vast that we can only glance at a few cases in which we observe modifications of the archetype, obviously concurring to serve useful ends in the economy of the animal.

Whatever difference of opinion may exist in regard to the number of the segments entering into the formation of the body of the perfect insect, the best authorities are agreed that the different pieces are homotypes of each other, and that all modifications and departures less or greater from a common model. We are now to shew that these modifications are intended to serve an end which is more or less obvious. The varied forms of the whole body, in different insects, depend upon the relative development of the parts of each segment and appendage, and the diversities are invariably in direct harmony with the peculiar function to be performed.

The reader is doubtless familiar with the transformations, greater or less, through which insects pass before reaching maturity. How different is the general appearance of the caterpillar from that of the winged butterfly—the one incapable of flight, and feeding upon the solid parts of vegetables, the other possessed of powerful wings, and having extensive and rapid means of aerial progression, and feeding on the sweet juices of flowers! Both possess the same number of true appendages for walking, namely, three pairs attached to the segments of the thorax; those in the caterpillar, or larva, are nearly of the same size and form. But many larvæ, as requiring efficient means of locomotion on a hard surface, are furnished with additional limbs, usually called false, because they are not appendages of the archetype, but only prolongations of the external covering of the body, and are attached to the abdomen. Without entering into details respecting the very numerous modifications of these false appendages, it may be sufficient to state that whatever their number or form, they are invariably so constructed as to answer every purpose for which they may be wanted in the economy of the animal.

It may further be observed that many larvæ are destitute of feet, and yet possess the power of locomotion. And here we see a beautiful compensatory arrangement in the form of minute hooks, which are prolongations of the external covering of the body, the position, number, and forms of which are wonderfully adapted to the peculiar habits of the individual. We may conclude this part of the subject by quoting a passage from Mr. Newport:*—"In apodal larvæ, endowed with powers of locomotion, the place of the true organs of progression is supplied by peculiar developments of the cuticular covering of the

* Cyclopædia of Anatomy and Physiology, Art. *Insecta.*

body, analogous to the scales on the bodies of Ophidiam reptiles, and these are employed by the larvæ in all their progressive movements in the same manner as the scales on the body of the snake. But in those apodal (footless) larvæ, which remain in the same locality until they have passed through all their changes, as the larvæ of the bee and wasp, these developments of the cuticular surface do not exist, but the body is perfectly smooth."

If such remarkable conformity exists between the habits of the immature animal and the development of certain temporary organs with which it is furnished, we may be prepared to expect harmonious adaptations of the archetype all conducing to the existence and comfort of the perfect insect, suited to its instincts and fitting it to the position which it is to occupy, in earth, air, or water. The usual elongated body of the grovelling larva in general presents evident uniformity in the development of the segments as well as of the true appendages when present, in other words, there is a close approach to the archetype. The new sphere which it is subsequently designed to occupy, demands corresponding modifications in the form of the whole body, and in that of the segments and appendages.

In the perfect insect, division of the body into three regions, head, thorax, and abdomen, is generally obvious. Each of these consists of parts adapted to certain ends, and all concurring to the well-being of the entire organism. All of them present entire fitness for their respective functions ; those of the head support certain sensatory organs and appendages for capture, retention, and reduction of the food ; those of the thorax afford attachment to wings and limbs ; the abdominal segments protect certain viscera, and serve other purposes besides.

The differences to be observed in the hardness of the framework are remarkably adapted to the uses of the part Where close union and density are wanted for strength, there we find them ; in the head this is specially evident ; mobility is sacrificed for firmness precisely where such is necessary. The consistence of the head segments is, as a general rule, greater than that of any other region of the body. The head is the part of all others most exposed during progression, whether in air, earth, or water ; besides, it supports mandibular organs, whose function frequently is to act upon very hard materials and fit them for digestion. Owing, in fact, to the close union of the elements of the typical rings forming the head, there has been more difference of opinion regarding the number of its segments than those of any other part of the body. The muscles of the insect are inserted on the internal surface of the framework, and we might naturally expect a relation between the development of the two. Where strong organs of mastication are needed, the segments of the head are large, being directly proportional to the power which the mandibular apparatus is fitted to exercise. Mr. Newport remarks, "we invariably find that in those insects in which the mandibles are large, the whole head is either short and wide, or its posterior portions, to which the muscles of the mandibles are attached, greatly exceed those of the anterior."*

The great extent of surface occupied by the organs of vision in many insects, has an influence also on the general development of the whole head and of its elements. The rapacious dragon-flies, for example, hunt solely by sight, and their eyes occupy almost two-thirds of the surface of the head, and we observe corresponding modifications in the segments. It is unnecessary to enter into minute details regarding the variously modified appen-

* Cyclopædia of Anatomy and Physiology, Art. *Insecta.*

dages of the different segments of the head; it will be sufficient to indicate some of the more obvious adaptations of the elements to their respective functions. The wide dissemination of insect life implies considerable range in the instincts and means of existence. The predatory habits of some constitute them the carnivora of their class, and others are not less fitted—than rodent mammals—to gnaw hard vegetable matters. The instinct which leads some to sip the sweet fluids of flowers, or stimulates others to tap the integuments of animals or of plants for the purpose of feeding on their juices, equally require adaptation of the mouth to such purposes. But whatever the end to be accomplished, and however great the apparent difference of the organs which minister to the subsistence of the insect, it was long ago demonstrated by Savigny that in every case the parts are fundamentally identical, though varied to suit a purpose. The study of the mouth-organs in insects has occupied the attention of numerous observers, and the results of such researches have shewn how admirably each piece is fitted for its function, and at the same time accommodated to act in harmony with every other.

FIG. 55.*

In the great water-beetle (Hydrous piceus) the mandibles are two strong, arched and toothed jaws moving horizontally in opposition to each other; this species is omnivorous. In the truly carnivorous forms, as the brilliantly-coloured and active tiger-beetles, the mandibles are acutely pointed, strongly toothed, and crossing each other like the blades

* FIG. 55. Mandible of a large water-beetle, (Hydrous piceus.) There are two such which act in opposition to each other, like the blades of scissors. The opposed edges are hard and toothed.

of scissors, and are thus admirably fitted for dividing the prey. Those of Melolontha (the cockchafer) have short blunt teeth fitted to bruise vegetable matter ; in Cetonia which feeds on the pollen of plants, the edges of the mandibles are soft and flexible. The mandibles of the locust are in front so constituted as to form cutting organs, and behind act as grinders of the vegetable food.

The maxillæ, or lesser jaws, are organs of prehension and retention chiefly, but may aid also in mastication. Like the organs just described, they present differences in form and texture in direct consistency with the habits of the insect.

FIG. 56.*

Among Hymenoptera, comprehending bees, wasps, &c., the mandibles present very considerable difference in form ; "in the Vespidæ, (wasps,) which gather the materials for their nests by rasping off little packets of fibres from decaying wood, they are broad, triangular, and armed along their edges with strong teeth ; and such is also their structure in Anthidium manicatum, which scrapes off the down from the woolly stems and leaves of plants for the same purpose ; while in the hive-bee, which employs them in moulding the soft wax in the construction of the combs, they are shaped at the apex like a spoon, without indentations ; their form in each instance being thus distinctly conformable to the habits of the insects."†

The highly-developed instincts of bees, which lead to

* FIG. 56. Maxillæ, or smaller jaws of the Hydrous. They act in pairs, but as their function is to hold the food and convey it to the back part if the mouth, they are not so strong as the mandibles, which divide and bruise the food ; they, however, have a general resemblance in shape.

† Newport, Cyclopædia of Anatomy and Physiology, p. 898.

the formation of very ingeniously constructed nests, imply the necessity of tools for the work; these are furnished by the mandibles, while the maxillæ and another cranial element termed the labium, are principally concerned in collecting the food; the former are elongated, and with the latter beneath, together constitute a tube by means of which the honey of flowers is conveyed to the mouth.

But we must pass on to consider arrangements suitable to the habits of suctorial insects properly so called, and here also, while the general plan is evidently adhered to, the modifications are in strict conformity with the wants of the animal, and all concurring to a common end.

Hitherto we have seen that the mandibular appendages have occupied either the chief, or at least the prominent place in the operation of feeding; in the Haustellate insects (those furnished with a proboscis) the mandibles no longer perform the same important offices, while the maxillæ and the labium now assume greater prominence and importance in the economy of the insect.

Every one must be familiar with the habits of moths and butterflies "hovering around those opening flowers," and closer inspection would reveal that the insects carry with them an apparatus admirably fitted to reach the sweet juices in parts of the plant, into which the body of the animals could not possibly find access. The short mandibles of the voracious vegetable-feeding caterpillar, though admirably fitted to that stage of life, would be utterly useless in the new sphere which it occupies, when, issuing from the mummy-like case of the pupa, it emerges as a winged imago, endowed with new instincts and new faculties. The perfect insect carries with it an instrument admirably fitted for reaching and drawing up the nectar of flowers. The mandibles are no longer capable of supplying the wants of the animal, as the sweet fluid on which it feeds requires no mastication; but an organ is needed to suck it up, and of sufficient length to reach the parts of the plant where it abounds; such an organ is supplied.

It would be difficult to select, in the entire range of the animal kingdom, such a remarkable example of special modification of typical organs, as that presented to us in the proboscis of the butterfly. The problem is to convert the maxillæ (which in some insects we have seen to be organs for prehension and mastication) into organs adapted to the function they have to perform in the moth or butterfly; for, as we have just said, the portable flexible tube in these animals really corresponds to the maxillæ of a beetle. Sweet juices abound in flowers, access to the bottom of every floral tube would be impossible to insects having the large prominent eyes of those under discussion, and so a peculiar contrivance is necessary under the circumstances—that contrivance is simple, yet efficient for every purpose required.

The structure of the mouth-apparatus in the Lepidoptera has been so fully illustrated in other works, that a summary may be sufficient here.

The appendages called maxillæ constitute the sucking apparatus. In the words of Mr. Newport, "each maxilla is composed of an immense number of short, transverse, muscular rings. It is convex on its outer surface, but concave on its inner, and the tube is formed by the approximation of the two organs."* But something more is necessary. By what means are the two opposed channels to be kept in sufficiently close contact so as to form a perfect tube? Reaumur, Kirby, and others, have described numerous minute and delicate hooks or teeth, (for they assume varied forms in different species,) which

* Newport, loc. cit., p. 90.

are arranged in close series along the inner margin of each maxilla, and the teeth of the one set lock between the teeth of the other. The animal is now furnished

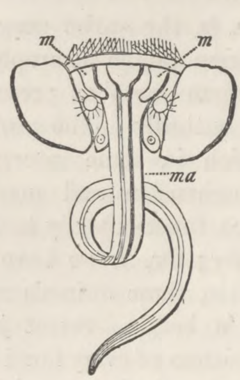


Fig. 57.*

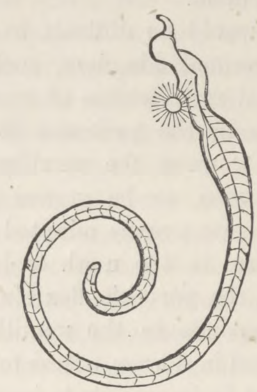


Fig. 58.†

with a means of searching every crevice of a flower for the tempting juice which is formed there. But something more is necessary. Not a few Lepidoptera feed upon wing, and the act of feeding is very quickly performed ; in the twinkling of an eye the tube is inserted, and the flower is robbed of its sweets. The act of suction, by producing a vacuum, which enables the infant to procure nourishment from the breast, is also brought into play in order that the fluid may rise in the butterfly's proboscis. The peculiar air-tubes which traverse the bodies of insects, for the purpose of respiration, are abundantly distributed throughout the maxillæ in the head, and over the gullet and alimentary canal. Experiments made by Mr. Newport led to the conclusion that the

* Fig. 57. Head of Noctua libatrix; *m*, mandibles, small; *ma*, the two maxillæ, large, and forming the proboscis or sucking apparatus.

† Fig. 58. A single maxilla of the same.

insect first makes a strong effort to expel the air, and just when the proboscis comes in contact with the fluid, a powerful inspiratory effort is made, which occasions dilatation of the tube, producing a vacuum, and thus causing the liquid food to rise. There is still, however, another arrangement necessary in this simple but efficient apparatus. It must be long enough to reach to the very bottom of the floral shaft whence the food is to be drawn, but a long and flexible tube would be liable to injury, and also inconvenient during progression on the ground or in the air; it must, therefore, be portable; and here another modification comes in to provide for the comfort of the insect. The two maxillæ, conjoined in the way we have described, are, when at rest, coiled like the spring of a watch, but can be extended with ease and surprising rapidity as required. (See *Fig.* 58.)

The mandibles—which, as we have seen, are so highly developed in some insects of prey, and are, on the contrary, so useless in the butterfly—assume a new aspect and function in the blood-sucking Tabanidæ. In the typical genus of that family, they are long and lancet-shaped; and Mr. Newport describes them as acting not from side to side, but with a horizontal movement from behind forwards, cutting also vertically with a sweeping stroke, like the lancets of a cupping instrument. We may add, that the bite of the gnat is effected in the same way.

We may now proceed to examine the modifications presented by the next region of the body—the thorax, namely. The three different segments which constitute this part will also afford means of illustrating the argument.

The first or anterior ring (prothorax) supports the first pair of legs; the second or middle portion (mesothorax) gives attachment to the first pair of wings and the second pair of legs; the third or posterior (meta-thorax) bears the second pair of wings and third pair of legs. All these segments and their corresponding appendages present notable differences, according to their relative importance in the same or in different insects.

We have now to examine organs concerned principally in that faculty which is so eminently characteristic of the insect tribes. We have seen the very admirable provision made for enabling each to secure its peculiar food; no less remarkable are the modifications of organs in co-operation for the function of locomotion, so that the necessary food may be sought after.

The alar appendages, or wings, are viewed by some as not constituting a necessary part of the archetype, but organs superadded, and serving both for flight and respiration.* Their relative development in different species is accompanied with co-ordinate changes in the segments which support them, and the other appendages which form the legs of the insect. Entomologists in treating of this part of the body, cannot avoid alluding to and enlarging upon the evident relation between the habits of the insect and the modifications of the thoracic segments and their elements, and we cannot do better than introduce an abstract of Mr. Newport's remarks.† There is wonderful modification in shape and variety, in size and position, of the thoracic elements, in order that the body of the insect may be in conformity with its mode of life. In the great water-beetle, (Hydrous piceus,) which burrows deeply in the mud of stagnant waters, and rises also to the surface to bask in the sun, the form of the lower surface of the entire thorax is admirably adapted to its habits. The sternal elements of the meso-thorax and the meta-thorax

* The wings may, however, be considered as homologous with the upper appendages of Annelida;—sea-worms are examples.

† Cyclopædia of Anatomy and Physiology, Art. *Insecta*, p. 917.

are strongly keeled and firmly united together, enabling the insect to float securely. In others nearly allied, but of more active aquatic habits, swimming with ease and quickness, and capable of rapidly turning and following all the movements of their living prey, there is but a slight keel below, and the edges of the body are sharp, so as to oppose little resistance to the water. In beetles there is always a beautiful relation between the general structure of the thorax and the habits of the insects, whether in walking, flying, or in swimming. In those which pass great part of their lives on the ground, running or walking, the middle and posterior segments of the thorax are often firmly joined together, in order to give greater strength to the whole body. This occurs in all beetles which require great muscular effort during flight, and in those accustomed to laborious efforts in tearing, in burrowing, or in running.

But, without enlarging on this subject, it may be observed that the size and strength of each segment of the thorax are in direct proportion to that of the appendages which it supports, and the whole structure of rings and appendages present admirable conformity to the mode of life. For example, when, as in bees, moths, and the common fly, the anterior pair of wings are the chief locomotive organs, the meso-thorax or middle segment is highly developed, and there is corresponding decrease in the other two.

The proper appendages of the thorax may now be examined, and in them we find notable correlation between the habits of the insect and the modifications of the parts. Here there is a wide field illustrative of the argument; but since this subject has been already so fully discussed in different treatises on natural theology, it will be unnecessary to do more than refer to a few examples.

The legs are the proper organs employed in terrestrial locomotion, and for other purposes besides. As already stated, there are three pairs of such appendages attached to the corresponding segments of the thorax.

We have seen that in the vertebrata the limbs or diverging appendages of certain parts of the model framework are variously and suitably modified, according as they are intended for grasping, walking, swimming, or flying. The same law of consistency between form and function prevails among insects, and as in the higher animals, unity and diversity are singularly combined, the same is true among the winged Articulata ; in the words of Professor Rymer Jones—" Nothing is, perhaps, better calculated to excite the admiration of the student of animated nature, than the amazing results obtained by the slightest deviations from a common type of organization. The limbs used in swimming exhibit the same parts, the same number of joints, and almost the same shape, as those employed for creeping, climbing, leaping, and numerous other purposes ; yet how different is the function assigned to them !"* The predatory tiger-beetles are swift of foot—freedom of motion and lightness of the organs are necessary accompaniments, and such is the character of their thoracic appendages ; it is the same in every instance where the habits are similar. In those which swim and dive, as the water-beetles, &c., length of lever-power, breadth of surface, and strength of the parts, all are necessary—and such we find to be provided in their limbs. They are not, however, all of equal length, nor do all act equally in aquatic progression. The posterior pair, as regards position and form, are the chief propellers of the insect, they are flat like the end of a paddle, and the extent of surface presented to the water is very much in-

* The Animal Kingdom, p. 245.

creased by a fringe of hairs, which do not materially add to the weight of the whole limb. This admirable contrivance serves another purpose, viz., what is called feathering the oar, when a new position is necessary for a fresh impulse ; for in the forward stroke of the limb the hairs are of such nature and so arranged, that they change their position and accomplish the object in question. Limbs simply intended for walking are usually equally developed in all respects. Surfaces intended to act as sucking discs by the pressure of the air, are by no means uncommon, as in certain water-beetles. In some instances, flat cushions on the limbs, giving out a clammy secretion, are provided in order to enable the animal to climb smooth perpendicular surfaces, or hang with its body lowest from the ceiling ; such is now generally believed to be the arrangement in the house-fly. Mr. Newport remarks, "those insects which support themselves upon the surface of water, as the common gnat, have the under surface of each tarsus covered with rows of fine hairs, which repel the water and support the insect upon the surface. If the under part of the tarsi be wetted with spirits of wine, the insect can no longer support itself upon the surface, but immediately sinks down."

The powers of the most accomplished vaulter, aided by mechanical adjuncts, are insignificant in comparison with those possessed by not a few insects. For the accomplishment of such mode of progression, we find corresponding modifications of the posterior pair of legs, which are chiefly concerned in this kind of function. The large and strong coxa or first piece, is received into a deep depression of the supporting arch ; the piece called thigh is of great length, and very greatly enlarged in transverse diameter, so as to furnish attachment to the powerful internal muscles. The sudden unbending of the strong limb enables the animal to accomplish its purpose. An additional arrangement is alluded to by entomologists as being provided in such cases ; the lower surface of the tarsus is covered with elastic cushions, which are supposed to assist in the first effort, and finally to act in breaking the fall when the insect alights. The flea, turnip-fly, grasshoppers, &c., present examples of such limbs.

In the mole-cricket the fore-limbs are used in tunnelling, and admirably suited they are for such purpose, and the corresponding part of the thorax is of commensurate strength. The basal joint of the limb, called coxa, is of unusual size. The thigh is joined to both coxa and trochanter—an arrangement which adds materially to its strength. The succeeding portion, the tibia or leg, usually so called, is the instrument by which the soil is penetrated and thrust aside ; it is short and broad, the outer surface of it also is furnished with several strong, curved projections, the whole presenting a strong and broad surface, and therefore becoming an efficient instrument by which the animal burrows in the soil.

In conclusion, it may be observed that the last joint of the foot in insects is usually furnished with a pair of strong hooks, which afford important aid in climbing or clinging to rough surfaces.

In a word, whatever the peculiar habit of the insect, the elements of the limb are variously modified to minister to its existence and comfort.

We pass on to examine the last part of the body, and in it, the abdomen namely, we shall find modifications of the model not less instructive than those already brought forward.

Some difference of opinion exists respecting the exact number of segments entering into the formation of the third or abdominal region of the insect; whatever may be the normal number, it is nevertheless admitted that all are homotypes, and each fitted to its respective function.

Generally speaking, the appendicular elements are wanting, or, for the most part, of very secondary importance, in the abdomen. This part of the body protects a large proportion of the organs concerned in nutrition and reproduction, and, as the space occupied by these is liable to vary, we generally find considerable capacity of expansion in the segments of which it consists, and, indeed, throughout the whole of this region.

But abdominal appendages are not always wanting, and sometimes they are of the utmost importance in the economy of the insect; they usually belong to some of the terminal rings. There is an order of insects denominated Hymenoptera, among which we meet with highly developed instincts, leading to the performance of various acts, which could not be accomplished without some corresponding adaptations in the frame; all of these are provided and are exactly suited to the instincts and to each other. The saw-fly, the gall-fly, the inchneumon-fly, and others, in the larva condition, feed upon different parts of plants, or on the internal organs of other insects. The female deposits her eggs in suitable localities by means of an instrument, the ovipositor, fitted specially for that purpose. Others are provided with formidable weapons of defence and offence, in the form of a sting. But whatever be the function of the instruments in question, they are invariably modifications of the same abdominal elements, and in every instance suited to their end.

It is among Hymenopterous insects that we find the most perfect forms of an egg-depositing instrument; and as the localities in which the eggs are placed differ, the modifications of the instruments are of commensurate import. The leaf-flies, the gall-insects, the saw-flies, and ichneumons, all present instruments varying in length and strength, according to the substance which each is intended to penetrate. Those of the leaf and gall-insects are just sufficient to allow them to penetrate vegetable tissues : neither is there any great force requisite to enable the ichneumon female to deposit her ova in the bodies of other insects, or in the cocoons of spiders, or in the eggs of butterflies. The saw-flies, which penetrate hard wood for a similar purpose, are provided with an apparatus of great power and admirable construction. In every special case there is some remarkable harmonious adaptation, so that by inspection of the apparatus we can ascertain the way in which the eggs are deposited. The elements concerned in boring are placed in pairs, and furnished with teeth on the edge and sides, the former serving as a saw, the latter as a rasp. This delicate instrument requires support when acting, as well as protection ; and accordingly these desiderata are provided, and the sword does not more accurately fit the scabbard than are the respective parts of the ovipositor suited to each other, and to the habits of the insects.

Certain elements and appendages of the terminal part of the abdomen are transformed into a saw or file, or both, as the case may be, and others are fitted to give them strength and protection.* It matters not what the size of the insect, whether the comparatively large Sirex or the very minute Ichneumon ovulorum,† the general plan is the same, but in every instance presents some peculiarity adapted to the nidus selected by the species.

* Lacaze Duthiers, on Genital Armature of Insects, Annales des Sciences Naturelles, 1849, 1852.

† This tiny insect deposits several ova in a single egg of a butterfly, the contents of which afford sufficient food, as well as protection, to all the young which are produced.

The formidable sting of the bee and of the wasp are examples of other modifications presenting no less beautiful harmony between organ and function. Generally speaking, the appendages of the abdominal segments are absent, or if present, very rudimentary, because not required in the economy of the insect. What we have stated respecting the ovipositor and sting, affords proof that when certain appendages are necessary they are provided.

We find them, however, in other cases, furnished for a different purpose. The insects called skip-tails present remarkable examples of this. In the genus Lepisma, there is a pair of appendages attached to each abdominal segment. In Podura, and others, the singular tail-like organ consists of an elastic stem ending in two branches, like a fork and its handle. During repose this instrument is bent beneath the insect, and is lodged in a groove; when suddenly straightened the animal is thus enabled to spring a considerable distance. The handle of this fork-like organ is believed to represent the sternal or lower part of the abdominal segment, the two prongs are stated to be the homologues of the lateral appendages.

We may finally, and very briefly, allude to a remarkable transformation of abdominable appendages in another class of the jointed invertebrata.

The web of the spider is constructed of delicate threads, which are given out by parts called spinnerets; these are organs consisting of two or more joints. The end of the spinneret is pierced with a great number of small holes, each of which gives out a drop of fluid which hardens in the air. The minute threads of each organ are joined to form one, and those of all the spinnerets again unite to form the apparently simple thread of the spider, which is therefore in reality complex. There appears to be no doubt that the organs which produce the spider's thread are really abdominal appendages, thus singularly modified for the animal's convenience. They are composed of several joints, as limbs are, and in some species one pair of them—not being perforated nor furnished with an organ to produce the thread, and therefore apparently not needed—are nevertheless of interest to the zoologist, as indicating the real nature of the true spinnerets.

CHAPTER VIII.

RADIATA.

SECT. I.—TYPICAL FORMS OF RADIATA

THE Radiate type of animal structure, as the name indicates, is characterized by a tendency to repetition of parts round a centre. This division of the animal kingdom comprehends, on the one hand, the minute and soft hydra of our fresh waters, and, on the other, the hard and formidably-armed urchins of our seas.

At one time, many of the radiates were supposed to belong to the vegetable kingdom; more accurate observation has resolved the doubts respecting their nature, and demonstrated that they belong to the animal kingdom. It may be added however, that still more recent discoveries have shown that, in the mode of reproduction by buds and ova, they present a remarkable parallelism to plants. And here we see evidence that certain animals and plants have so much of unity of plan, as to shew that they have been constructed by the same Architect.

Our aim is to shew that, while there is adherence to a Radiate plan, there are departures from it on the one side and on the other—deviations which have reference to some end in the economy of the animal. We meet with difficulties in this as in other departments, but we doubt not that as science advances, and our knowledge of their development, of their structure, and of their habits, becomes increased, additional proofs will accumulate in favour of our argument.

Professor Huxley has done good service in shewing the relations of certain Radiata, viz., Medusæ, Physophoridæ, and Diphydæ, belonging to the Acalepha, or sea-jellies, and Hydra and Sertulariadæ, placed among Hydroid Polyps. He considers them "members of one great group, organized upon one simple and uniform plan, and, even in their most complex and aberrant forms, reducible to the same type."* Among Echinodermata,† there is evident adhesion to a common type, while there is, at the same time, wide range in their general aspect. In some of the sea-urchins the body is almost spherical, in the sea-stars it is angular; but these extremes pass into each other by almost insensible gradations. Among the sea-urchins, Echinocyamus and others present a pentangular outline; in Asteriscus, one of the sea-stars, the general form is similar, the angles, however, being very indistinct. In Solaster, the angles are more prominent; in Asteracanthion, Ophidiaster, and Luidia, the angles are changed into true rays, and become more and more distinct from the body. In Ophiura, this separation into arms and body is complete, and in Euryale, the arms become very much branched. The flattening of the body also differs;—in Palmipes membranaceus, we have a good example of extreme depression, while in some species of Oreaster, the arms are very much dilated, so as to present in section the form of an equilateral triangle. Among the sea-urchins we observe similar dif-

* Philosophical Transactions, 1849.

† Some hold that the Echinodermata possess annuloso or articulate characters. We here follow the views usually adopted respecting them.

ferences; the Echinus Sphæra is remarkably in contrast with the depressed form of the Echinocyamus pusillus. The soft and vermiform Holothurias are examples of other sub-types of the Echinoderms; still, a general plan can be traced in all.

In star-fishes and urchins, we find copious deposits of calcareous matter in the skin, in the form of distinct plates. M. Gaudry has very fully illustrated the general plan which regulates this part of their organization.* He has shewn that the protecting armour in all may be referred to three systems of parts—the endodermic or internal, the dermic or intermediate, and the epidermic or superficial. The internal system is absent in some. The dermic consists of four systems in parts—the *ambulacral*, so called from the locomotive function of the soft appendages which pass through them; the *inter-ambulacral*, placed between the former series, and adding strength and solidity to the whole framework; the other two, *ovarian*, and *anal* or *tergal* plates, are respectively connected with the reproductive and digestive systems. The epidermic part of the armour comprehends all those appendages called spines, scales, tubercles, &c., which he shews to be formed after a common plan.

There are, moreover, traces of unity, when we examine the minute structure of the plates or of the superficial appendages. The microscope demonstrates that the hard matter consists of branches disposed vertically, and connected together by lateral branches, all of which are referable to a typical form.

But while the Radiate law generally regulates the external form (and the general arrangement of certain internal organs as well) we find that the number of the radii is also subject to law. However much a sea-star

* Annales des Sciences Naturelles, 1851.

seems to differ from a sea-urchin, the number five prevails in both. The question was long ago put by Sir Thomas Browne, "Why, among sea-stars, Nature chiefly delighteth in five points?" and again, "By the same number (five) doth Nature divide the circle of the sea-star, and in that order and number disposeth those elegant semicircles or dental sockets and eggs in the sea hedgehog." "Every plate of the sea-urchin," says Professor E. Forbes, "is built up of pentagonal particles. The skeletons of the digestive, the aquiferous, and tegumentary systems, equally present the quinary arrangement, and even the hard framework of the disc of every sucker is regulated by this mystic number."*

The same writer remarks, "When the parts of Echinoderms deviate from it (five) it is always either in consequence of the abortion of certain organs, or it is by a *variation by representation*, that is to say, by the assumption of the regnant number of another class. Thus do monstrous star-fishes and sea-urchins often appear quadrate, and have their parts fourfold, assuming the reigning number of Actinodermata, consistent with a law in which I put firm trust, that *when parallel groups vary numerically by representation, they vary by interchange of their respective numbers.*"

Four is the number which generally prevails in the Acalephs or sea-jellies. In Cyanæa, for example, the stomach is usually subdivided by four; four æsophageal tubes are continued to their commencement, which is in the form of a quadrate mouth, the angles being prolonged into four tentacles. Sixteen canals radiate from the central cavities.†

In the charming Cydippe of our own seas, the same

* Forbes' British Star-fishes; Introduction.
† Owen's Lectures on Invertebrata, p. 165.

quaternary subdivision of the digestive system prevails. Moreover, the cirri by which it makes progression in the water, are arranged along eight equidistant bands.

The Actinæ or sea-anemones, not merely have some general resemblance to the well-known flower after which they are named, but we find remarkable order as regards number and relative position of organs, such as we have seen to prevail in plants. M. Hollard has shewn that the concentrical series of tentacula in the sea-anemone are subject to a law of alternation. This is well illustrated in the full-grown Actinia senilis, the four concentric series of tentacles alternate with each other, and, as regards the numbers in each, the following is the formula :—

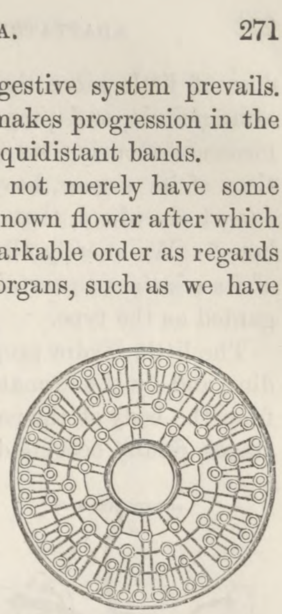


FIG. 59.*

$$10+10+20+40=80$$

In some others the typical number is six or a multiple of six. Thus there are twelve tentacula in the first row in *Actinia equina*, six in *Actinia pedunculata*, and there are four rows in the first species, and five in the second.†

SECTION II.—ADAPTATION OF RADIATE TYPES TO THE MODE OF LIFE.

Amid the general adherence to the Radiate type, we find modifications of parts in reference to locomotion, prehension, and retention of food, protection from external injury, and reproduction, all in evident accordance with the wants of the animals.

The simple Hydra of our fresh waters, consisting as it

* FIG. 59. Plan of Sea-anemone, upper surface. The center circle represents the mouth. The smaller circles represent the tentacula in concentric and alternating series.

† Annales des Sciences Naturelles, 1851.

does of little more than stomach, has, in the position, arrangement, and properties of its tentacula, admirable means of securing its prey. Its habits, and the adaptations of its organs, have been so often and so fully discussed elsewhere, that we need not dwell on the subject here.* We merely allude to it in the outset on account of its relations to certain others of which it may be regarded as the type.

The little Hydra propagates both by a process of budding and by the formation of ova. The buds sprout out from the body of the parent, and passing through various stages, finally become detached and independent beings, each capable of producing others by the same process. But sometimes this mode of reproduction is so rapid, that each new Hydra-bud actually has buds of its own before it quits the parent stock. These buds, however, finally drop off and become independent, each forming a fresh colony.

Fig. 60.†

The same mode of budding takes place in many others of the Hydroida, with this difference, that the buds usually remain attached to the stock or parent.

* See Trembley's Memoirs; Johnston's British Zoophytes, &c.

† Fig. 60. Hydra fusca propagating by buds. *a*, mouth; *b*, base or point of attachment. *a* to *b*, the original animal or stock from which the young or buds are formed *c*, point of origin of one of the buds.

But this building up of a tree-polyp could not proceed to any great extent if all polyps were entirely of the same soft texture as the Hydra. And here comes in a modification to which we owe many of those varied arborescent forms with which the ocean abounds. Long regarded as plants they are now well known to be compound Hydroida. The development of hard matter on the outside serves as a means of protection and support, in a medium liable as the sea is to such fluctuations in its condition. The soft material which pervades the centre of the hard covering is just a continuation of the digestive system of the polyps, each of which, protected in its little cell, captures food by means of its tentacula. The nourishment thus obtained contributes to the growth of the united colony, furnishing pabulum for the formation of new cells and new polyps. But there is another mode of propagation. There is a limit to the increase of the polyp-tree, and necessity for the establishment of new colonies at a distance from the parent. There appear at certain periods in the life of the Zoophyte, cells differing in form and size from those which protect the individual polyps

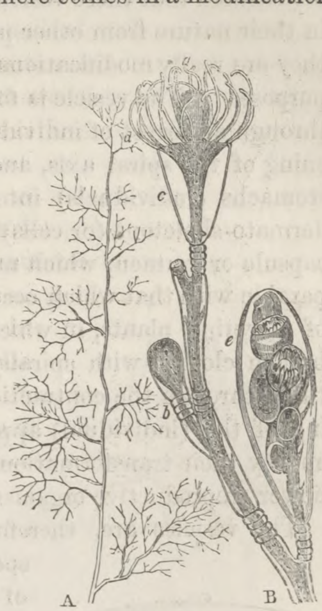


FIG. 61.*

* FIG. 61. Campanularia gelatinosa. A, fragment natural size; B, portion enlarged; *b*, young polype-bud; *d*, adult polype in its horny cell *c*; *e*, transformed branch with medusoid buds in different stages.

These are usually known by the names of ovigerous vesicles. (*Fig.* 61, *e.*) The late Professor E. Forbes has demonstrated that these vesicles are not new organs differing in their nature from other parts of the organism, but that they are really modifications of a part or parts for a special purpose. "The vesicle is formed from a branch or pinna, through an arrest of individual development by a shortening of the spiral axis, and by a transformation of the stomachs (individuals) into an ovigerous placenta, the dermato-skeletons (or cells) uniting to form a projecting capsule or germen, which metamorphosis is exactly comparable with that which occurs in the reproductive organs of flowering plants, in which the flower-bud (normally a branch clothed with spirally arranged leaves) is constituted through the contraction of the axis, and the whorling of the (individual) appendages borne on that axis, and by their transformation into the several parts of the flower (reproductive organisms.)"*

The vesicles are, therefore, branches modified for a special purpose in the economy of the animal, in the same way as we have seen that the parts of the flower in plants are merely modifications of the typical appendage (the leaf) arranged upon a shortened axis. In some instances special buds or individuals issue from the vesicles, becoming detached to enjoy for a time an independent existence, for which they are accordingly fitted by special

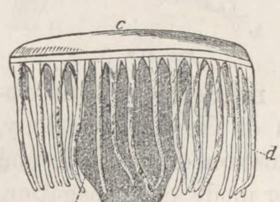


Fig. 62.*

* Annals of Natural History, vol. xiv. 1844.

† Fig. 62. Medusoid bud (See *Fig.* 61, *e*) of Campanularia; it swims freely in the water. *a*, body; *b*, mouth; *c*, upper surface; *d*, cirri. It is believed to produce ova, which are developed into a Campanularia stock.

modification. Through means of these buds the true reproductive process by ova is effected. These individuals when fully matured are flat discs, they may be compared to an expanded umbrella with a short stalk. The margin of the disc is provided with appendages, by which, and by its own contractile powers, the organisms move and disperse themselves in the water. They, in fact, correspond to the flower in plants. Their organization fits them admirably for an independent existence, and for dispersing the ova at a distance from the parent stock.

The sea-anemones may in general terms be compared to a jointless cylinder, the extremities of which present two distinct modifications in accordance with their function. The base or lower end is that by which the animal is fixed to a shell or rock, the part acting on the principle of the sucker, but capable also of becoming detached and

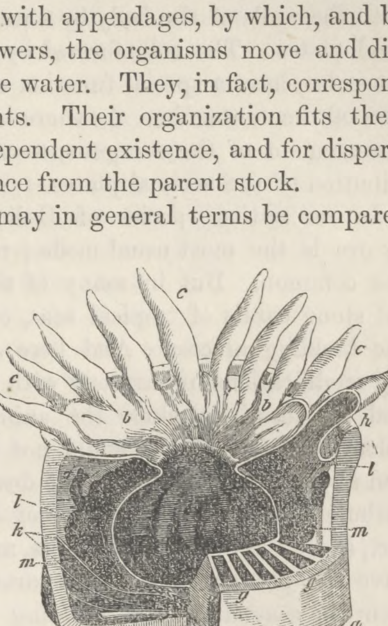


FIG. 63.*

performing lateral progression to a new place at the will of the animal. The free end of the body presents one or more radiate series of hollow tentacula capable of protrusion or retraction, and this by a very simple mechanism, the injection or expulsion of water. When fully ex-

* FIG. 63. To show form and structure of Actinia or sea-anemone. *a*, point of attachment or base; *b*, mouth, *c*, tentcula; *e*, stomach; *g k*, partitions or vertical plates *h*, passages into tentacula.

panded, these tentacles are effectual means of capturing and retaining prey, and of conveying it to the central mouth. This opening leads by a short canal to the capacious stomach, the outer surface of which is connected with the walls of the body by a number of radiating vertical plates. The cells formed by the plates, which are muscular, have a special function as regards the protrusion of the tentacula. As there is a certain order in the arrangement of these organs, we find corresponding distribution of the vertical plates.

In our native species of Helianthoida, reproduction by ova is the most usual mode; reproduction by buds is less common. But in many of the varied and beautiful stone corals of tropical seas, colonies are formed by the budding process. And here we meet with interesting modifications in harmony with this mode of increase, and the localities where the animals usually occur. A colony of soft Actinias could not attain any great size, and at the same time resist the destructive influence of a turbulent ocean. The species of Millepora, Madrepora, etc., so well known to navigators, are Helianthoida, which have the peculiar power of separating carbonate of lime from the sea-water, and building it up in forms which equally astonish us by their size, and please us by the beauty of their details. The coral-builders, it is well known, thrive best in the surf of the breakers, and their peculiarities of organization fit them admirably for such localities. In many of them we find calcareous matter deposited in the interstices of the perpendicular plates already alluded to, which afford support to the soft parts, and enable them to resist the action of the surrounding medium; the sea-water, at the same time, yields to them the material for such purpose. In former epochs of the earth's history, as well as in our own, the coral-builders have contributed in no small degree to modify the earth's surface, and prepare it for the abode of higher animals.

The statements already made regarding the compound Hydroida and their detached animal-flowers, apply also to certain of the *Acalepha* or sea-jellies.

The true Medusæ commence their existence as animals resembling in no small degree the common fresh-water polyp. They multiply for a time, by a process of budding, and the final effort is to produce other buds which become developed into the full-grown Medusæ. In both the conditions the radiate type is retained, but in each kind of organism there is a special modification in accordance with the mode of life. The ordinary buds are modified in accordance with their sedentary existence; one end forms a point of attachment, the other is provided with tentacula for the capture of food. The other special buds, which pass off from the common stock, are fitted for independent existence, and for progression in the water; they move from place to place by the undulations of the umbrella-shaped disc and the action

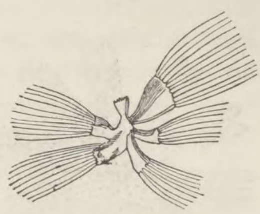


Fig. 64.*

Fig. 65.†

* Fig. 64. Original stock, or polype condition of Medusa. Shews a gronp of five, four of which have sprouted as buds from the original stock.

† Fig. 65. Polyp of Medusa, producing young Medusæ. *a*, the stock or body; *e*, a bud, as in last figure; *c*, tentacula of stock; *d*, young Medusa, (corresponds to flower-bud in plants,) with its tentacula and proboscis. Tentacula, *c*, are a second growth.

of marginal appendages. They are provided with a digestive system, and organs for capturing prey, and, finally, produce abundance of ova, each of which becoming fixed to a rock or shell forms a polyp stock, and gives origin to similarly modified organisms.

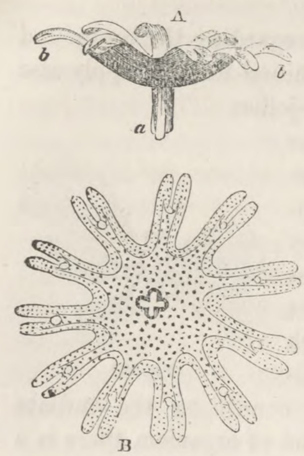


FIG. 66.*

Among *Echinoderms,* as we have already seen, there is remarkable unity amidst great diversity of form and consistence of parts. This diversity in particular cases has an evident relation to the wellbeing of the species. The hard covering of starfishes constitutes a mailed defence, combining, in most instances, strength and flexibility. The many pieces (thousands) of which it consists in some species, are evidently suited for both the functions mentioned. While the ovarian plates, pierced for the passage of the ova, and the ambulacral, giving exit and support to the delicate cirri, respectively occupy important relations as regards the economy of the animal.

The Comatula, or rosy star of our own seas, presents modifications in conformity with its habits. In its adult condition it can cling to a rock, a sea-weed, or a coral, by means of the simple-jointed arms with which it is provided for that purpose ; while, on the other hand, the large pinnated arms may be used for free progression in

* FIG. 66. Advanced state (Medusa) of *d*, *Fig.* 65. A, side view; *a*, proboscis; *b*, lobes, or subdivisions of margin. B, upper view of A, shows quadrilateral mouth in the centre.

the water. In striking contrast with it are the sluggish sea-urchins, whose protecting spines serve both for progression and defence, while the numerous cirri protruded from the openings in the ambulacral plates, acting on the principle of the sucker, enable the animal to anchor itself, or when occasion requires, to move up a perpendicular surface.

The *Holothurias*, while preserving the same general radiate type in certain organs, differ in this respect that their body is elongated—approaching the vermiform—and the integuments are generally soft. They present us with another modification adapting them for a different mode of life. Now moving by the suckers, which protrude from the pores of the skin, and again by the extension and contraction of their soft bodies, they are fitted for localities inaccessible to their allies, the starfishes and sea-urchins.

CHAPTER IX.

NERVOUS, VASCULAR, AND MUSCULAR SYSTEMS.

In these systems of parts so essential to the animal economy, we may expect also to find examples of types and special adaptations, and our argument would be incomplete without some reference to the subject. It must not be supposed that the brevity with which we discuss this department is any indication of its inferior importance. More space has been devoted to types and modifications in the internal and external skeleton and appendages, because we believe that the proofs are more easily accessible to the general reader.

NERVOUS SYSTEM.

The presence of a system of nerves is the most marked character which separates the animal from the vegetable kingdom. In some of the lower forms, its existence has not been clearly demonstrated; in many it is very rudimentary. But as we rise higher in the scale we find an evident advance, commensurate with the endowments of the animal.

The simplest function of this system is that of conveying an impression sufficient to excite the contraction of muscular tissue, and thus effect some motion in an organ or its parts. The impression is conveyed by one set of nervous fibres to a centre—a ganglion, and from this it is communicated to the muscle, which is thus stimulated to contract. This reflex function is not necessarily accompanied by sensation, and the movements of the lower forms of animal creation appear to be of the nature just mentioned. But when we take a general view of the animal kingdom, we find other superadded functions dependent on this system; "it is the instrument of consensual and instinctive actions, of mental processes, and of voluntary movements."*

In Mollusca, the typical nervous system is usually described as consisting of three sets of nervous centres or ganglia:—1st, cephalic, supplying the eyes and other parts about the head and mouth; 2d, pedal, supplying principally the foot; 3d, parieto-splanchnic, supplying the walls of the body, the heart and gills, &c. (See *Fig.* 45, parts marked *n.*) Now, we observe modifications of this type corresponding to the development of the different organs, and the necessities of the animal. In different mollusca, where the foot is more or less developed, we observe corresponding development of the pedal ganglion.

In the Cephalopoda, or cuttle-fishes, the large organs of vision, the complicated buccal apparatus, and active movements, are all in relation to the increase of nervous matter, and concentration of its parts. Professor Sharpey has further shewn an interesting modification in the nerves of the arms in evident harmony with the habits of these cuttle-fishes. Each sucking disc (on the arms) is connected by a set of fibres with a ganglionic centre, while all the ganglia are at the same time brought into connexion by another fibrous tract with the cephalic portion of the nervous system. Each sucker can, therefore—by reflex action—attach itself to any body which

* Carpenter's Comparative Physiology.

touches it, while all are also under the control of the animal.

In Articulata, the typical nervous system consists of two nervous cords running parallel to each other, and connected at intervals by dilatations or ganglia in pairs. (See *Fig.* 67.) The general arrangement is such that every part of the body is furnished with two sets of nervous connexions; one of these is with the ganglion of its own segment, and another with the cephalic ganglia. The distribution of the nervous system in Articulata was an obvious relation to the general arrangement of the hard parts, the body, as we have seen, being composed of homotypal rings, bearing lateral appendages in pairs. And as we find various modifications of this type in harmony with some important function, we also find corresponding modifications in the nervous system. The late Mr. Newport, to whose investigations we owe so much in connexion with this subject, has shewn that in certain cases there is an enlargement of a portion of the nervous system at certain points, "corresponding to the apparent greater necessity for accumulations of nervous matter at those parts of the cord." This remark is generally applicable as regards the ganglia of the head, the arrangement being evidently in direct relation to the functions of the important appendages of that part. There are, farther, certain local modifications, having more special connexion with the appendicular organs. Mr. Newport states, regarding the nerves which supply the mandibles and maxillæ, that "union of those nerves at their base is interesting from the circumstance that during manducation a consentaneous movement of the parts is required, since, while the mandibles are employed in chewing, the maxillæ are also employed in turning and assisting to pass the food into the pharynx."

The concentration of the nervous matter in the thorax is evidently a modification of the type in conformity with the presence of wings and legs, the active appendages of that part of the body. The wings require the exercise of great muscular effort in order to support the insect during flight, and the distribution of the nervous matter is in accordance with this necessity. But there must also be perfect unison in their action, and this is also provided for. Mr. Newport has demonstrated that there is a remarkable peculiarity in the relations of the thoracic ganglia and their connecting fibres, in those insects in which both pairs of wings are actively concerned in flight. He remarks, "that this is the reason for this curious union of the nerves for the wings, seems apparent from the circumstance that it exists in very many tetrapterous insects of rapid or powerful flight, as in the

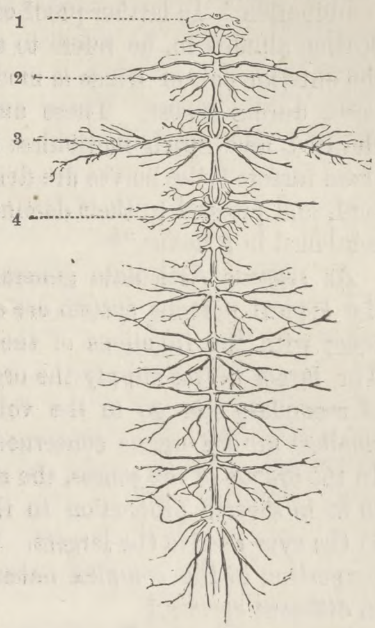


Fig. 67.*

* Fig. 67. Nervous system of pupa of Sphinx ligustri, composed of two parallel nervous cords, for the most part joined together side by side, and connected knots of nervous matter—ganglions. The two larger masses and branches of nervous matter, or the upper part, supply organs in the head, as eyes, jaws, &c., viz., 1 and 2; the two nervous masses and branches succeeding to these supply the wings and legs, 3 and 4. The remaining portions are more uniform.

Apidæ and Ichneumonidæ ; while in others, even of the same order, as in Athalia centifoliæ, which is well known to fly heavily and but a short distance, there is no such combination." In farther proof of the reason for the modification alluded to, he refers to the Coleoptera, in which the anterior pair of wings is modified to protect the posterior during repose. These anterior wings are merely elevated, and nearly motionless during flight. Now, in these insects "the nerves are derived separately from the cord, and proceed to their destination without being first combined in a flexus."*

As regards Articulata generally, the modifications of the typical nervous system are admitted to be in consistency with the functions of the organs to be supplied. The larger nerves supply the organs of the senses, those of secondary size go to the voluntary muscles, and the smallest are for organs concerned in automatic motions. In the organs of the senses, the size of the nerves appears to be in inverse proportion to the density of the agent, so the eyes receive the largest. The size is also in direct proportion to the complex nature of homologous organs in different species.†

The remarks of Dr. Carpenter are so much to the point in reference to this part of our subject, that we cannot do better than sum up in his words :—" In Invertebrata, the nervous system consist of a series of isolated ganglia, connected together by fibrous trunks. The number of these ganglia, and the variety of their function, depend upon the number and variety of the organs to be supplied. In the lowest Mollusca, the regulation of the ingress and egress of water seems almost the only function to be performed ; and here we have but a single

* Cyclopædia of Anatomy, Art. *Insecta*.

† Straus Durckheim, Comparative Anatomy of Articulata.

ganglion. In the star-fish we have five or more ganglia; but they are all repetitions one of another, and are obviously the centres of action to the several segments to which they respectively belong, neither having a predominance over the rest. And in the higher Mollusca, and in Articulata, we have a ganglion, or more commonly a pair of ganglia, situated at the anterior extremity of the body, connected with the organs of special sensation, and evidently exerting a dominant influence over the rest. In the lower Mollusca, we have but a single ganglion for general locomotion; but this is doubled laterally and repeated longitudinally in the Articulata, in accordance with the multiplication of their locomotive organs, so as to form the ventral cord. In like manner, the Mollusca possess a single ganglionic centre for the respiratory movements; and this is repeated in every segment of the Articulata, forming a chain of respiratory ganglia, which regulates the action of the extensively-diffused respiratory apparatus of these animals. The acts of mastication and deglutition, again, in both sub-kingdoms, are immediately dependent upon a distinct set of ganglionic centres, which are connected, however, like the preceding, with the cephalic ganglia. And wherever special organs are developed, whose operations depend on muscular contraction, ganglionic centres are developed in immediate relation with them; so as to enable them to act by their simple reflex power, as well as under the direction of the cephalic ganglia, as in the case of the suckers of the cuttle-fish."*

From what has been stated, we see evidences of a common plan, with numerous special modifications necessary to some end in the animal economy. In Vertebrate animals, we find a very obvious correspondence between

* Manual of Physiology, p. 528.

the arrangement of the bony framework and the distribution of the nervous centres; skull and spinal column are respectively constructed to give them support and protection.

In viewing the entire animal kingdom, we find that we cannot compare the whole of the well-developed nervous system in the higher forms with that of the lower; still we find, in the nervous system of the Vertebrata, certain parts which are homologous with the whole of that of Invertebrata. In the higher Articulata, the cephalic ganglia are considered homologous with a series of ganglia forming a most important part of the brain-mass in Vertebrata, and having relation to certain organs of sense, as the eye, &c. The abdominal nervous cord in Insects, &c., is homologous with the spinal cord of Vertebrata, the essential difference being greater condensation of parts in the latter than in the former. The superadded portions in the nervous system of Vertebrata have an evident respect to the superior endowments of the animal. Cerebellum and cerebral hemispheres have no distinct representatives among the Invertebrata series.

On comparing the very lowest of the Vertebrata with the highest, we find evident difference in the relative development of the most characteristic parts of their cerebral system. The lowest forms of fishes have the hemispheres of the brain in a very rudimentary condition, while in man they attain their highest development. "The size of the *Cerebral Hemispheres* holds a close relation with the increase of the *Intelligence*, and with the predominance of the *Will* over the involuntary impulses. The increased size of the cerebellum, on the other hand, seems connected with the necessity which exists for the adjustment and combination of the locomotive powers, when the variety in the movements performed by the animal is great, and a more perfect harmony is required among them."*

Such being the functions of brain and cerebellum, we may expect to find modifications consistent with the necessities of the animal. The size of the cerebellum differs very much in the class of fishes; but its development appears generally to be in direct proportion to the active powers of the animal. "Thus it is very small in the lazy lump-fish, and extremely large in the active and warm-blooded Tunny."† In the Lampreys, whose mouth acts on the principle of the sucker, so that they can attach themselves to their prey and devour it at leisure, we find that the cerebellum is relatively small. Whereas, in the active and predacious sharks, it is of great size; these Felidæ of the ocean have no swim-bladder, and their mouths being placed transversely beneath the snout, they require peculiar and active movements of the whole body for securing and overcoming the struggles of the resisting prey. This conformity of the development of the cerebellum to the peculiar habit of the animal is equally illustrated in the class of Reptiles. Their habits are generally inert, and the cerebellum is proportionately small. The very reverse is true of birds—characterized by the variety and power of their muscular movements.

We have already seen that in Articulata there are local adaptations of the nervous system, co-ordinate with the functions of the parts supplied by it. In the homologous part—the spinal cord—of the vertebrata, we find similar harmony. In certain reptiles we find this correlation very obvious. In the serpent the absence of limbs is accompanied with a remarkable uniformity of the spinal cord and the nerves given off from it. On the other

* Carpenter's Manual of Physiology, p. 530.

† Owen's Lectures on Comparative Anatomy, vol. ii., p. 176.

hand, in the frog, whose hind limbs are highly developed and of great comparative muscular power, we find corresponding enlargement of lower part of the nervous cord.

Two enlargements occur in the spinal cord of birds, one corresponds to the wings, the other to the legs. As might be expected, these enlargements generally present differences of relative size, corresponding to the different relative development and powers of the anterior and posterior extremities. The posterior enlargement is greater than the anterior in the Struthious birds (ostrich, &c.) in which the whole function of progression is effected by the posterior extremities. In contrast with this, we observe that in birds of powerful flight, the greatest enlargement of the nervous matter corresponds to the position of the wings.

VASCULAR SYSTEM.

Our remarks under this head will be confined to the highest animals, viz., mammals and birds. In them we find a highly developed system of vessels for distributing the products of digestion, removing certain materials derived from the waste of the animal frame, and supplying the system with oxygen gas. These two latter functions are in intimate relation to a surface or organ for respiration.

The central organ of circulation—the heart—presents the same structure in mammals and birds, and, generally speaking, the blood-vessels are distributed according to a plan which is common to both. Of the four cavities of which the heart consists, two are set apart for the purpose—the one receives, the other propels—of transmitting the dark-coloured or venous blood to the lungs, for the purpose of respiration.

Such are the functions of the cavities on the right side, constituting the *respiratory heart*. Of the two on the left side, one receives and the other propels the blood —arterial—which has been oxygenated in the lungs.

We have already pointed out the harmony between the development and distribution of nervous matter, and the necessity for variety and force of muscular effort. But nerves and muscles cannot perform their respective functions without a supply of oxygen. Now such co-ordination of parts is clearly illustrated by some peculiarities in the arterial system of birds. The large muscles called pectoral, (from their position on the breast) which are chiefly concerned in the movements of the wings, are supplied by arteries of great magnitude, "which, instead of being inconsiderable branches of the axillary artery, are the continuations of the trunk of the subclavian, of which the humeral is only a branch."*

Another adaptation in the arterial system of birds we shall allude to in the words of Dr. Carpenter:—"In most Mammalia, as in Man, the right anterior extremity is more directly supplied with blood from the aorta than the left; so that the superior strength and activity of this limb would seem to be not altogether the result of habit and education, as some have supposed. In birds, however, where any inequality in the powers of the two wings would have prevented the necessary regularity in the actions of flight, the aorta gives off its branches to the two sides with perfect equality."†

Among the mammalia, also, we find singular departures from type in order to accomplish a special end. We have already alluded to the habits of the sloth, and the remarkable provisions in the structure of the skeleton. The distribution of the vessels in its fore and hind limbs

* Cyclopædia of Anatomy, Art. *Aves*, p. 334.
† Principles of Comparative Physiology, p. 264.

is admitted to be a modification of the general plan suited to the habits of the animal. The arteries which supply the fore and hind limbs are subdivided into a number of branches, of nearly equal size, which communicate laterally with each other, and are exclusively distributed to the muscles. Those which supply the bones and other parts, present no such peculiarity. The effect of such distribution of the arteries will be to diminish the velocity with which the blood flows to the parts. The peculiar arrangement is admitted to have a relation to the slow movements of the animals, though it may not be easy to say "whether such slow movements of the blood sent to the muscles be a subordinate convenience to other primary causes of their slow contraction, or whether it be itself the immediate or principal cause."*

The celebrated John Hunter long ago pointed out a remarkable distribution of the vascular system in the whales, an evident provision in conformity with their power of diving and remaining for a time under water. Their arterial system is characterized by extensive networks of vessels, chiefly distributed over the walls of the chest. "It is to be presumed that this singular complication of vessels is caused by the necessity in which the Cetacea are often placed of suspending their respiration, and consequently the oxygenation of their blood during a considerable time. These numerous arteries form, therefore, a reservoir of oxygenated blood, which, re-entering the circulation, supports life throughout, where venous blood would only produce death."†

We may now briefly allude to adaptations in the vessels which carry dark-coloured or venous blood. The typical venous system of the mammalia, according to

* Cyclopædia of Anatomy, Art. *Edentata.*
† Cyclopædia of Anatomy, Art. *Cetacea.*

Rathke, consists of four lateral primitive trunks. We have just stated a peculiarity in the arterial system of the whales; the same animals present also a special modification of the venous system in evident adaptation to their habits. The extensive net-works of veins in the interior of the chest and abdomen, serve as reservoirs of blood highly charged with carbonic acid, the accumulation of which in the right side of the heart would occasion death. The suspension of respiration during the act of diving, renders such co-ordination of parts absolutely necessary.

As connected with this subject, we may allude to a peculiarity of the veins of the bat's wing, described by Professor Jones. The wall of these vessels are endowed with a power of rhythmical contraction and dilatation, which, in the natural state, is continually going on at the rate of seven to thirteen in a minute. This contractile power, "supported by the presence of valves, is called forth to promote the flow of blood in the wings, which, on account of their extent, are, as regards their circulation, in a considerable degree, though not entirely, beyond the sphere of the heart's influence."*

RESPIRATORY SYSTEM.

We shall only briefly refer to type and modifications in this department. Allusion has already been made to the necessity for oxygenation of the blood, and the removal of the carbonic acid which accumulates in it during its course through the system. In the warm-blooded animals, whose temperature is generally higher than that of the medium, air or water, which surrounds them, there is another requisite, viz., the power of keeping up such temperature by the combination of oxygen with materials

* Philosophical Transactions, Part I., 1852.

supplied by the food, a process which is really a kind of combustion.

In many of the lower animals there are no special organs for respiration, the fluids of the tissues being sufficiently aerated through the medium of their own walls, or of the general external covering of the body. When, however, special organs for respiration are provided, they are admitted to be all mere modifications of one plan, viz., a portion of the surface of the body of more delicate texture than the rest, and permitting the atmospheric air to pervade the parts, and come in contact with the numerous vessels with which the organ is provided. Such is the common plan on which both lungs for aerial and gills for aquatic respiration are constructed.

Hitherto, in treating of types and modifications, we have spoken of homological organs; but in examining the respiratory system, we have to do with some which are analogous, but not necessarily homologous, that is to say, similar in their function, but frequently different in their nature. Nevertheless, it appears that in this view also there are arrangements bearing on our subject. Generally speaking, gills and lungs are respectively in singular conformity with the different media inhabited by the animals. Gills are usually extensions of some part or other of the external surface of the body, and being necessarily in contact with the water which yields the air requisite for the performance of the function of respiration, complex arrangements of organs are less requisite, more especially since the general surface of the body takes a part likewise in the act of respiration. In reptiles,* in birds, and mammals, the respiratory surface is internal, and the whole apparatus is more complicated,

* Certain reptiles begin life with gills, and some, even when mature, have both gills and lungs.

and there are adaptations of various organs for performing the acts of inspiration and expiration.

We have said that respiratory organs are not necessarily homologous, and in connexion with this, we find a remarkable instance of departure from a plan, in accordance with the necessities of the animal. The gills of fishes are not of the same nature as the lungs of other Vertebrata, still the latter organs have their homologues in the fish, but they assume a new function, and one which is admirably suited to the wants of the animal. The sound-bladder, swim-bladder, or air-bladder (for it has all these names) by which certain fishes can regulate their depth in the water, is a rudimentary lung turned to a new purpose.

Finally, whatever be the modification of the respiratory system, there is general adaptation to the nature of the medium and the wellbeing of the animal. The gills of fishes require no powerful efforts to bring fresh supplies of water, and thus there is room for greater expenditure of muscular force in swift progression through the medium they inhabit. Internal extension of respiratory surface, well protected from external injury, is just such a provision as is most conducive to the comfort of the mammal. The whale, living in water, yet breathing by lungs, has arrangements, in the form of its tail and in the position of its nostrils, which enable it to rise to the surface with ease, and get fresh supplies of necessary air. The wide diffusion of air from the lungs through the soft parts and bones of the bird, all directly co-operate to facilitate ascent in the air, by diminishing the relative weight of the body.

In Articulata, we find homologous parts concerned in respiration, but acting through different media. In some of the lower aquatic forms, the water-vascular system is homologous with the branched vessels of insects, which are adapted for aerial respiration. In both instances the arrangement is suited to the necessities of the individuals ; the extensive distribution of the air-vessels in the perfect insect being in correspondence with the power of flying, by reason of the diminished specific gravity of the animal consequent on the very free access which the air has been to every part.

MUSCULAR SYSTEM.

In this as in other departments, there is still much to be accomplished as to our knowledge of a plan, and of modifications. The few observations which we have to offer will be confined to vertebrate animals. The general arrangement of the muscular system corresponds very much to the form of the skeleton. The greater or less flexibility of the vertebral column, the size of the limbs, the mode of progression, whether in water, in the air, or on the ground, all imply greater or less peculiarities of this system. The idea of general correspondence with a type is clearly indicated by the nomenclature adopted in describing the muscles of at least the three higher classes of Vertebrata, viz., mammals, birds, and reptiles. The following are some of the principal groups admitted by anatomists :—muscles of the *skin*, of the *spine* and *head*, of *ribs*, and *walls* of *abdomen* and *chest*, of *limbs*, of the *lower jaw*, of *voice*, *eye*, &c.

Intimately connected with the skin, and lying beneath it there is a layer of muscular fibre in all Vertebrata—with the exception of certain reptiles where it is unnecessary, owing to the development of hard matter in the skin, and its consequent inflexibility.

At different parts of the body in the same animal, we find local modifications evidently suited to some peculiar end in the economy. Such tegumentary muscles are intended to act either on the skin itself, or on some of the appendages which arise from it.

Among fishes, tegumentary muscles appear in connection with the dorsal and other fins, which can be thus elevated or depressed according to necessity, either for defence or offence, or as balances or partial aids in aquatic progression.

In the class of birds, the muscles of the integument frequently attain a high degree of development. In the Apteryx of New Zealand they are of great strength—a provision of the utmost importance, because its habits expose it to accumulation of soil about its feathers, which must be shaken with some force in order to dislodge it. But there are bundles of small muscles connected with the quill portion of the feathers. In some of the web-footed species each feather has four or five small muscles specially intended to move it in different directions. In the Gannet it has been calculated that there are about 3000 feathers provided with such muscles, the total number of which will therefore not fall short of 10,000 or 12,000. It is by means of such skin-muscles that the cockatoo elevates or depresses its crest, and the turkey-cock bristles up his feathers. There are numerous occasions on which these and other special arrangements of the cutaneous muscles are needful in the economy of the bird, and essential to its comfort.

The peculiar shield-like scales on the belly of serpents are put in motion by muscles which belong to the cutaneous system, and are thus fitted to aid in progression over a rough surface.

In Mammalia, we find greater or less modification of the same system in conformity with the habits of the animal. The quills of the porcupine and of the hedgehog are set in motion by similar cutaneous muscles, and the latter animal presents an additional arrangement in other muscles of the same part, by which it can roll itself into a ball, and thus present a surface bristling with formidable spines.

Fig. 68.*

In other parts of the muscular system, while there is conformity to a general plan, we also meet with local modifications. The very large proportion which active voluntary muscles bear to the whole body, requires not only proper adaptation to their uses, but also such peculiar packing and arrangement as may be most conducive to the comfort and well-being of the animal. We do not find the same proportional distribution of muscle in whales, in fishes, in birds, and in swift-footed mammals. In birds, for example, "the principal masses of muscle being collected below the centre of gravity, beneath the sternum, beneath the pelvis, and upon the thighs, act like the ballast of a vessel, and assist in maintaining the steadiness of the body during flight; while, at the same time, the extremities require only long and thin tendons for the communication of the muscular influence to them, and are thereby rendered light and slender."†

The great importance of the hand in man, and the special development of his first digit, the thumb, imply a correspondingly perfect system of muscles in the limb. In the apes, which approach him nearest, the digits are endowed with less individual mobility, and there is corre-

* Fig. 68. Shows muscular apparatus by which the hedgehog rolls itself into a ball.

† Owen, Cyclopædia of Anatomy, Art. *Aves*.

sponding departure from the muscular type. These animals are destitute of the power of appointing or indicating by means of the fore-finger, and man alone, who has this faculty, possesses a distinct muscle for its performance. The muscle homologous with that called latis simus dorsi in man, gives off in the apes a slip which is attached to the elbow part of the ulna (the innermost of the two bones of the fore-arm). This modification is especially obvious in the long-armed species, and enables them to sling the arm forwards with great force and quickness, by which they are better fitted to grasp distant branches during their more rapid acts of climbing.

The singularly modified nostrils of the elephant, constituting its trunk, present modifications of size, as well as of relation in homologous muscles which are of less general importance in other mammalia. The levator and zygomatic muscles of the upper lip are very large, and incorporated with those of the prolonged nostrils—arrangements which are admitted to be commensurate with the important functions of the parts. In hoofed animals, fitted for rapid progression, the extensor muscles of the limbs are more powerful than their opposing flexors, the tendons also are long, the muscular portion being short but strong—a modification suited to their habits. When treating of the typical form of the vertebral elements, we have alluded to the singularly modified arm-bone of the mole, a departure from the type in distinct relation to the no less remarkable arrangement of powerful muscles in the limb, so necessary to the burrowing habits of the animal.

The habits of that remarkable bird, the cross-bill, (Loxia curvirostra) render necessary certain modifications in the muscles of its jaws. Feeding on the seeds of firs, it requires an apparatus to extract them from the hard and tough scales of the cones. The jaws cross each other, and act much in the same way as the blades of scissors. We find a want of symmetry in the muscles on the two sides of the jaws, and this has constant relation to the position of parts. In a state of rest, the lower mandible is drawn to one side or the other—for there is a difference in this respect in different individuals. Now, the muscles are strongest upon that side to which the jaw is so directed, and being of great strength, the animal is thus provided with an apparatus which enables it, with ease and rapidity, to cut up the tough cones and disengage the seeds. Perching birds present a curious adaptation, by which the act of bending the knee and ankle necessitates also bending of the toes, independently of any active effort; they can thus grasp a branch even while sleeping. They are enabled to do this by a peculiar disposition of the tendon of a muscle, which is the homologue of that called *gracilis** in mammalia. This muscle passes over the convex part of the knee-joint, and then over the projecting portion of the heel, and ends by being connected with a flexor muscle of the toes. It is obvious, therefore, that the digits must bend simultaneously with the bending of the knee and ankle when the birds fall into sleep. In other parts of birds we observe certain muscles differently modified for different purposes. Thus, generally speaking, those on the upper part of the tail are more highly developed than those on the lower surface; by such arrangement it is that the peacock expands his gaudy tail feathers. On the other hand, we find in some species that the muscles which depress the tail are the strongest. This is well illustrated in wood-peckers, which use that part as an additional means of support when climbing, by pressing it strongly against the bole of the tree.

* Meckel considers it homologous with the muscle called *Rectus femoris*; this, however does not affect the importance and singularity of the modification alluded to.

CHAPTER X.

COMMUNITY OF PLAN, WITH SPECIAL ADAPTATIONS IN THE DEVELOPMENT OF ORGANIZED BEINGS.

PRECEDING observations have been confined to plan and modifications of perfect adult organisms. It will be necessary, in order to complete the argument, to glance at the co-existence of the same two principles in the embryonic condition of plants and animals. The nature of the topic and its extent, obviously preclude its full discussion in this treatise; but an epitome of some of its leading truths will be found to fit in with what has gone before, and with what is to follow.

If we enter a large ship-yard (to borrow an illustration from a friend) we may be able to discover a community of plan in the materials gathered together and cut out for use, and in the very first blocking out of every vessel. But it is as the fabric advances that we begin to detect—what, however, was all along known to the builder—what is the special purpose for which the ship is intended; whether it is to be propelled by sails or by steam; whether it is meant for warlike or peaceful occupations; whether it is to carry articles of commerce or passengers. We are to show that it is the same in organic nature. Every plant and animal is formed after a general plan, while it is intended all along by its Maker for a special end, and no other; but it is only as it advances that *we* can discover that end. We are to show that there is a close resemblance between the foundation structure, or earliest rudiment, of all plants and animals ; we are to show that as the structures advance, each takes its peculiar form to suit it to its evidently predetermined end ; and we are to show, at the same time, that there is a remarkable parallelism in the development of organic beings, and this along the whole separate lines of their progress.

At an early part of our work we pointed out the identity of cell material in all organized beings. The germs of every animal and plant present to us unmistakable evidence of conformity to a model. The embryonal vesicle of the animal, and the embryonic cell in the plant, are obviously similar. Our remarks will be chiefly confined to the former, as best fitted to illustrate the two principles which are occupying our attention.

In plants, the contents of one peculiar cell (the pollen grain) applied to the embryonic cell, determine all future changes of the latter. Subdivision of the above-named cell (embryonic) takes place ; the same goes on with consecutive cells ; these increase at the expense of the pabulum supplied by the ovule, and the result of the process is the formation of cotyledons, of rudimentary stem, of root, and of leaves.

The structure of the ovum of the animal is very simple ; it consists of a sac containing yolk, in the midst of which there lies the embryonal vesicle which is essentially a cell. This becomes filled with a mass of smaller cells, to which it finally gives exit as a preparation for the process of fecundation : after which a new cell, a primordial, undergoes a change like that which follows the application of the contents of the pollen to the vegetable germ. This primordial cell begins to multiply by self-division, until, from a single cell, we find that an aggregate mass of minute cells has been produced. It is worthy of notice here, that as the cells forming the simpler plants increase by subdivision, according to a fixed law as regards number, viz., 2, 4, 8, 16, &c., so it has been distinctly established that the same law of geometric progression regulates the subdivision of the primordial cell, in the lower forms of animals at least. In some of the Articulata this process of increase is confined to the primordial cell and its progeny, all being nourished at the expense of the entire yoke, which disappears. But in other cases, the subdivision of the above-named cell determines also a similar process in the yolk which surrounds it, each cell produced from the former attracting to itself a certain portion of yolk, so that the increase of the original cell occasions a corresponding subdivision of the yolk. In certain animals higher in the scale, it is observed that the development of the cells (from the primordial one, placed near the surface of the yolk, and not in the centre as in lower forms) gives rise to subdivision of the yolk only which lies near them. And here comes in one of those adaptations presented to us in this early chapter of the animal's history. The two portions of yolk are distinguished by different names, that which becomes subdivided is termed "germ-yolk;" the other portion, exempt from such change, is called "food-yolk." The latter is looked upon as something superadded to the former, and is considered as a store of nourishing material to be used up in the subsequent development of the new being. It may be remarked that the size of the yolk is generally in direct proportion to the advance made by the animal before leaving the egg. Thus in birds it is very large, they escape from the egg in a well-developed condition. Insects quit the egg in an imperfect state, and the yolk of their ovum is small.

In Echinoderms (sea-stars, &c.) there have been disclosed some remarkable modifications in the ovum for special ends. The observations of Sars,* rightly interpreted by Professor Müller, have shewn that soon after the subdivision of the yolk, the young embryo of Echinaster rubens escapes from its membrane, and becoming free and independent, is able to make progression in the water. Here the mass of cells provided with numerous cilia on the surface, assumes a kind of independent life, and moves from place to place, thus providing for the wider dispersion of the new being, which is subsequently formed from it by a kind of budding process. A similar example occurs, with some modifications, in course of the development of the sea-urchins. The ovum escapes at an early stage, and the ciliated surface of the cells is a provision for locomotion and wide dispersion of the new generation. Among Mollusca we meet with similar examples of adaptations for special ends. In the embryo of certain Tunicata, we observe that a portion of the yolk separates from the remainder, and is considered as forming a tail-like organ, (the young animal is, in fact, very like a tadpole) which is a most effectual means of progression in the water, and accomplishes its purpose in the same way as a single oar at the stern of a boat enables us to scull it along. At a subsequent period, the new animal becomes attached to some fixed object, and the tail-like appendage disappears after having accomplished its temporary function.

In the ova of Vertebrata, we also meet with examples of arrangements for special ends; one may suffice. In the egg of birds, we have concurrence of adaptations very clearly illustrative of our subject, while, at the

* *Sars*, Fauna littoralis Norwegiæ; and *Müller*, über den allgemeinen Plan in der Entwickelung der Echinodermen.

same time, the essential parts of the ovum are constructed on the same plan as that of other animals. Commencing in the centre, we observe the yolk with the *germ-spot* or *cicatricula* enclosed in the yolk-bag; these are suspended in the midst of the soft albumen, and retained in position by means of two elastic chords, the *chalazæ*, which originate at the broad and narrow ends of the egg. The albumen is in turn surrounded by a tough membrane, (lining the shell) consisting of two layers, which, being separated at the broad end of the egg, constitute a chamber which serves as a reservoir of air to be used up in the earlier stages of development. The hard shell on the outside, and the lining membrane for protection, the soft bed of albumen in which the yolk is suspended by the elastic chalazæ, and so suspended that, being lighter than the other parts, the *germ-spot* always rises uppermost, and so is nearest the warm body of the parent during incubation—all constitute a series of remarkable adaptations for special ends.

But without dwelling longer on the combination of the two principles in the ova of organized beings, we may briefly glance at certain conclusions which have been founded upon the unity of structure which we have been examining.

Because there is such remarkable similarity in the outset of life, it has therefore been rashly asserted that there is resemblance also in subsequent stages, and that the higher animals pass through a series of changes, each of which exactly represents the permanent condition of some other being, lower in the scale. It is true that in the earlier stages of development, the ova of the highest and of the lowest animals are much alike, and both also very similar to the embryo of the higher plants, and to the adult forms of some of the lower. Still we are not entitled to conclude that there is absolutely identity. The animal ovum, removed and transferred to the same medium as the simple plant, would assuredly perish. The resemblance amounts to this, the one is cellular as the other is, and the cells in both propagate according to the same law. But there is no ground for asserting more. And, as regards the advanced stages, we have no foundation for the belief that there is absolute identity of certain embryonic conditions with permanent forms of animals lower in the scale. The embryo of man is never, at any stage, of the same nature as that of a worm, of a fish, a reptile, or a bird. In loose terms, the higher fœtus at a certain period may be vermiform in the sense of oblong, but it is never articulate; the relations of its parts are such that it could never by possibility be declared that the two are absolutely the same in organization. But as such assertions are not now supported by authorities of any weight, we deem it unnecessary to enter into further details. The great general principle enunciated by Von Baer gives us the true explanation of the phases of embryonic life, viz., "a heterogeneous or special structure arises out of one more homogeneous or general;" which may be simply illustrated by saying that the common homogeneous or general material gives rise in course of development to other special structures which are heterogeneous.

The idea has also been entertained by some that even in the full developed or adult state there is unity of plan in all, that the four types, Vertebrate, Molluscan, Articulate, and Radiate, are identical. Thus Geoffroy St. Hilaire considered the cuttle-fishes to be doubled up vertebrates. This comparison cannot hold; for although Cephalopoda are the most highly developed of the molluscan type, and, in some sense, higher even than that singular fish called Lancelet, yet we cannot view them as modified vertebrata; they are essentially molluscan. Insects were denominated by St. Hilaire, vertebrata with free ribs—the legs being so considered. Others have compared them to a vertebrate animal turned upside down, the abdominal surface of the insect, next which its nervous system lies, being considered as representing the back of the higher animal, and the limbs as the homologues of the laminæ dorsales.* That is to say, the articulata were compared to the embryo of vertebrata with the dorsal laminæ free, not entering into the formation of the neural arches, but modified for purposes of locomotion. There can be no doubt, from what has been already stated in a previous part of this work, that such attempts at indicating identity in the four plans of structure are overstrained and far from representing the truth. We have seen that in all animals alike there is a common starting-point, but as the development advances, we observe that varied structures and arrangements of organs appear, respectively suited to the sphere to be occupied by the new being, and assigned to it by Him who is great in power and excellent in working.

It has been already remarked how close the resemblance is between the ovum of the animal and of the plant in the earlier stages of existence. But farther, there is very striking similarity between the simpler kinds of plants (Protophyta) and the lower forms of animals (Protozoa). This has given rise to the idea, that between these at least there is no true line of demarcation, and that therefore there is a merging of the vegetable kingdom into the animal kingdom at the lowest extremes of each. In both cases we have beings composed either of a single independent cell, or of aggregated groups of

* These appear at a very early period of embryonic life, their external portions form the rudiments of the back-bone and cranium.

cells, and this has given rise to a difference of opinion in defining which is the simple animal and which is the simple plant. Both may have this in common—they can propagate by simple subdivision of their parts. A mark of distinction has been sought for in their mode of nutrition, and it is probably in this that the true difference lies. The simple plant is dependent on the presence of carbonic acid and a sufficient supply of moisture; the animal organism receives its supplies from other animals or plants.

In the resemblance which they bear to each other, we can at least trace an amount of unity which indicates the Oneness of the Designer.

In still higher forms of both animals and plants, we have no difficulty as to fixed characteristics; but even among such, strange to say, we observe a remarkable parallelism in the phases of development. In certain animal organisms, a detached part, bearing the ova, has been described as an entire and perfectly independent organism, while the animal stock which produced it may have been either overlooked or described as something different. We have already alluded to this subject (see *Radiata*) and, without further discussion, we shall now, in further illustration of it, give a few parallel passages from the history of the animal and of the plant.

PLANT.	RADIATA.
Plant.—1. Seed.	*Medusa.*—1. Ovum.
2. This seed germinates, and forms stem and buds; some of the latter may drop off, and produce plants like the parent stock.*	2. This egg becomes fixed, and grows into a polyp-like animal or stock, which produces free buds of the same nature as the stock.
3. The stock finally produces flowers, fruit, and seeds.	3. The stock gives off free swimming Medusæ, these produce ova, which repeat the two phases described.

* Free buds are produced in not a few plants, as Lilium bulbiferum, Polygonum vivi parum, Saxifraga cernua, &c., &c.

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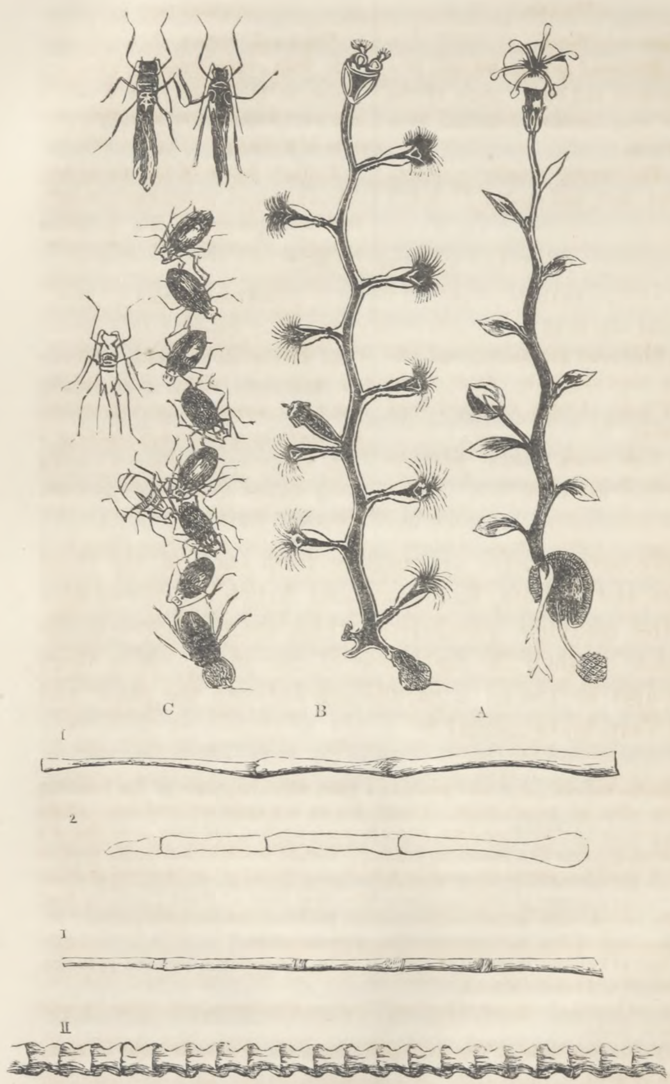

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MCCOSH ON TYPICAL FORMS. p. 307

PLANT.

Plant.—1. Seed.

2. This seed germinates, and produces stem and buds; some of the latter may become detached from the stock.

3. The stock finally produces flowers, fruit, and seeds.

MOLLUSCA.

Salpa.—1. Ovum.

2. This ovum produces a *solitary Salpa*, in the interior of which a *chain of Salpæ* is produced by a process of budding.

3. Each Salpa of the chain produces an ovum, which attains nearly full development, as No. 2, before escaping.

PLANT.

Plant.—1. Seed.

2. This seed germinates, and produces stem and buds; some of the latter may become detached from the stock.

3. The stock finally produces flowers, fruit, and seeds.

ARTICULATA.

Aphis.—1. Ovum.

2. This ovum, in spring, produces an individual which gives origin, during summer, to several others *like itself*, by a process of budding.

3. In autumn, males and females are produced by the same process; the latter deposit ova.*

We have selected an example from each of the three types, the Radiate, Molluscan, and Articulate, illustrative of the complete parallelism which there is between the phases of their life and those of the plant. May there not also be traced a parallelism between the plant and the Vertebrate animal?

* See ENGRAVING. *A.* A seed produces a plant, which increases by the formation of buds, which are usually fixed. Finally, flowers and seeds are produced. *B.* An ovum produced a ciliated organism, which becomes attached, and then gives rise to a succession of polyps by a process of budding. Certain modified individuals produce ova. *C.* An ovum produces a wingless Aphis (green-fly, &c.;) this gives rise to others like itself by a process of budding; (these differ from those of B and C in being free.) Finally, perfect males and females (winged) are produced, and ova are deposited.

1. Leaf-stalk of Ash, composed of a series of similar pieces.

2. Digit of Pithecus, (a species of Ape,) consisting of metacarpal bone and phalanges, all presenting similarity of form.

I. Small branch of a species of Bamboo, (Bambusa arundinacea,) consisting of a series of similar pieces.

II. Part of back-bone of Proteus, (reptile,) composed of a linear series of similar pieces, (centra.)

1, 2, I., II., illustrate the remarks on typical form at pp. 185, 186.

A, *B*, and *C*, are adopted from Professor Owen's work, entitled "Parthenogenesis."

PLANT.	VERTEBRATA.
1. Seed.	1. Ovum.
2. Stem (internodes) and leaf-stalk. (See p. 185 footnote.)	2. Typical bone. (See pp. 184-187.)
3. Ramified branch and venation, (pp. 104-119.)	3. Typical vertebra.
4. Axis, subterranean and aerial, with appendages.	3. Vertebral column, with appendages.

We can trace throughout organic nature a system of Homotypes, or serially repeated parts, in the *individual* plant and animal. We can also discover, in *each of the great leading divisions* both of the vegetable and animal kingdoms, a system of Homologous or answerable parts. In very *different organic structures* we can find Analogies, or different organs fulfilling the same function. But we can do more: *when we compare the various organic kingdoms one with another*, we can detect parallelisms in development, (Homœophytes.*) These parallelisms may not be of the same scientific value as homologies which now enter into the very structure of every department of natural science, but they are of equal, or at least of similar, value in Natural Theology. The homœophytes shew fully as clearly as the homotypes, the homologies, or the analogies, that all organic creation has proceeded according to a plan devised in eternity, and being realized in time.

* This phrase has been suggested to us by our friend and colleague, Prof. M'Douall.

CHAPTER XI.

GEOLOGY.

SECT. I.—TRACES OF PLAN IN FOSSIL REMAINS.

We have discovered proofs of One Designing Mind in the organization of plants and animals in the existing epoch of our earth's history. But our earth has also had a past history. Could our globe relate the story of the scenes which have taken place on its surface, what a thrilling narrative would it furnish! The dumb earth possesses no power of detailing its past changes in language, but it has carefully prepared in its crust, records, which man has faculties to decipher, and which he may succeed in deciphering, provided he proceeds with pains and caution, and in the spirit and method of the induction of Bacon. The archæologist draws conclusions from the style of the ancient buildings examined by him, and finds an entire history in the coins which he disinters from their crumbling ruins; the geologist can also gather most important instruction as to the past from the still more valuable relics which are preserved in the rocks and dust of our earth. It will be found that geology extends our argument in respect of time throughout ages which cannot be numbered, and shews that God has been proceeding in a pre-arranged system from the commencement of creation.

First, On examining the deposits of geological eras, there is little difficulty in shewing that plants and animals have been constructed on the same general plan from the beginning.

Secondly, As the organisms of different geological eras, while formed on a general model, do yet differ widely from each other, the question is started, Is there a predetermined scheme in the successive appearances of animated beings ; or, in other words, is there plan in the creation of classes, orders, genera, and species ? It should be frankly acknowledged that geology is not yet prepared to give a certain and decided answer to this question. Still it has revealed phenomena which raise the question, and supplied some facts which may help to answer it, and furnishes proofs that there is order in the succession of animal races, even though it has not yet entitled us to say with confidence that we have discovered the plan. Geology thus opens up glimpses not only of a plan in respect of contemporaneous and existing nature, but of a plan in respect of past and successive nature.

Thirdly, Geology has a further, and this a most important principle to reveal. It shews not only a uniform but an advancing plan. It does more, it unrolls a prophetic scroll, in which the earlier animated creation points on to the later, and in which the later comes as a fulfilment of the anticipation of the earlier. These are the topics to be discussed in this section.

I. Uniform Plan.—The silex dissolved in the water of some ancient spring or lake has often entirely replaced the materials of a stem, taking not merely the place but assuming the very form and essential character of every cell and modification of it, so that, when subjected to the wheel of the lapidary, slices may be cut which, under the microscope, reveal the most minute structure of the original plant. The elements, the living stones of the extinct vegetable, have thus been wonderfully preserved for our examination and instruction. Even when scarcely a trace of vegetable structure can be detected, the inorganic material of the earth's crust—the clay or mud of some ancient lake or swamp, or the sand now forming the stone of some modern quarry—has come into the place of the organic framework, or received such an impression by contact, that we have thus singularly preserved for our inspection an accurate representation of a fruit or of the venation of a leaf torn from the parent plant by a passing hurricane, or shed naturally in the autumn of some one of those countless years which elapsed before man appeared. These relics shew that the same system governed the building up of the ancient tree-ferns, palms, and pines, as still regulates the formation of those that surround us with all their symmetry and gracefulness. How interesting is it to trace on these fossils, as we have often done, the same crossing or winding spirals, and the same rhomboidal figures produced by their intersection, as we have in the tree-ferns and firs still growing on our earth; a proof that the spiral then, as now, regulated the position of the appendages of the plant.

A similar conclusion may be drawn from the animal remains imbedded in the crust of the earth. The Uraster obtusus of the older Silurian rocks has a striking resemblance to the Uraster rubens of our own coasts; the radiate arrangement of parts is identical in both. The earliest Crustacea known to us, the Trilobites, present the articulate type so familiar to us in the lobster and crab. The shell of the little Nucula varicosa, found in the same old strata, must have given protection to an animal like that of our living species of that same genus. The earliest spiral shells which have been discovered are governed by the same mathematical principles as those which the molluscs are following at this day in the construction of their habitations. The vertebrate column and appendages of fossil fish, bird, and mammal, whether of the older or more recent geological epochs, were formed on the same models as those of the same models that still people our earth and its waters. The teeth of extinct animals were constructed on the same general plan as those of existing species, and this, whether we view them as regards form, position, number, or minute structure.

Indeed, the geologist proceeds, and is entitled—by a large induction of facts, and the verifications which are ever casting up—to proceed, on the principles which we have all along been illustrating in this treatise. It is seldom that he finds a fossil plant or animal entire; most commonly he falls in with only a fragment; yet this fragment, if it be a significant one, enables him to reconstruct the whole. The process of theoretical reconstruction is conducted on those very principles of homology and teleology which we have shewn to pervade all organic nature. The palæontologist supposes that the whole organism, whether plant or animal, was constructed on a plan; that there were answerable parts in the genus or species, and a series of homotypes in the individual; and he goes on confidently to supply the wanting parts on the principle of homology. He proceeds, too, on the principle of final cause; he supposes that the part had an end to serve, and that there would be a conformity of every other organ to fulfil that end. By means of these two principles he can often, when he is in possession of but a fragment, make the entire organism stand before us with all its harmonies and its fitnesses. When at any time he falls in with an entire fossil organism, he finds that his principles are verified, and that he is entitled to proceed on them. In the next section we shall shew how he uses the principle of final cause ; in this section we are to observe him as proceeding upon model forms in his investigations of the various kingdoms of nature.

Fossil Plants.—Certain vegetable organs have been imperfectly preserved in the earth's strata, or have undergone such changes that it is often difficult to detect their relations. The palæontologist does not hesitate to trace up these to one or other of the great leading divisions of the vegetable kingdom. He may not have before him, or be able to find, some one part of the organism—say the seed, so as to ascertain the structure of the embryo ; but he is not thereby prevented from referring the plant to its proper place, provided he can find out the structure of some other part—say its stem, or the arrangement of the veins of its leaves. If the venation of the leaf is netted, he concludes that the plant proceeded from a seed with two cotyledons, and was exogenous. Associations of character, such as we have described in the chapter on the Forms of Plants, are all important, not only in the examination of living, but of fossil plants. Fortunately the structure, whether exogenous or endogenous, can be detected in most fossil plants, and thus we have a key to explain other arrangements which must have been associated with it, and this holds true, whether we have the whole stem or merely a fragment. In most cases we have only a part, but when we do meet with an entire trunk, as of Mantellia nidiformis in the petrified forest of the Isle of Portland, we see at once that we have drawn legitimate conclusions.

The characteristic venation, whether netted or otherwise, obvious in the impressions of leaves met with in various geological strata, it is so well preserved, that botanists do not hesitate to refer them to one or other of the leading divisions of the vegetable kingdom. The special modifications of the veins are also such that we can state whether the leaf belonged to a plane or a beech; and one of the highest authorities, the late Von Buch, has recommended a close study of the venation of the leaves of living species as necessary for the discrimination of vegetable leaf inpressions belonging to extinct forms. In the remarkable Clathraria Lyellii, found in the chalk marl of the Isle of Wight, the appearances are such as to indicate that the leaves were shed naturally, just as in existing trees; a proof that the same organic relation of stem and appendages existed in ancient as in modern epochs.

Radiata.—The relics of corals, of sea-stars, and sea-urchins, preserved and handed down to us in the pages of the Palæographic volume, must be studied according to the principles which apply to living forms. We can expect fruitful results only when we proceed on the idea of a regulating type.

The corals of different periods have in general a certain plan of structure, but at the same time present a remarkable contrast as to numerical type. It appears, from the researches of M. Milne Edwards, that the cup-shaped corals of the *Palæozoic* age have the stony lamellæ or rays regulated by the numbers 4, 8, 16, &c.; while in those of the *Neozoic* period, (including all epochs from the Trias to the present time,) or newest type, the regulating numbers were 6, 12, 24, &c.* Here we have a remarkable example of order, enabling the geologist to arrive at instructive results respecting the position, in time, of rocks in which corals are preserved.

* It is stated that only two exceptions occur; one species of the quaternary type being found in the chalk formation, and one of the ternary type in the Silurian rocks.

Mollusca.—But few traces remain of the soft bodies of the Molluscan inhabitants of the ancient world, and these generally in such a state that we cannot draw any sure conclusions as to their organization. The perfect condition of fossil shells, however affords us data from which to reason as to the ancient modifications of the archetype; and we cannot doubt that extinct species were formed after the same general plan as those which still exist.

The mathematical principles which determined the forms of the shell in living species, as demonstrated by Moseley, Naumann, and Elie de Beumont, have been applied by D'Orbigny in the examination of fossil species. In his "Palæontologie Française," he shews that, even when fragments alone remain, as is often the case in geological formations, the whole shell can be restored theoretically, provided we have so much as two contiguous turns of a spiral shell entire.

Articulata.—The Crustacea or crabs, the insects, and other jointed animals of former ages, present the same type of structure which prevails among the same families at present, and this holds true from the very remote epoch of the earliest Trilobites to the more recent forms of Crustacea, preserved to us in the Lithographic slate of Solenhofen. The Astacus Leachii and A. Sussexiensis, from the chalk of the South Downs, had their rings and appendages formed on the same general model as their living allies, the lobster and cray-fish. Professor M'Coy has shewn, that some disputed points in the characters of the Trilobites can be interpreted when we proceed on the principle of a general plan.*

Vertebrata.—The able investigations of Cuvier, of Owen, and of numerous other Continental and British observers, are founded on the existence of a type or model

* British Palæozoic Fossils, Part II.

in Vertebrata. It matters not how far back we examine the records of the geological volume, we can see that the method which regulated the construction of the most ancient vertebrate animal known, was identical with that which we can recognise in every being of the vertebrate sub-kingdom which surrounds us. The well-preserved jaws with teeth, and other relics, disinterred from the bone-bed of the upper Ludlow rock, enable us to draw conclusions as to the nature of the skeleton, and the modifications of the archetype presented by it.

The ancient reptile, Telerpeton Elginense, is, so far as we know at present, the oldest of its class. Imbedded in its stone sarcophagus, we can recognise the existence of a skull, back-bone, ribs, pelvis, and limbs. We can count the ribs and the pieces of the spine, and see that the pelvis is placed after the 24th vertebra, just as in the living Iguana.

Even "footprints in the sands of time" are capable of yielding valuable results, where nothing else is left. We can recognise, in ancient sandstones, the trail of tortoises, of frogs, of lizards, and of birds. The feet which imprinted them, and the entire beings, may have decayed but the impressions left are such, that the nature of the digits can be made out; and authorities are agreed as to the extinct Vertebrata having been respectively furnished with the same kind of limbs which characterize living forms belonging to the same classes of the vertebrate type.

II. Progressive Plan.—The inherent desire of our intellectual nature to discover laws, prompts us to inquire whether there has not been order in the successive creations of animals and of plants. The facts already disclosed by geology seem to us to show that there was a predetermined plan in the appearance of new species of organized beings. It is, however, very difficult to enunciate what this order is.

One of our most distinguished geologists holds that we have not arrived at a stage of knowledge to entitle us to draw dogmatic conclusions as to the order of the appearance of animated beings, and his arguments, as well as his name, must ever carry great weight. "I shall simply," says Sir Charles Lyell, "express my own conviction that we are still on the mere threshold of our inquiries; and that, as in the last fifty years, so in the next half century, we shall be called upon repeatedly to modify our first opinions respecting the range in time of the various classes of fossil vertebrata. It would therefore be premature to generalize at present on the non-existence, or even on the scarcity of vertebrata, whether terrestrial or aquatic, at periods of high antiquity, such as the Silurian and Cambrian."* While admitting the force of this statement, it will, nevertheless, be necessary briefly to state and examine some other views which have been advanced.

First, it will be needful to notice the view of those who maintain that there has been a gradual rise in the type of animated beings, from the earliest period to the present epoch. There has been at times associated with this, another theory which derives all the higher and later forms by natural law and progressive development from the lower and earlier. It is proper to state, however, that these two opinions have no necessary connexion; the former may be maintained by persons who deny the latter; the former may be true while the latter is false.

The facts revealed by geology seem to point to a beginning of organized life. The lower we descend in the

* Lyell's Manual of Elementary Geology, 5th edit., 1851, p. 668.

strata of successive periods, the fewer the remains of living beings. In passing downwards we reach a point where there is but a single record preserved of the existence of any organism ; we refer to the Zoophytes, Oldhamia antiqua, and O. radiata, found in the lowest Silurian rocks. If we proceed from this point upwards, we find what looks at first sight like a rise in type. What we mean may be made evident without entering upon the consideration of any other fossils than those belonging to the vertebrate sub-kingdom.

And here we first of all meet with the fact that the Invertebrata preceded the Vertebrata ; for there are no traces of the latter till we reach the upper Silurian rocks, far more recent in time than those which are lower. The thin bone-bed of the upper Ludlow rock contains fragments of fishes, relics of the most ancient beings of their class. If we continue our examination, we next meet with remains of reptiles in the upper Devonian strata. The quarry of Cummingston, near Elgin, has yielded the earliest reptilian relic known to us, and so well preserved that the ribs and most of the skeleton can be distinctly seen. It appears to have combined in itself the characters of the lizard and of the frog. Next in order of time, birds and mammals appear in the Trias formation. The Connecticut sandstone, which bears well-marked impressions of footprints of birds, would seem to present the earliest indications of that class.* And in the upper Trias, Professor Plieninger has found molar teeth of an insect-eating quadruped. Now we have here an evident progression in one sense ; first, invertebrata alone present

* In birds, every toe has the number of its bones remarkably constant, and each having a characteristic number, it is obvious that we can by such marks distinguish the foot-print of a bird. The outermost toe has always five phalanges, the fourth has four, the third has three, the second has two, and the spur or inner toe, has only one piece.

themselves ; next, and after a long period, vertebrata appear, beginning with the lowest, viz., fishes, next reptiles, then birds and mammalia, in the inverse order which they occupy as regards organization. But then another question comes in, Is the first fish the lowest of its class ? A similar question has to be asked of reptiles, birds, and mammals.

The fish relics of the Ludlow bone-bed are sufficiently well preserved to enable us to judge of the characters of the beings of which they are the remains. Their jaws and teeth are very perfect, and they give indications that they were not the lowest of their class. The Onchus of the upper Silurian rock "was a fish of the highest and most composite order ; and it exhibits no symptom whatever of transition from a lower to a higher grade of the family, any more than the crustaceans, cephalopods, and other shells of the lowest fossiliferous rocks. The first created fish was as marvellously constructed as the last which made its appearance, or is now living in our seas."*

But it may be inquired whether the ancient Silurian ocean was stocked only with fishes of high organization. Suppose a sea with its scaly inhabitants, comprehending sharks with hard teeth and shagreen skin, and also soft lampreys and hags ; it is obvious that the relics of the two former are more likely to be preserved to us than those of the two last. This may be admitted, without, however, improving the argument as to a progression in type. For although all are comprehended in Cuvier's division characterized by soft skeleton, the sharks rank much the higher—they are, in fact, the highest of their class ; the highly developed brain, their organs of sense, &c., prove them to hold the rank we have stated, the lampreys and

* Murchison's Siluria, p. 239.

hags being far lower in type. The unequal development of the tail (heterocercal) in the full-grown shark is the only remaining argument in favour of their being permanent representatives of an embryonic state, and, therefore, low in type. But this also must fall to the ground as an argument, because founded on an erroneous or mistaken view of the case ; for the symmetrical development of the tail actually precedes the unsymmetrical, in certain fishes. The observations of M. Vogt, in reference to this matter, has been either misunderstood or misrepresented. The young Coregonus, (one of the salmon family,) on which his investigations were made, has actually at the first rays of the tail-fin arranged symmetrically above and below the end of the spinal column, and therefore homocercal ; the unequal development of the tail-fin (heterocercal) is the final condition, as, indeed, it is in the Salmonidæ, contrary to the usual opinion.* The earliest fishes known to us were not the lowest of their class, but actually among the highest.

Evidence of a similar tendency is derived from a consideration of some of the earlier invertebrata. One of the most ancient Crustacea yet discovered, Hymenocaris vermicauda, found in the Bangor slate, is not of low type, it is among the highest of the Phyllopod order, which is not very far removed in structure from the very highest of the Crustacean class. It is not true, as has been affirmed, that man and the higher animals, in their different stages of embryonic life, represent some permanent forms of organisms lower in the scale ; nor can any proof be adduced of an analogous progress in the womb of time. Even if it were strictly true that there was a gradual improvement in type as time rolled on, it would

* For additional remarks on this subject, we would refer to a Lecture by Professor Huxley at the Royal Institution, April 1855 Annals Nat. History, July 1855.

still be necessary that those who adopt the "development hypothesis," should prove that transmutation of a low into a high grade had been accomplished. Allowing that the first position had been established, the question remains, whether this might not have been the plan of the Creator in bringing forward the beings which live on our earth.

The supporters of the idea of progressive development and transmutation of species in a long series of ages, believe also in a progression of life from sea to land, and that this explains what they denominate "the barrenness of Creation;" that is to say, that certain conditions of the earth's surface, favourable to the support of animals, long preceded their appearance, inasmuch as time was required for the necessary transformations of marine animals into others fitted to live upon the land. It may be true that uninhabited dry land existed at periods when the sea was the abode of many invertebrata, and so may have continued for a time previous to the appearance of terrestrial beings. But all this does not prove transformation of one animal into another, nor the progression of life from sea to land. It remains to be proved—and the onus probandi lies with those who make the assertion—that marine animals can, by any force of circumstances, or in any course of time, however long, become converted into beings fitted to a new sphere of life on land.

If certain terrestrial conditions have preceded the appearance of animals suited to them, we have in all this a manifestation of the foresight and beneficence of the Author of all, and proof of a method which pervades all creation. The bird constructs its nest before the callow brood appears; the bee lays in a store of food when the flowers yield their sweet juices in abundance, and long before winter arrives; an internal instinct leads to innumerable acts on the part of animals for the preservation of their own lives, and for their young. In a word, there are acts of anticipation flowing from instinct, which have a special relation to some important end as yet in the womb of time. And when we attribute foresight and work of anticipation to Him "who knows the end from the beginning," we do not consider such as derogating from the infinitude of the wisdom of the Great Creator.

We find so many remarkable relations between the physical condition of our earth and the wellbeing of its races, that we cannot avoid seeing in the historical evidence of geology some traces of order, a winter, a spring, the seed-time, and a harvest of creation ; a winter when life was absent ; a spring when preparation for it was accomplished, and an era when it was called into being ; and so sucessively to the time when the highest created intelligence of our earth was brought forward to take possession and occupy the earth now prepared for him. As taking this view, we think that the argument in favour of progressive development and transmutation of species, founded on the pre-existence of conditions fitted for organic life—before that life appeared—is of no value.

The late Professor E. Forbes, by whose researches geology has been so much enriched, has propounded an ingenious theory on this subject.* In order to characterize it he uses the term, "Polarity in Time," as expressive of a law which corresponds to the primitive plan of the Divine creation, but which, as being Divine, is completely independent of the notion of time, although only comprehensible by us in relation to time. The different geological epochs he comprehends under two heads, the Palæozoic, or most ancient, and the more modern, styled Neozoic. On comparing these he finds that "the mani-

* Royal Institution, Evening Meeting, April 28, 1854.

festations of generic types during each exhibit striking and contrasting phenomena. The maximum development of generic types during the Palæozoic period was during its earlier epochs; that during the Neozoic period towards its later epochs."

The following table renders the meaning more evident:—

Neozoic period,	Present and tertiary epochs, Cretaceous epochs,	Epoch of maximum development of Neozoic generic types.
	Oolitic epochs, ...	Intermediate.
	Triassic epochs, ...	*Epochs of poverty of production of generic types in time.*
Palæozoic period.	*Permian epochs,*	
	Carboniferous epochs, . .	Intermediate.
	Devonian epochs, . . . Silurian epochs, ...	Epoch of maximum development of Palæozoic generic types.

But besides the concentration of a maximum of generic types toward the earlier stages of one and the later of the other great period, he thinks also there is a substitution of group for group during the contrasting epochs, as shewn by the following comparison:—

Neozoic.	Palæozoic.
Cycloid and Ctenoid fishes.	Ganoid and Placoid fishes.
Malacostracous Crustacea.	Entomostracous Crustacea.
Dibranchiate Cephalopoda.	Tetrabranchiate Cephalopoda.
Lamellibranchiate Acephala.	Palliobranchiate Acephala.
Echinoidea.	Crinoidea.
Six-starred Corals.	Four-starred Corals.

Some objections have been made to the general classification of geological epochs adopted by the author of these views.* Where experienced and professed geolo-

* The objections refer to the position of the Permian and Triassic epochs in the tabular view, and the propriety of comparing the primary period with the Jurassic, Chalk, and Tertiary formations.

gists are at issue, it would be presumption in us to offer any dogmatic decision; but we cannot help thinking that an obvious objection applies here—and indeed, more or less to every theory—it seems to be taken for granted that we have almost, if not altogether, attained a sufficiently complete knowledge of extinct forms. This is surely far from being the case, and the lamented author of the theory of Polarity had himself, in his comparatively brief career, contributed so largely to our records of extinct beings, that there is room for expectation that very much still remains to be done, and that more information must flow in as time rolls on.

But we pass on to another opinion, which seems, upon the whole, very consistent with facts hitherto revealed by the observations of palæontologists.

As there is a certain law of progress in the development of the young animal to the day of its birth, so there seem to be some traces of parallelism to this in the order of creation—a progress in uterine life, and a parallel march in the womb of time, from the beginning of the Creation to the day when man was ushered into existence. In the development of the animal, Von Bäer has shewn that "*the more special type is developed from the more general.*" There seem to be proofs of similar progress in time.

The subject has been very fully illustrated by Professor Owen in his various writings. He remarks, "As we advance in our survey of the organization and metamorphoses of animals, we shall meet with many examples in which the embryonic forms and conditions of structure of existing species have, at former periods, been persistent and common, and represented by mature and procreative species, sometimes upon a gigantic scale."*

* Lectures on the Invertebrata.

The common crab, in the different periods of its life, represents conditions which resemble those met with in the Crustacea of succeeding geological epochs.

DEVELOPMENT OF THE COMMON CRAB.	EXTINCT CRUSTACEA.
1. Entomostracous, ...	Trilobites of the Palæozoic age.
2. Macrourous. (Tail long,) . .	Crustacea of the Oolite formation.
3. Anomourous. (Tail moderately developed, and of soft consistence,)	Crustacea of the Chalk formation.
4. Brachyourous, the adult condition. (Tail short, and turned in beneath the thorax,)	Crustacea of the Tertiary epoch.

Other examples might be cited; the above is sufficient for our purpose. It must, however, be specially observed, that "no extinct species could be reproduced by arresting the development of any known existing species of Crustacea; and every species of every period was created most perfect in relation to the circumstances and sphere in which it was destined to exist."*

But extinct forms are not always the representatives merely of the earlier stages of higher forms in the earlier periods of creation. We find another principle illustrated: in some instances it is very evident that the earlier forms "present *in combination* those characters which are found to be *separately* distributed, and *more distinctly* manifested among groups that have subsequently made their appearance."†

A remarkable extinct order of Echinodermata has been very fully examined and described by the late Professor E. Forbes—the Cystidea: it illustrates the point alluded to.

* Owen's Lectures on Invertebrata.

† Carpenter's Principles of Comparative Physiology, p. 112, 4th edition. In this admirable work the reader will find a very lucid demonstration of the subject.

Palæozoic.	Recent.
Order Cystidea. A stem, and intestine with two openings.	Order Crinoidea. A stem, and intestine with two openings.
Order Cystidea. Certain species have arms like those of Ophiurida.	Order Ophiurida. Rays or arms snake-like, spines for locomotion.
Order Cystidea. In certain genera the body is lobed.	Order Asteriada. Body lobed, that is, angular or rayed.
Order Cystidea. Body enclosed in a shell of polygonal plates.	Order Echinida. Spherical or depressed shell, of polygonal plates.
Order Cystidea. Ovarian opening single.	Order Holothuriada. Ovarian opening single.

From the above comparison, it will be seen that the single extinct order Cystidea comprehended in itself characters which are, so to speak, divided among five orders at the present day. We have here, therefore, a very notable instance of a progress from the more general character to the more special in the lapse of time—for the orders in the right hand column were very partially represented in earlier epochs, and some of them did not exist at all. Other illustrations might be brought forward among Vertebrata; we shall only allude to one, as regards dentition. Professor Owen remarks that *the typical character of the dentition was more closely and generally adhered to in genera than existed during the oldest tertiary epochs in geology, than in their actual successors.* The earlier forms of mammals, whether herbivorous or carnivorous, very generally presented the typical number of teeth, (p. 215,) whereas, in the present day, such dental character is the exception and not the rule.

It would be presumptuous in any one, at the present stage of science, to suppose that he had been able adequately to apprehend the plan in the Divine mind; but these facts seem to show that there has been an advancing series of some kind, proceeding all the while on a uniform plan.

III. Prophetic Plan.—We are next to inquire whether the earlier books of the stone-volume present any records of organic forms, which point to higher forms to come forth in later epochs; whether it discloses any foreshadowing of beings that were to follow; and especially of man, the consummation of all.

The nature of the divine and creative act by which the earliest of earth's creatures were summoned into being must ever remain unknown to us. But it is allowable to examine the aspect of these early organisms, and inquire into the relations which they bear to the succeeding series of animated beings. Our position in time, and the vantage ground on which natural science enables us to take our stand, admit of our drawing an instructive comparison between the forms of the Fauna in earlier epochs, and those that appeared in later times. We confine our attention, in what follows, to the Vertebrate type.

Siluria, rendered notable by the resistance of Caractacus to the invaders of his country, is as famous in geology, as its former people are in the history of ancient Britain. In its rocks are a succession of strata which reveals to us what seems the dawn of creation in our world. Its signatures appear to be the most ancient records of organic life. Those beautiful organisms, the Graptolites, are not found in any palæozoic rock younger than the Silurian;* and only one—the Graptolites priodon—is plentiful in the upper divisions of that system, Grap. Flemingii of the Wenlock rock being rare.† We have, therefore, a mark by which to determine the relative age of the upper Ludlow bone-bed, in which the

* Murchison's Siluria, p. 47. † Ibid., p. 208.

earliest vertebrate remains occur. There is clear evidence that they belonged to fishes, and, consequently, animals formed after the vertebrate model. This is enough; here we find at a very early period, a plan of structure which has appeared under various modifications in every subsequent era.

Those few species of the upper Silurian period were but the herald to indicate the subsequent advent of those of the old red sandstone, remarkable not only for their numbers, and their singularly bizarre forms, but some of them especially interesting in relation to this head of our subject. The highest authorities are agreed as to their general place in the class of fishes, and the names of Agassiz, of Professor Fleming, of Mr. Hugh Miller, and others, must ever remain associated with the elucidation of the history of these singular beings.

As the Onchus of the Ludlow rock announced, as it were, the dawn of vertebrate life, and foreshadowed also others of its own class that were to follow, so the Holoptychus, and others of the old red sandstone, in turn pointed forwards to the Reptilian class. The term Sauroid (lizard-like) has been applied to many extinct, and a few living forms, in order to indicate their relationship to the reptiles. The still existing Lepidosteus of America, and Polypterus of the Nile and of Senegal, present a combination of characters eminently developed in not a few of those found in the rocks of the Devonian epoch, (Old Red Sandstone.) We can here take shelter under the high authority of Agassiz, who remarks, "In Lepidosteus the articulation of the vertebræ differs from that of the vertebræ of all other fishes, no less than the structure of their scales. The extremities, especially the pectoral limbs, assume a higher development than in fishes generally. The jaws, also, and the structure of the teeth, are equally peculiar. Hence it is plain that before the class of reptiles was introduced upon our globe, the fishes being then the only representatives of the type of vertebrata, were invested with the character of a higher order, embodying, as it were, a prospective view of a higher development in another class, which was introduced as a distinct type only at a later period ; and from that time the reptilian character which had been so permanent in the oldest fishes was gradually reduced, till in more recent periods, and in the present creation, the fishes lost all their herpetological relationship, and were at last endowed with characters which contrast as much with those of Reptiles as they agreed closely in the beginning."*

In a few existing forms, (Lepidosteus of America, and Polypterus of the Nile,) and in all primeval fishes, the pelvis and posterior limbs retained their position in connexion with the point of junction of trunk and tail, a character indicating superiority of type. This does not apply to the fishes of subsequent epochs, for, from the period of the chalk formation down to our own day, a large proportion of them have the ventral or hind fins removed from the typical position and placed far forwards, near the head.

Such position of posterior limbs in the very dawn of vertebrate creation, indicates an arrangement which was largely to prevail in the vertebrata of subsequent epochs.

The Telerpeton of the Elgin sandstone ushered in the dawn of reptilian life ; it is the earliest of its class yet known to us. Fitted for a sphere of existence different from that proper to fishes, it presents to our view a new modification of the vertebrate plan. Its well developed limbs point to a character which was to come forth more prominently in succeeding periods.

* Natural History of Lake Superior.

In 1726, Scheuchzer detected, in the comparatively recent rock of Œningen, a fossil which he set down as human, styling it "homo diluvii testis," (man a witness of the flood.)* This opinion did not stand the test of comparative anatomy, and the supposed human relic turned out to be that of a large salamander. The time had not yet arrived for the advent of man; long ages had yet to roll on before the consummation of the vertebrate type; the preparations for man's appearance were not yet completed. Nevertheless, in this fossil of Scheuchzer's, there was a prefiguration of the more perfect type which man's bony framework presents.

In 1847, Professor Plieninger of Stutgardt found two fossil molar teeth, which must have belonged to a warm-blooded quadruped; they were disinterred from a bone-bed in Wurtemburg, lying between the Lias and Keuper formations. The original owner of these interesting relics is supposed to have been an insect-feeder. A well-marked tooth, pronounced on the highest authority, to have been that of a warm-blooded quadruped, implies adaptations of the vertebrate archetype of a far higher character than any yet indicated in previous geological records. Such a relic indicates associations of structure which are found in man himself; and at this point in the earth's history, we have the herald of the great mammalian class at the head of which man is placed—the first in nature, though the last in time.

Certain bipedal footsteps in the new red sandstone of Connecticut, are recognized as those of birds. Man, the true biped, was to appear in a subsequent and still distant epoch.

But such early impressions and remains are not with-

* It is agreed on all hands that the origin of the human species is of comparatively modern date. All fossil human remains, those of Guadaloupe, for example, are within the historical epoch.

out their instruction; we may recognise in all these pre-existent beings the same type of skeleton, the *beau ideal* of which was to come forward in the time appointed, after the lapse of long ages.

Fishes, reptiles, birds, and mammals, predecessors of man, presented in their frames anticipations of more perfect structures which characterize *him*. They had arrangements to protect the eye and the organ of hearing, a bony vault to contain the brain, and limbs for various functions necessary to their wellbeing.

The Supreme could foresee that which was to come, and which He had pre-ordained; the revelations of geology enables us to take a retrospective view. But they do more; they afford us the means of exercising a reflex faculty; we can examine the first figure in the vertebrate series, and from that point look down the long vistas which are opened, to the period when man appears as the final and foreseen product of the one mighty plan—the last in time, but the first in the contemplation of Him who called them all into being. Precedent vertebrata shadowed forth certain peculiarities of frame and of psychical powers, which have their full, and evidently intended, significance brought out and manifested only in man. When he appears on the scene which had been so long prepared, and, as it were, waiting for him, the consummation of the earthly type comes out;—in a goodly frame, with gait erect; in eyes to contemplate, and mental faculties to appreciate, the beauty of the objects around him; in limbs to bear that frame upright, and carry it on in the fulfillment of its high sphere of duties; and in hands to minister to the wants of the individual and of his fellows. Doubtless the structure of his body binds him to the earth's surface, but he has mental powers which enables him to soar from earth to heaven, to penetrate far into the regions of space, and throw back a reflective glance upon the remotest points of time.

In the exercise of these mental faculties, it is expected of him that he should contemplate with wonder and adoration the wondrous scene spread out before him ; and in the survey of the past he can discover that the earliest fishes of the palæozoic age pointed onwards to a higher realization of the vertebrate plan ; that the plan has never in any succeeding age been departed from ; that it was at last perfected in his own wonderful frame ; and that all this had been from eternity in the counsel of Him who worketh in the whole from the beginning unto the end.

We are happy to be able to adduce, in favour of this general view, the testimony of the two greatest living comparative anatomists. "It is evident," says Agassiz,* "that there is a manifest progress in the succession of beings on the surface of the earth. This progress consists in an increasing similarity to the living fauna, and among the vertebrata, especially in their increasing resemblance to man. But this connection is not the consequence of a direct lineage between the faunas of different ages. There is nothing like parental descent connecting them. The fishes of the Palæozoic age are in no respect the ancestors of the reptiles of the secondary age, nor does man descend from the mammals which preceded him in the tertiary age. The link by which they are connected is of a higher and immaterial nature ; and their connexion is to be sought in the view of the Creator Himself, whose aim in forming the earth, in allowing it to undergo the successive changes which geology has pointed out, and in creating successively all the different types of animals which have passed away, was

* Agassiz and Gould's Comparative Physiology, p. 417.

to introduce man upon its surface. Man is the end towards which all the animal creation has tended from the first appearance of the first Palæozoic fishes." The language of Owen is equally explicit.* "The recognition of an ideal exemplar in the vertebrated animals proves that the knowledge of such a being as man must have existed before man appeared; for the Divine Mind which planned the archetype also foreknew all its modifications. The archetype idea was manifested in the flesh long prior to the existence of those animal species that actually exemplify it. To what natural laws or secondary causes the orderly succession and progression of such organic phenomena may have been committed, we are as yet ignorant. But if, without derogation of the Divine power, we may conceive of the existence of such ministers, and personify them by the term 'Nature,' we learn from the past history of our globe that she has advanced with slow and stately steps, guided by the archetypal light amidst the wreck of worlds, from the first embodiment of the vertebrate idea under its old ichthyic vestment, until it became arrayed in the glorious garb of the human form."

SECT. II.—ADAPTATIONS OF FOSSIL ORGANISMS TO THEIR FUNCTIONS. PREPARATIONS FOR MAN.

Plants.—The stem of the extinct plant (now converted into stone) must have been as well fitted to sustain itself erect, to receive and convey the fluids taken in by the roots, and to support leaves for the elaboration of these fluids, as the axis of any of our living trees. If we meet with but the impression of a leaf, we cannot avoid drawing the conclusion that the original, now lost to us, must

* On Limbs, p. 86.

have had a framework of veins and an arrangement of the softer tissues to enable the organ to fulfil its functions. But any doubt existing on this point is removed by the investigations of Göppert, who has found, in the coal of Silesia and other countries, vegetable remains in such a state of preservation that he could point out the structure of the cuticle, and of its numerous stomata or pores. He has also fallen in with a fossil plant, nearly allied to the birch, with its branches bearing flowers. And as, in our day, pine forests emit clouds of yellow pollen, (giving rise to reports of showers of sulphur,) so the giant pines of the ancient world have left proofs of their existence, in abundant deposits of the same material, characterizing certain strata in Bohemia and other localities. On finding, in a geological formation, any remain of what bears evidence of having been a fruit, the principle of concurrence between structure and function leads us to infer with confidence that the said fruit must have been fitted to receive the pollen, and transmit its fertilizing principle to the ovule or ovules, and subsequently to protect them during the process of ripening.

Radiata.—In fossil Radiata, the original hard material of the body may remain, or silex has taken its place, (as in some flints,) or merely casts of the organism may have been preserved for our inspection; but in whatever shape presented, palæontologists invariably proceed in their examination, whether consciously or unconsciously, from the two principles of a plan and modifications.

Corals are abundant, even from the most ancient fossiliferous strata to the present epoch. In the seas of the primeval earth, they were effectual agents in bringing about changes in the contour of the land surface not less important than those which are but too familiar to our navigators in the form of coral reefs. The same modifications of the Radiate structure which fit our modern coral-builders for the part they are to play in the economy of nature, must have existed in species long since extinct.

The Wenlock limestone of Siluria abounds in remains which afford unmistakable proofs of the agency of coral-builders even in a very remote epoch. Species of Favosites, of Stenopora, of Heliolites, (one of which is said to resemble the Heliopora cærulea of the Australian reefs,) were silently at work in former times, abstracting from the sea-water its calcareous matter, and transforming it into shapes which now delight us by their regularity, while at the same time, they aided in adding to the solid part of our earth's crust. Proofs of similar agency occur in the carboniferous limestone, the reefs of which, now rearing their crests far above the level of the existing ocean, present us with evidences of some of the scenes and changes through which our world has passed during its eventful history.

In different geological strata, we meet with very perfect relics of Echinodermata, shewing modifications of the type to which they belong, similar to the star-fishes and urchins of our seas. Different adaptations for defence, for capture of food, and for locomotion, present themselves to us in species which have long since perished, as in those with which we are so familiar. They give evidence of relations of hard parts, and modifications of form, and relations of form and function, similar to those which we can read in a relic of any existing species cast up by the tide, or put to the test, if we choose, in the living animals themselves.

The Pentacrinus Briareus of the Lias is sometimes found attached to fossil wood, which must have belonged to some ancient tree, whose fragments formed drift-wood in the sea in which this singular Echinoderm lived. It was a stalked species, characterized by excessive repetition and subdivision of the radiate arms, ever ready to secure the prey, as the animal was borne along on its wooden float. If any doubt could exist respecting the modifications of the radiate type in this extinct Pentacrinite, it must be dispelled when we compare it with the singularly organized species (Pentacrinus caput-Medusæ) which still lives in the Gulf of Mexico.

In the upper Silurian rocks, we find preserved to us an extinct form, which must have perished in the very act of feeding. The Marsupiocrinites cælatus is frequently found with its proboscis inserted into the shell of a mollusc, (Acroculia Haliotis,)—both alike extinct.

In various strata we meet with abundance of animals allied to the sea-urchins of our coasts. We can recognise in the one, as in the other, some adaptations of the hard parts to form a strongly arched shell for protection, pierced with holes for the protrusion of the suckers, and presenting the same arrangement of spines moving by ball-and-socket joints.

Articulata.—Animals constructed after the Articulate type had their representatives from the most ancient periods in which traces of organized beings appear, (Lower Silurian,) down to the most recent epoch which preceded our own.

The Crustacean sub-type was a characteristic feature of the Lower Silurian fauna: the singular Trilobites must have swarmed in those early periods, and the remains handed down to us, while they shew conformity to a general plan, present also an almost endless variety in the sculpture of their exoskeleton and the nature of its contour. The admirable investigations of Burmeister have thrown great light on the organization and habits of these remarkable Crustaceans. They were nearly allied to the Phyllopoda, characterized by the bladder-like gills—the modified palp and flabellum of the appendage. The Silurian strata yield them in great numbers, and their bodies are often found rolled up, so that the head and tail are in contact. The best authorities seem to be agreed as to the adaptations of the type, in these ancient Crustaceans, to fit them for the kind of life assigned to them. They constituted a remarkable feature of the Fauna of the Silurian Ocean. The soft abdomen, and its delicate appendages, were liable to injury, and by way of compensation, they possessed the power, when alarmed, of doubling up the body, so as to bring the tail under the head—the hard covering of the back thus serving to protect the more delicate under parts. The sudden catastrophe, which in some instances must have occasioned their destruction and their imbedding in the mud of the primeval ocean, induced also that change in position to which we have alluded, and hence the occurrence of rolled-up Trilobites in the Silurian rocks.

In some parts of the Old Red Sandstone formations, fragments of a giant crustacean have been occasionally met with. Being allied to the existing Limulus, or king-crab, of warmer regions, the extinct species must have presented similar adaptations ;—the limbs differing little from each other ; the more anterior serving for capture, retention, and mastication of the food, as well as for locomotion.

Other articulata of the primeval world have been found in excellent preservation. In the gypseous marl of Aix, spiders are not unfrequently found. And in some specimens, the spinnerets are distinctly perceptible. These species, now lost to us, were, therefore, like our living forms, provided with similar modifications of abdominal appendages for spinning the delicate web to ensnare their victims.

Fossil insects, belonging to different orders, are not uncommon in certain strata. We can recognize Neuroptera, Coleoptera, Diptera, and others, all implying well-known adaptation of the articulate type. In the Lacustrine deposits of Œningen, a species of dragon-fly is found in its different stages of larva, of pupa, and of perfect insect.

Mollusca.—A skilled conchologist, finding a bivalve or a spiral shell on a sea-beach, has little difficulty in forming an opinion as to the general characters of the being which reared such a habitation for itself. And so it is when similar remains are disinterred from some stratum of the earth's crust.

There seems to exist no doubt respecting the nature of those fossils called Gomphoceras, Orthoceras, the Clymenia of the Devonian epoch, the Ammonite, the Hamite, and the Baculite. They were the Cephalopods of the primeval seas, and, in general organization, were allied to the cuttle-fishes with which we are familiar. They must have been distinguished by their voracious habits, and were provided with the necessary means of securing and resisting the struggles of their prey. Shells, which were built up by the ancient cuttle-fishes, abound in various strata, and enable us to form some opinion respecting the animal which they protected and supported. We can recognize an apparatus like that of the living Nautilus. Compartments of the shell, not occupied by the body of the animal, served as air-chambers, giving buoyancy to the whole, and, by greater or less compression of the air so enclosed, afforded a simple means of rising or sinking in the water. It is no romance when we picture to ourselves the same modifications of the archetype in the extinct Cephalopoda, which we have already seen to characterize those which are our cotemporaries. The rapidity of their varied movements, and their powerful arms, provided with sucking discs, must have rendered them formidable enemies to their fellow-inhabitants of the primeval oceans. But if any doubt could exist respecting the general organization of the beings about which we cannot help speculating, such must vanish on examining the relics, or at least one species, which have been presented for our inspection. The Oxford clay of Chippenham has yielded the Belemnoteuthis antiquus, with shell, mantle, fins, ink-bag, funnel, eyes, and tentacula covered with sucking discs and hooks. We have here, therefore, a complete epitome of structures which we find in species which are our cotemporaries, and a complete confirmation of all our conjectures.

In certain of the older Silurian rocks there have been found relics which must have belonged to species of Pteropoda; Conularia, Theca, &c., are examples. As Creseis, Cleodora, and others of our own time, flit from place to place in their ocean element—in a habitation of their own building—so the extinct species have made progression by wing-like appendages, a modification of the epipodium of the archetype. But there were giants on the earth in those days. Judging from their shells, the Pteropods of the Silurian ocean greatly exceeded in dimensions the species which swarm in some of our seas.

Vertebrata.—Not only do we find in fossil remains evidence of the first great law we have been illustrating, there are equally clear proofs that the different organs preserved for our examination had a final cause, and it is impossible to avoid the conclusion that there must have been a concurrence and co-operation of other parts to accomplish the end in view. The statement of Cuvier on this point can never be set aside ; "every organized individual," says he, "forms an entire system of its own, all the parts of which mentally *correspond and concur* to produce a certain *definite purpose* by reciprocal reaction, or by combining towards the same end." "If the viscera of any animal are so organized as only to be fit for the digestion of recent flesh, it is also requisite that the jaws should be so constructed for seizing and retaining it ; the teeth for cutting and dividing its flesh ; the entire system of the limbs, or the organs of motion for pursuing it and overtaking it, and the organs of sense for discovering it at a distance. The animal must also have been endowed with instinct enough sufficient for concealing itself, and for laying plans to catch its necessary victims."

The giant Megatherium of the new world presents, in itself, an epitome of departures from the archetype skeleton for special ends. Its comparatively light skull was supported by neck-vertebræ, small when compared with their homotypes in other parts of the body. Those of the loins are largely developed in harmony with the great size and strength of the hind limbs ; and for the purpose of additional strength, the sacral portion is united in a peculiar way to the pelvis. The vertebræ of the tail are of large dimensions, commensurate with the functions of this part, which was used as an additional supporting pillar, just as the same part is employed by the living Armadillo in certain of its movements. The high development of the hæmal arches of the Megatherium's tail, indicates that the blood-vessels supplying it were duly protected from risk of injury from pressure. Its powerful arms were so formed as to allow free rotation when rooting up the plants necessary for subsistence, the strong hind limbs and tail together forming firm pillars of support during the process.

In certain geological epochs, the earth had also its feathered inhabitants. In the remains which have been preserved for our inspection, we find special adaptations in the skeleton such as occur in the class of birds generally, and also local modifications in harmony with the habits of the particular species. The giant Dinornis of New Zealand doubtless employed its beak as a kind of pick-axe (which it resembles in form) for digging the farinaceous roots on which it fed. The peculiarities of the neck-vertebræ, and the strong ridges and processes of the occipital part of the head, all indicate the presence of powerful muscles necessary for the exercise of such a habit as that mentioned.*

A period was, when numerous reptiles, of varied form and habits, constituted a leading feature of the Fauna in the primeval world. The waters swarmed with species fitted for aquatic life ; others roamed on the dry land ; and not a few, possessed of the power of flight, obtained sustenance by pursuit and capture of insects—pursuers and prey being now alike extinct. In all cases the relics which have been discovered present such marked modifications, that anatomists are agreed as to the habits of the species, so that the restoration of their forms and descriptions of their habits with which we have been furnished from the ready pencil and graphic pen of palæontologists, however romantic they may seem, are, we believe, nearer the truth than the accounts which have sometimes been given even of certain animals which still exist. The Pterodactyles (wing-fingered) were enabled to support themselves in the air by means of membranous expansions, supported principally by the fifth digits of their fore-limbs, each of which exceeded in length the whole vertebral column of the animal, and

* Professor Owen, Zoological Proceedings, 1848.

was therefore not a little finger, though the homologue of the smallest in the hand of man.

In the British Museum there is a model of a young individual of an extinct colossal tortoise (Collossochælys Atlas) from India. This model is ten feet in length, tweny-five in horizontal circumference, and fifteen in vertical girth, a third less than in the full-grown animal. In this giant of former days there existed the same singular modifications of skeleton (p. 204) which we have already alluded to as a characteristic of tortoises which still exist.

The fishes which glided through the seas of the primeval earth have left behind them such well-marked relics that we can see pectoral and ventral fins, and a well-developed tail for aquatic progression. We observe that the same modifications of skeleton and appendages had the same relation to the wants of the animals which we find in the scaly inhabitants of our own waters.

The *teeth* of extinct vertebrata are found in such abundance, and in such a state of preservation as to afford indisputable evidence of special adaptations, whether we examine them in mammals, reptiles, or fishes.

The gigantic Iguanodon, of the Wealden formation, presents singular adaptations in the form and structure of the dental apparatus with which it was provided. "To preserve a trenchant edge, a partial coating of enamel is applied, so that the thick body of the tooth might be worn away in a more regularly oblique plane ; the dentine diminishes in density as it recedes from the enamel. Finally, when the enamel is worn away by constant use, and the tooth from a kind of cutter becomes a grinder, a third substance of a different density from the dentine, viz., the ossified pulp, adds to the efficiency of the tooth in its final capacity."*

* Professor Owen's Odontography, p. 283.

In extinct fishes, adaptations of teeth are equally obvious. The Rhizodes had long and powerful teeth, fitted for overcoming the struggles of its prey. In order the better to fit them for holding fast, "the teeth have a broad base divided into a number of long and slender cylindrical processes, implanted like piles in the coarse bony substance of the jaw."*

When peculiar modifications have enabled us to ascertain that a fossil bone belonged to fish, reptile, bird, or mammal, we hesitate not to conclude that scales, feathers, hairs, &c., must have been respectively the external covering of the animal. The extinct Glyptodon of South America has left behind it relics of a tessellated, bony cuirass, very much resembling that of living armadillos. The carcase of the mammoth, embalmed in the frozen soil on the banks of the river Lena, has supplied our museums with samples of hair and wool, which must have assisted to protect the animal from the cold blasts of the region it frequented. And, in fact, the presence of such covering affords us no insignificant evidence of the probable nature of the climate in that remote epoch and region, when those northern elephants formed a chief characteristic of a fauna which is now so changed.

Finally, the history of our earth's crust cannot be profitably examined apart from the different plants which have at various periods clothed its surface, or the animals which were successively brought into being. A palæontologist must also be a zoologist and botanist, for we cannot view living and extinct forms as essentially different embodiments of the Divine Counsel, but rather as manifestations of the same Supreme Wisdom in various consecutive ages. Respecting the unity of plan in all epochs, there seems to be no difference of opinion. The

* Odontography, p. 63.

universality of the second principle—adaptations for special ends—may not be equally capable of demonstration in extinct forms. It is scarcely to be expected that we should be able, in every instance, to prove a relation between means and end in the economy of every extinct animal or plant, seeing that in general we have only fragments to deal with. Such expectation would be, besides, presumptuous on our part; for while our finite understandings can comprehend so much, they cannot fathom the full depths of the Infinite Mind. As science advances, however, we may expect that obscure points will be rendered more clear, our doubts dispelled, and proofs of special ends increased. The admission of the first principle—of type, namely—will greatly aid as a means of multiplying examples illustrative of the second, and simplify the study of the organic beings of every epoch. We shall close this part of our subject with a quotation from Professor Owen:*—"Of the nature of the creative acts by which the successive races of animals were called into being we are ignorant. But this we know, that as the evidence of unity of plan testifies to the oneness of the Creator, so the modifications of the plan, for different modes of existence, illustrate the beneficence of the Designer. Those structures, moreover, which are at present incomprehensible as adaptations to a special end, are made comprehensible on a higher principle, and a final purpose is gained in relation to human intelligence. For in the instances where the analogy of humanly-invented machines fails to explain the structure of a divinely-created organ, such organ does not exist in vain, if its truer comprehension, in relation to the Divine

* Orr's Circle of the Sciences, Treatise, No 2; a work which contains an admirable summary of facts regarding type and modifications in skeleton of vertebrata. The low price of the work brings it within reach of all.

idea or prime Exemplar, lead rational beings to a better conception of their own origin and Creator."

Turning to a somewhat different branch of the same general subject, we find that throughout the whole series of geological ages there has been an adaptation, one to another, of the animals and plants on the one hand, and of the state of the earth, its atmosphere and climate, on the other. There has also been a preparation going on all along for the appearance of a higher being on our earth's surface. The comfort of man is dependent on the condition of the earth—the place of his temporary abode and probation, and this is the result of methodical operations going on for long successive ages. Man's life, too, is inseparably linked with the plants and animals which coexist with him, and these are also the issue of long anticipations and preparations. The eternal Logos—himself in due time to become flesh—had contemplated all this from the beginning. "The Lord possessed me in the beginning of His way, before His works of old. I was set up from everlasting, from the beginning, or ever the earth was. When there were no depths, I was brought forth; when there were no fountains abounding with water. Before the mountains were settled; before the hills was I brought forth: while as yet He had not made the earth, nor the fields, nor the highest part of the dust of the world. When He prepared the heavens, I was there: when He set a compass upon the face of the depth: when He established the clouds above: when He strengthened the fountains of the deep: when He gave to the sea His decree, that the waters should not pass His commandment: when He appointed the foundations of the earth: then was I by Him, as one brought up with Him: and I

WAS DAILY HIS DELIGHT, REJOICING ALWAYS BEFORE HIM; REJOICING IN THE HABITABLE PART OF HIS EARTH; AND MY DELIGHTS WERE WITH THE SONS OF MEN."

Since the remote period when dry land first appeared, the different substances entering into the formation of the crust of the globe have been continually subjected to a process of decomposition brought about mainly by the influence of heat, and moisture, and by the action of the atmosphere. The same moisture which aided in this process has been the means by which the products of such decomposition have been carried off and re-arranged in some new form. Rivers and their tributaries have served to convey the debris of the rocks to the ocean, there to be deposited in the form of a fine sediment, which enriched, perhaps, by the decay of marine organisms, and, after various changes, has been finally upheaved above the surface of the waters. The extent and greatness of those operations by which the dry land has been fitted for the growth of land vegetation, and prepared for the reception of animals, may startle us by their vastness; but there are abundant proofs of such great changes —the records of geology indeed teem with them. The gigantic scale on which operations, which may be styled the husbandry of nature, have been conducted, may well surprise us; but we cannot withhold our belief as to such processes, and the important results which have followed in their train. Subsoil ploughing, mixing and re-mixing of soils, have been going on in all ages. Man is but the unwitting copyist, on a small scale, of actions which have been conducted on a far greater scale, and apparently with his benefit in view. Those very qualities which a good soil ought to possess, have been induced in course of time by various chemical and physical agencies, which have been in continual operation. The debris of rocks yielding calcareous, silicious, aluminous, and other mineral ingredients, have been brought together, and mixed in a way which the husbandman imitates when necessity demands. The furrows drawn by our ploughshares are but scratches on the surface of the soil, compared with the changes to which that same soil has been subjected in former ages, and to which it owes its varied capabilities of supporting plants, and yielding subsistence to the animal kingdom.

The respiration of animals, the decay of certain organized substances, the act of combustion, and emanations from volcanic foci, add to the atmosphere a gas which is not chemically a necessary ingredient of that atmosphere. The gas referred to is carbonic acid, which at the present day forms about one thousandth part, by weight, of the air which surrounds us. It is one of the chief sources from which plants derive their more solid ingredients. They are continually taking it in, and storing it up by moulding it into shapes and qualities, of which we continually avail ourselves for different necessary purposes. An excess of carbonic acid (the miner and well-digger call it choke-damp) would render our world unfit for animal life. It does not accumulate in our atmosphere, because every plant is busily, yet silently, absorbing it, and under the stimulating influence of light and heat, selecting, so to speak, the carbon; while the remaining ingredient, the oxygen, is given out for the behoof of animal life.

The earliest traces of terrestrial plants were about coeval with the first appearance of vertebrate life in the form of fishes. These ancient land plants were the forerunners of a vegetation which gradually advanced in richness to the carboniferous epoch. The fragmentary samples preserved in the upper Ludlow rocks appear to have been of the club-moss family, (Lycopodiaceæ.)* They ushered in the Flora of the succeeding or Devonian epoch, richer than its predecessor, but of minor importance when compared with that garb and stature which characterized the rich vegetation of the carboniferous period. The flora of the coal formation must have equalled, perhaps even far excelled, the most luxuriant vegetation of tropical lands at the present day. Dense forests of tall Sigillarias, with their scar-marked and fluted stems; furrowed and jointed Calamites; giant pines, allied to our Eutassa and Araucaria, with an undergrowth of graceful ferns, the delicacy of whose forms cannot be excelled by any of the fern beauties of our own day; these constituted some of the principal features of a Flora which has left us abundant and imperishable records of its character, and has enriched our country with its valuable relics in the shape of coal.

We have the high authority of M. Brongniart for the belief that carbonic acid was far more abundant in the air during certain epochs than it is at present. The atmosphere of the Palæozoic period was warm, moist, and highly charged with the gas mentioned. These conditions have been shewn by Professor Daubeny to be peculiarly favourable to the development of a rank vegetation,† such as certainly prevailed during the later Palæozoic ages. We cannot doubt that the plants composing the ancient Flora required supplies of carbonic acid for their full development. In the vegetables of the carboniferous epoch we can recognise the existence of agents destined to perform an important part in the economy of those days. While able to obtain abundance of necessary pabulum to build up their organs and add

* Murchison's Siluria, p. 238.

† Professor Daubeny, in Proceedings of British Association.

to their carbonaceous ingredients, they were, at the same time, preparing the way for the advent of animals by subtracting the excess of a gas noxious to animal life.*

We have reason to believe that living beings must have required supplies of pure air, in whatever epoch they lived. Only a few vertebrate remains, those of reptiles, have been found in the rocks of the carboniferous era. Animals of this class are capable of surviving under less favourable conditions of atmosphere than birds or mammals. These facts are adduced by geologists† as at least some confirmation of the theory they hold regarding the atmospheric features of the coal epoch. At all events, there is something more than mere accidental coincidence in all such relations of organized beings at the time alluded to; we could scarcely expect aerial breathers to abound at a period when the air was charged with choke-damp.

But the plants of the epoch succeeding that of the Devonian, were undoubtedly the sources whence supplies of coal have been derived, and deposited in the storehouses of the earth for the benefit of mankind.

It has been calculated that the coal of Great Britain alone, counting only what comes to the surface, contains carbon enough to add one-fifth to that now existing in the whole atmosphere. The plants of the coal period have left us obvious proofs of their existence in the shale of our coal mines; and in the coal itself, we can find some data from which to estimate the vast amount of carbonic acid which (from whatever source derived) was abstracted by the plants of that remarkable epoch, and then stored up in a convenient form for our use. In our coal fields, we have a rich deposit of material available

* Phillip's Manual of Geology p. 613; 1855. † Ibid.

for various purposes, and among others, as a generator of mechanical force—in fact, a latent power—which, in its proper application with its usually associated ironstone and limestone, has contributed largely to give to the present age "its form and pressure."

All this invaluable treasure—in the form of deeply-seated coal basins—must, however, have remained buried for ever in the bowels of the earth, beyond our reach, had it retained its primary geological conditions and relations. But, by various and gigantic appliances of subterranean force, the original deposits of coal have been broken up, changed in position, and brought nearer the surface, and thus placed more within the reach of man. Upheavings have followed the internal throes of mother earth; elevating forces have brought about dislocations of strata; and if the deposits of subterranean fuel have not in every case been brought to the very surface, those still remaining in a buried condition have had their original relations so altered that they can be subjected to the explorations of the adventurous miner with greater prospect of success.

The regularity in the succession of different strata, and the peculiarity of the organic remains by which these are characterized and become capable of recognition, afford man important assistance in his search after the coal which lies under his feet. He has some more trustworthy guide than the divining rod, to indicate the locality in which he may expect the subterranean treasures, as well as calculate their probable extent. A knowledge of geology affords invaluable aid in the discovery of coal where it has never previously been wrought, and we may trust to the same sure guide in forbidding the waste of time and capital in searching for it where it cannot possibly be found. But when infallible marks have brought us to the spot where the coal lies, the same principles aid us in getting at it, or (as the miners say) "winning it." Geology affords a sure guide in the development of those commercial and industrial resources which the different regions of the earth possess.

The carboniferous epoch, constituting the "reign of the Acrogens," whose characteristic features have been briefly alluded to, was followed by times when Pines and Cycases prevailed—the "reign of the Gymnosperms." The pines had the predominance in the dawn of that kingdom; they were finally almost entirely supplanted by the Cycadeæ—a family probably familiar to our readers in one of their aspects, under a form which may be compared to a gigantic fir-cone, with a tuft of wiry, fern-like leaves growing from the top.

But we pass on to a new epoch of terrestrial vegetation. With the Chalk period there began a fresh era, the "kingdom of the Angiosperms." In its dawn there was a kind of transition from the previous dynasty to the new one which we are now to consider, and which reached the zenith of its strength in our own time. Through the Eocene, Miocene, and Pliocene epochs, the Angiosperms increased in numbers, and some families which characterize our own days became more and more numerous.

We have, in a previous part of this work, endeavoured to shew that those species which delight us by their forms and colours are peculiarly characteristic of existing Floras. And if we seek for more substantial properties, we still miss, in the species of the primeval epochs, those distinguished for their utility at the present day. Doubtless the earth formerly yielded Ferns, Firs, Cycases, and Palms, and plants of the same families to supply useful products. The New Zealander and Tasmanian derive some sustenance from the subterranean stems of a fern;

we ourselves owe much to the firs of our own forests ; and the natives of Northern Europe sometimes use the ground bark of a pine (as well as of other trees) to eke out their scanty meal ; some of the human family can, by a troublesome process, extract nourishing matter from the stems or seeds of a Cycas ; and certain Palms do furnish valuable products—constituting, in fact, a vegetable bazaar, yielding food and clothing, and luxuries besides ; but how small a part, after all, of the millions of men in our world do the foresaid plants support, and that part is the least civilized and intellectual !

While it must be acknowledged that the researches of the Palæontologist have not yet exhausted our information as to the plants which clothed the earth before man was called into being, we cannot but remark the almost total absence of families whose products minister to his wants and comfort. We find few traces in the tertiary epoch, which immediately preceded man's, of plants belonging to families from which he derives his necessary food. In that tertiary age there were, so far as geology reveals to us, few or no spices yielding "cinnamon, and odours, and frankincense, and wine, and oil, and fine flour and wheat. There are few evident indications of any vegetables from which man derives food and valuable fibre, and, in a word, of species which support and clothe by far the largest proportion of the human race. Scarcely any Gramineæ (grasses appear in the lists of extinct forms ; may we not conclude that the principal cereal plants are characteristic of man's epoch, that barley, oats, rye, wheat, millet, Indian corn, and rice, were special provisions in order to man's appearance ? From the lists of Pliocene vegetation we miss the Labiate plants, which so charm us by the beauty of their flowers, and which yield essential oils to regale us by their perfumes. Of

Rosaceæ there are few traces, and in the list of finally-added species, we must include the roses which yield us their precious "Attar," and the delicious fruits which characterize our more temperate climes.

There were thus long preparations made both in the crust of the earth and in its living organisms for the support of man, who appears when all is prepared for him. "THE EARTH HATH HE GIVEN TO THE CHILDREN OF MEN." "AS FOR THE EARTH, OUT OF IT COMETH BREAD, AND UNDER IT IS TURNED UP, AS IT WERE, FIRE."

CHAPTER XII.

INORGANIC OBJECTS ON THE EARTH'S SURFACE.

SECT. I.—CRYSTALLINE FORMS AND CHEMICAL PROPORTIONS.

In surveying, in a superficial manner, the mineral substances which compose the crust of the earth, the impression might be left that they are irregular throughout, and that they can exhibit no marks of intelligence. Paley, in the opening of his beautiful work, refers to a stone, as, in this respect, in striking contrast to a watch. The meaning of Paley is obvious and correct, but science will not admit, in the present day, that there are no traces of order and design in the stone. Isaac Barrow, two centuries ago, spoke, in one of his Sermons, of stones, metals, minerals, as "probably furnishing obvious proofs of the Divine Wisdom, provided our senses were able to discover their constitution and texture." What the senses cannot do has been done by the penetrating intellect of man, following the principles of inductive science. In dead minerals we observe—under a simpler, but, at the same time, more unbending aspect—the commencement of those wondrous forms which, under wider and more accommodating modifications, play so important a part in the economy of living beings.

No man can look on the columnar structure of Staffa or the Giant's Causeway without having a sort of vague notion, that here there is method and intelligence too. We feel as if we have traces of these in this architecture of nature, just as we have them in those objects of man's construction which they so much resemble—the columns of a temple, the pipes of an organ, or the oaken ribs of a ship. We are not sure that the impression is altogether a mistaken one. There is here, it is true, no special adaptation of parts to produce a useful end: this indication of design is altogether wanting; but there is general law operating here as in every other part of inorganic nature, producing an orderly result, such as is characteristic of intelligence. How often, too, may we see the coal on our fires tending towards a definite mathematical shape, and, on breaking up the pieces we find the fragments not less regular! When we open up the stones of the ground, we may discover, in the component parts of most of them, a regular structure, and the impression is left on the mind that they are crystalline throughout. In short, minerals are found everywhere in nature in very beautiful symmetrical forms, and most minerals assume regular forms in circumstances which admit of this operation being formed—that is, when there is a slow and gradual change of fluid into solid, and the arrangement of the particles is undisturbed by motion.

It was a happy misfortune which befell Abbé Haüy, when a fine group of calcareous spar which he was examining fell from his hands and was shivered into fragments. The original crystals were of a prismatic shape, but as he gathered up the broken pieces of one of the prisms in sadness, he observed that, while not less regular in shape than the original crystal, they were all rhomboidal; and the thought flashed on him—bright as the lustre from the mineral—that all the varied crystalline forms in nature might be derived, according to fixed laws, from a few primitive forms. He felt as if a new world had opened upon him, and he exclaimed, "All is found!" In prosecuting his investigations, he did not scruple to break his whole collection of crystals to pieces, and he succeeded in discovering certain laws, the determination of which has turned out to be a more precious acquisition to human science than all the crystals in all the museums of the world.

The regular forms assumed by minerals has now been carefully examined, and the science of Crystallography is the result. The figures of crystals found in nature and formed artificially are very diversified, but any given substance is limited in the number of crystalline forms which it takes: thus, fluor spar crystallizes in cubes, but never in six-sided pyramids. The forms are all in conformity with a beautiful law of symmetry. In every one of them there will be found a line passing through the centre of the crystal, round which all different parts of the crystal are symmetrically grouped; this is called the crystalline axis. The numerous crystalline forms which exist in nature can all be reduced, on rigidly scientific principles, to a few primitive forms. There are Six Primitive Forms, according to Professor Weiss of Berlin, whose views seem to be generally adopted.*

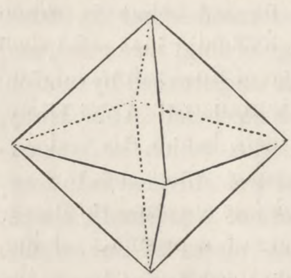

Fig. 69.

First, The Octohedral System. It has three equal axes at right angles to each other. (See *Fig.* 69.) Owing to the perfect symmetry by which it is characterized, it has been called the regular system of crystallization.

* The views of Professor Miller of Cambridge are substantially the same.

Second, The Square Prismatic System. In this, as in the former, there are three axes, which intersect each other at right angles; but in this system only two of the three are equal. (See *Fig.* 70.)

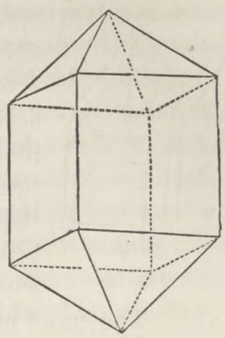

FIG. 70.

Third, The Right Prismatic System. Here, as in the two preceding, there are two rectangular axes, but no two of the axes are equal. (See *Fig.* 71.)

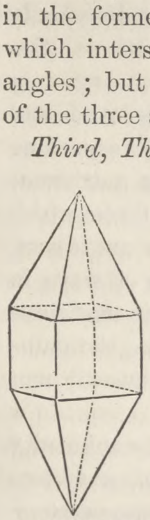

FIG. 71.

In these three systems the axes of the crystals are all at right angles to each other. In those which follow, there is the same symmetry round the axes, but the axes are not rectangular.

Fourth, The Rhombohedral System. Here, as in the first group, the axes are equal. They cross each other at equal angles, but not at right angles. (See *Fig.* 72.) The most simple form is the rhombohedron, which is bounded by six equal and similar rhombic faces.

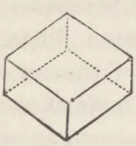

FIG. 72.

Fifth, The Oblique Prismatic System. In this system, two of the axes intersect each other obliquely, while the third is perpendicular to both. The axes are unequal in length. (See *Fig.* 73.)

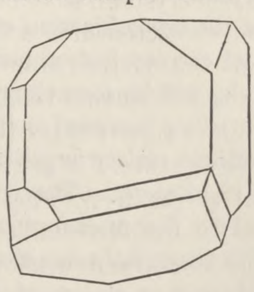

FIG. 73.

Sixth, The Double Oblique System. The three axes intersect each other obliquely, and are unequal. Much of the symmetry of form observable in the others disappears in this system. Still, the faces which are diagonally opposed are parallel to each other. (See *Fig.* 74.)

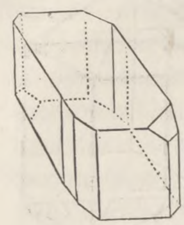

Fig. 74.

Out of these primary forms, other and derivatory ones are fashioned, according to principles which are of a mathematical character. Thus, the forms which the octohedral system takes are seven, being limited to the number of ways in which a plane can intersect the three axes. The most prevalent are the octohedron, the cube, and the rhombic dodecahedron, which are frequently met with in nature.

Simple forms of different systems are never combined,* but the mineral which assumes one form of a system may, and often does, take other forms of the same system. Thus the salt alum may be obtained in the form both of the octohedron and the cube. During the process of crystallization it will often happen that the faces of several of these forms are simultaneously developed, furnishing crystals of the greatest diversity of appearance. Thus, in the crystallizatian of alum, the faces both of the cube and the octohedron may be produced, and the faces of the cube will be seen truncating the angles of the octohedron. It is an instructive illustration of the means by which infinite variety is produced in nature, in accordance with a rigid unity. The transition from the more rigid crystal to the freer forms of organic nature, may be seen in the beautifully-ramified figures made by the frost on our flag-stones and windows, and also in the branchings of coralline structures.

* It should be stated, however, that the mineral may crystallize in a different system when in an *allotropic* condition.

An interesting connexion had been traced, by Mitscherlich of Berlin; between the crystalline form and the composition of bodies. Substances which take the same crystalline form may be substituted for each other in combination, without affecting the external character of the compound. Thus, sulphate of potassa and peroxide of iron may be made to take the form and aspect of alum without the presence of any aluminous earth. Substances which assume the same crystalline form are called Isomorphous. Isomorphous bodies have been distributed into distinct groups;—thus, oxygen, sulphur, chlorine, belong to one group; potassium, sodium, lithium, calcium, zinc, lead, silver, are associated in another group; while arsenic, antimony, phosphorus, and tellurium, form a third group. Bodies belonging to the same group may be substituted for each other in the composition of salts, or of minerals, without the external qualities of the bodies being affected. Isomorphous bodies have often very close points of resemblance in physical properties as well as in form. Thus, arsenic and phosphorus have nearly the same odour; they both form gaseous compounds with hydrogen; they differ from nearly all other bodies in their mode of combining with oxygen, and yet agree with one another, and their salts are disposed to combine with the same water of crystallization. Isomorphous substances, owing, doubtless, to the various points of analogy which have thus been traced, crystallize together with great readiness, and are separated from each other with difficulty.* These researches are not yet carried so far as to entitle us to lay much weight on them in our present argument, but, even at this stage, they furnish glimpses of depths which have not yet been explored. That which has only been imperfectly ascertained, points.

* Turner's Chemistry, edited by Liebig and Gregory.

equally with that which has been more fully determined, to designed connexions and parallelisms running through the whole of nature.

When we go still farther down towards the very elementary constitution of bodies, we find indications of what must be an order in respect either of form or number. From a very early data there was a vague impression that there must be something definite in the way in which bodies chemically unite. But the law was not scientifically evolved till within the last age, when Dalton propounded his atomic theory. Proceeding on the view commonly adopted in modern times, that matter is composed of atoms, he supposes that all atoms are of the same form, that the atom of each element has a specific weight, and that when bodies combine, it must either be by one atom of one body with one atom of another, or by one atom of the one element with two atoms, three atoms, or four atoms of the other element. It was thus that he gave expression to the law discovered by him, and accounted for the relation between the weights of the combining proportions of bodies. There has been a difference of opinion as to the atomic theory which Dalton employed to explain the laws of chemical combination, but there has been none as to the laws themselves, In order to chemical combinations between bodies, we must have a certain proportional weight of the one and a certain proportional weight of the other, and if an excess of either ingredient of the compound be present, it remains uncombined, and with its properties unchanged. Thus, in order to form water, it is necessary to have one part by weight of hydrogen and eight parts of oxygen; and if there be a different proportion, say one part of hydrogen and eleven parts of oxygen, then there will only be eight of the oxygen absorbed in joining one of the hydrogen to make water, and three will remain free and unchanged.

This, then, is the first part of the law of chemical equivalents or definite proportions ;—bodies combine in certain numerical proportions by weight, and in no others. As the result of the united labours of Thomson, Berzelius, and a host of other chemists, the equivalent number of the elementary bodies (about sixty in number) has been approximately determined. To give a few examples :—

Hydrogen, 1.	Chlorine, 35·4.
Oxygen, 8.	Potassium, 39·2.
Carbon, 6.	Copper, 31·8.
Nitrogen, 14.	Lead, 103·8.
Sulphur, 16.	Quicksilver, 100.

It is another part of the same law, following from that which has been explained, that in entering into other chemical compositions, the constituents of any chemical compound replace each other exactly in the proportion in which they combine. Thus it is found that one part of hydrogen combines with eight of oxygen to form water, with six of carbon to form carburetted hydrogen, and with 35·4 of chlorine to form hydrochloric acid. But these numbers express not only the proportions in which the last-named bodies unite with hydrogen, but the proportions in which they combine with each other. It follows that if we know the proportion in which one body combines with a number of others, we know also the proportions in which all these bodies combine with each other, and replace each other in new compositions.*

In order fully to understand this truth, which has reduced the science of chemistry to the most rigid law, it is further to be taken into account, that when two bodies

* See Liebig's Letters on Chemistry.

combine with each other in two or more proportions, the higher proportions bear a very simple ratio to the lower. Thus there will unite with 14 parts of nitrogen the following parts of oxygen, but no intermediate numbers :—

Nitrogen.	Oxygen.	
14	8	Protoxide of nitrogen.
14	16	Deutoxide of nitrogen.
14	24	Hyponitrous acid.
14	32	Nitrous acid.
14	40	Nitric acid.

It has been ascertained that a similar multiple relation, capable of being numerically expressed, exists between the proportions higher and lower in which all bodies combine with each other.

In consequence of the discovery of these great truths, which constitute the fundamental laws of chemistry, it has been found possible to employ symbolical language in that science, so as to enable chemists to express in the simplest manner the constitution of every compound body and indicate the way in which its elements may be replaced. Each elementary substance is designated by the first letter of its name, compounds by the combination of the initial letters of their elements, and the number of simple equivalents of each element by their attached numbers. The memory which would otherwise be burdened by the number of particulars, (described by Plato as infinite,) is able by their being thus bound into bundles, to use a phrase of Locke's, and happily labelled, to bear its knowledge about with it, and the whole doctrine of the composition of bodies becomes comprehensible by the human intellect. But chemists in setting forth their own discoveries, and in giving due praise to one another, are apt to forget that they have been able to accomplish their work through the simplicity and numerical regularity of the laws operating in nature. Human science is possible because there has been the strictest attention paid to order in the objects which it could arrange and classify.

It is also worthy of being mentioned that the volumes of compound gases always stand in a very simple ratio to the volumes of the elements thus :—

50 oxygen + 100 nitrogen	yield	100 protoxide of nitrogen.
100 oxygen + 100 nitrogen	"	200 binoxide of nitrogen.
50 oxygen + 100 hydrogen	"	100 water.
100 nitrogen + 300 hydrogen	"	200 ammonia.

Some curious discoveries seem to have been made in regard to the connexion between chemical equivalents, and volumes; but they are not so perfected as to allow of their introduction in such a treatise as this.

Attempts have been made in the same science to form bodies into groups or congeners. M. Dumas, in particular, has detected a number of triads, or series of three bodies, which have analogous properties, and showing a singular numerical progression in their equivalent weights; the equivalents of two of these added together, and divided by two, giving approximately the equivalent of the third thus :—

Chlorine,	35		Potassium,	40	
Bromine,		80	Sodium,		24
Iodine,	125		Lithium,	7	
Calcium,	20		Sulphur,	16	
Strontium,		44	Silenium,		40
Barium,	69		Tellurium,	64	

"Regarding," says Faraday, "chlorine, bromine, and iodine, as one triad, it will be seen that between the first and the last there is recognisable a well-marked progression of qualities. Thus chlorine is a gas, under ordinary temperatures and pressures ; bromine, a fluid ; and iodine, a solid ; in this manner displaying a progression in the difference of cohesive force. Again, chlorine is yellow ; bromine, red ; iodine, black, or, in vapour, a reddish violet."*

In the higher chemistry of organized bodies we meet with another kind of organic groups ; "these are named Organic Types, the meaning of which is, that the atoms are grouped together in a certain mode, on which the properties or the compound so entirely depend, that provided this grouping or arrangement be retained, great changes may be made in regard to individual elements, without changing the general character of the compound. This leads us to the very remarkable and important law of substitution, which has become so fertile in discoveries of late years."† In organic chemistry every compound represents a type, and all chemical changes are substitutions, but only like for like can be substituted, one metal for another, or chlorine for iodine, &c.

In organic chemistry, the *arrangement* of the atoms determines the character of the type. A certain arrangement gives acids, another ethers, and so on. As an example of such an *organic type*, Dr. Gregory gives the case of Naphthaline $C_{20}\ H_8$, the character of which is that it is volatile and combustible. Now the hydrogen in this compound may be replaced, atom by atom, by chlorine, yielding a compound $C_{20}\ Cl_8$, which still retains the general characters of the type.

But there is another form of substitution giving rise to *homologous series*, in which hydrogen is replaced by certain compound radicals which are themselves homologous and give origin, when substituted for hydrogen, to other

* Faraday's Lectures on Non-Metallic Elements, pp. 158, 159.

† Elementary Treatise of Chemistry, p. 265.

homologous series. The following tabular view will render this plain :—

	Hydrogen H.			Water HO.
Ethyles.	Methyle, C_2 H_3		Ethers.	Oxide of Methyle, C_2 H_3 O
	Ethyle, C_4 H_5			do. Ethyle, C_4 H_5 O
	Propyle, C_6 H_7			do. Perpyle, C_6 H_7 O
	Butyle, C_8 H_9			do. Butyle, C_8 H_9 O
	Amyle, C_{10} H_{11}			do. Amyle, C_{10} H_{11} O

Taking methyle, the first in the series, we can see the simple relation which exists between it and all the members of the series. The second, ethyle, is derived from the first by adding two atoms of carbon, and two of hydrogen. The third bears a like relation to the second, and so on throughout. The carbon equivalents form an even number, those of the hydrogen are odd numbers. It is farther worthy of notice, that the volatility of each is inversely as the amount of carbon and hydrogen, and, consequently, the density is in direct proportion to the amount of carbon and hydrogen. The density and boiling point increase from the top to the bottom of the scale, in the order in which they stand in the above table. Methyle is a gas like hydrogen, requiring twenty atmospheres to reduce it to a fluid state, amyle is an oily fluid boiling at 311° Fahr.

The radicles in the first part of the table are all homologous with, and analogous to, hydrogen. And as hydrogen, H, was the starting point in the series of radicles, (Ethyles,) so water HO is the starting-point of a new homologous series formed from these radicles, forming ethers, as represented in the second series in the table. The first of these, oxide of methyle, C_2 H_3 O, is a gas at ordinary temperatures, the others are liquids less volatile than ether, and so on.

From this second series a third homologous series is formed, viz., the alcohols, by the addition of two equivalents of water; one example may suffice: $C_2 H_3 O, HO$ give methylic alcohol, &c. It may be observed that these series, ethers and alcohols, are also analogous as well as homologous, that is, their general characters are the same.

"We can now see," says Dr. Gregory, "that the progress of science must inevitably reduce the whole of organic chemistry, in which we must remember only the same three or four elements are perpetually met with, to a collection of homologous series, in which every compound will have its natural place, indicative at once of its origin, its immediate derivation, and its properties both physical and chemical."*

It is not necessary to maintain that all the laws referred to in this section, or in any of the sections, are simple and original; it is not necessary that we should regard any one of them as being so. We are at liberty to suppose that the very law of gravitation itself is derived from a simpler law, as is maintained by some in our day; still the order in the derivative law would be a proof of order in the original law itself, and in the arrangements made in order to its operations; thus, upon the discovery of the law of gravitation, the laws of Kepler were accounted for, but by a law orderly in itself, and having beautiful arrangements made in order to its beneficent action. Most of the forms of crystals found in nature are derivative, but when we go back to the original forms, we find them, like the derivative, distinguished by the most methodical symmetry. On the same principle we may argue that should the laws at present acknowledged in science be resolved into simpler ones, it would still be found that the original laws, with the

* Gregory's Elementary Treatise on Chemistry, pp. 264, 269, 272.

adjustments made in order to their operation, are of a regular and mutually adaptive character. The forms of crystals, and the relations of chemical equivalents, if not simple, must, just because they are regular, proceed from forms or from forces, one or both, which are also characterized by regularity. From disorder there can flow only confusion ; order can proceed only from order.

SECT. II.—ADAPTATIONS OF INORGANIC OBJECTS TO ANIMALS AND PLANTS.

Many of the adjustments which might be adduced under this head are so obvious that it is not necessary to dilate on them ; indeed, they can scarcely be made more impressive by any scientific treatment. While the elements of nature obey their own methodical laws, they are so arranged as to form living organisms, and supply them with the needful sustenance. Each agent has its rule of action, but is made to co-operate with every other. Law is suited to law, property fits into property, collocation is adapted to collocation, and the result is harmony and beneficence. The whole is dependent on every one of its parts, and the parts all lend their aid to the production of the whole. A break in a single thread of the complicated network would occasion the failure of the whole design.

There are upwards of sixty substances, which, in our present state of knowledge, we must regard as uncompounded. Each of these has its own properties, and the system is sustained by the joint action of all. Very possibly the absence of any one of the elements, certainly the absence of any one of the thirteen more universally diffused, would throw the mundane system into confusion. Each has a purpose to serve which could be served by no other. Oxygen, so essential to animal breath and life, is the most largely distributed of them all, composing more than one half of the whole inorganic objects known to us. Hydrogen, the other element of water, no less necessary to living beings, seems to have a relation to every living organism. Carbon is a main source to us of artificial light and heat. In order that it should fulfil this end, it is necessary that it should be a solid while evolving its light and heat, (a gas has little, and this only a momentary, power of illumination); this is provided for by carbon being in itself always solid. But if the result of combustion had been also a solid, then the world would have been buried in its own ashes; this evil is avoided by the carbon going off in carbonic acid, which is volatile. The mass is all glowing one instant, the next it is dissipated into air. "Carbon," says Faraday, "possesses every quality to render it adapted to its intended uses; not one property, however seemingly unimportant, could be added or taken away without destroying the whole harmonious scheme of nature, devised with such wisdom, maintained with such care."*

Each of the powers and elements of nature is in itself potent, and capable of working destructive effects, but is checked and balanced by nice adjustments. What tremendous energies does oxygen display in the phenomena of combustion, and when in the condition of ozone; yet how tranquil and passive as one of the elements of water, and as locked up in so many of the constituents of the earth's crust. The electric force held in balance in a single drop of water would, if let loose, exceed in energy the electricity of a thunder-storm. Man is placed in a state of things in which, as he is dependent, he is made every instant to feel his dependence.

* Letters on Non-Metallic Elements, p. 277.

What a vast number of independent agencies must combine and co-operate in order to the life of organized beings! It is wrong to talk of an organism developing itself by its simple and independent energy. Whatever be its internal nature—in which also, in our opinion, there is complexity and combination—it requires external agents in exact adaptation to it. All plants need nourishment, and this is supplied by inorganic matter; all animals need nourishment, and can be nourished only by matter that has been organized, and this is furnished directly or indirectly by the plant. How beautiful that adjustment by which animals breathe of the oxygen of the atmosphere, and set carbonic acid free for the use of plants, while plants absorb carbonic acid, and set oxygen free for the benefit of animals! Then all animated beings need moisture, which depends on the chemical laws uniting oxygen and hydrogen to form water, and also on heat to retain it in a state of vapour in the air, and on certain adjusted relations, in respect of quantity and weight, to the atmosphere in which it floats. All organized beings, too, depend on light coming in the needed proportion from a distant body, and on heat, the measure of which depends on the state of the central part of the earth, on the radiations of the sun, and on the temperature of the regions of space. A considerable change in any one of these essential conditions would be fatal to the whole animated beings on the earth's surface.

But instead of dwelling on these familiar topics, we shall turn to, perhaps not so conclusive, but still to a less known set of facts, in which it has been supposed that disorder reigns.

We have, in a previous chapter, brought forward some evidences of adaptation in the march of events which preceded man's epoch, and which have given rise to important changes on the earth's surface, to fit it as the dwelling-place of animals and plants, and apparently effected with a view more especially to the advent of man. In the development of this scheme, a suitable vegetation was called into being, animal tribes were introduced, with the command to multiply, and finally, to man was committed a power over every living thing.

Our aim, in the present section, is to show that there are traces of fitness in the general aspect of the earth's contour, in the arrangement of its dry land and waters, and in the relations of its surface to temperature and moisture ; and that these, in turn, have some connexion, more or less evident, with the distribution of animal and vegetable life, and also with the wellbeing of the human family.

The study of Physical Geography, which has of late years come into prominence, has little or no reference to those arbitrary divisions of the world which occupy the attention of the mere geographer. In examining the structure of the earth's surface physically, attention is rather directed to the valleys and elevations which diversify its surface—those furrows drawn by the hand of time, and the mountains which, by their upheaval, have so remarkably diversified it, and indirectly have such important bearing on the existence and wellbeing of animals and plants. Those deep furrows and prominent ridges, constituting so remarkable a feature of the earth, are lasting records of the great changes to which it has been subjected : we cannot suppose them to have been fixed by mere chance ; they bear distinct traces of subjection to those great principles which regulate all the plans of Him, every part of whose works is adapted to every other.

The investigations of observers in different ages have established the following leading truths in regard to this subject.

Land predominates in the northern hemisphere, water in the southern; the lands comprising the old and new worlds stand at right angles to each other; the new world is perpendicular to the equator, the old parallel to it. In reference to the contour of the dry land, it has been observed, that the southern ends of the old and new worlds terminate in a point, while they widen toward the north; that the southern points are high and rocky; that the continents present, to the east of their southern extremities, a large island or group of islands; and that each continent has a large gulf to the west. Humboldt has indicated the parallelism of the two sides of the Atlantic; the projecting parts of the one correspond to the gulfs of the other. Steffens has remarked, that not only do the great continents expand towards the north, and become narrower toward the south, but that the same is true of their peninsulas also. He speaks, likewise, of the grouping of masses of land two and two together, and points out an isthmus or chain of islands uniting them.

Guyot, in his "Earth and Man," enunciates the following great laws, which apply to all continents in regard to their relief or elevation:—All increase gradually in height from the shore to the interior; in all the continents the maximum of elevation is not in the centre—hence there are two slopes of unequal length, and in the mean, one of these slopes is always at least four or five times greater than the other; and the height of the plains and of the table-lands increases at the same time with the absolute elevation of the mountains. In the old world, though the principal slope is toward the north, we still observe a gradual decrease of the reliefs from east to west: in the same manner, in the new world, while the principal slope is from the west to the east, it can be shewn that the reliefs go on gradually increasing from north to south, as in the old world.* Generally speaking, although the mountains increase in elevation from the poles to the tropical regions, the greatest heights are not exactly at the equator; in the old world they occupy the vicinity of the tropic of Cancer, and in the new, are near the tropic of Capricorn. To use the words of Guyot,—"A great law, a general law unites all the various systems of mountains and of table-lands which cover the surface of our globe, and arranges them in a vast and regular system of slopes and counter-slopes."

From all this it is evident that the position of the great masses of land, the forms of their coasts, the situations and relations of their mountains, table-lands, and plains, have not been left to chance. A casual glance at a map, or a cursory examination of an individual country, may leave the impression that there is a want of definite order, that all is in inextricable confusion; but careful examination of the entire wide surface of our globe, and of the relations of its various parts, conclusively demonstrates that He who commanded the dry land to appear, accomplished His purpose according to a predetermined plan, the issues of which must have been foreseen by Him, even as they can now be seen by us. An inquiry into the special modifications, in their relations to climate and the distribution of living objects, enables us to see what fatal consequences must have resulted, so far as the present economy of things is concerned, if the plan and modifications had been different.

A water surface is slowly heated, and the consequent

* Guyot, Earth and Man, p. 50

evaporation produced has an additional retarding effect; such surface is also slowly cooled by radiation. A land surface, on the other hand, becomes rapidly heated, and as rapidly parts with its heat. Change of temperature in water occasions a change of position in its particles; no such effect is produced on the land surface. The sun's rays are weakened in their passage through the atmosphere, owing to the presence of clouds and mists, and the increased density of the lower strata; the portion of that medium nearest the earth, however, receives its temperature principally through radiation from the soil. The variety of surface, whether in respect of smoothness or irregularity, elevation or depression, water or dry land, necessarily occasions also a corresponding difference in the amount of heat received by different countries; from which it appears that terrestrial as well as atmospheric conditions modify the distribution of the heat which we derive from the great central luminary of our system.

The processes of heating and those of cooling are slower and less sensible on water than on land, and the portions of air in contact with these surfaces respectively, are affected by the peculiarities of each: over the former the atmosphere contains more moisture, and is of more uniform temperature, than over the latter. Lands far from the influence of the sea have great extremes of heat and cold, whereas maritime districts have a more uniform temperature throughout the year. The division into torrid, temperate, and polar zones, though generally applicable as regards the climates of our earth, is greatly modified by local configurations of surface, so that there are no exact lines of demarcation separating the torrid from the temperate zone. In the words of Humboldt, "The temperature is raised by the proximity of a western coast in the temperate zones; by the divided configuration of a continent into peninsulas with deeply-indented bays and inland seas; the prevalence of southerly or westerly winds; chains of mountains acting as protecting walls against winds coming from colder regions; the vicinity of the ocean current, and the serenity of the sky in summer: it is lowered by elevation above the seas, when not forming part of a plain; the compact configuration of a continent having no littoral curvatures nor bays; the vicinity of isolated peaks; mountain chains whose mural form and direction impede the access of warm winds; and a cloudy summer sky, which weakens the effects of the solar rays."

That comparative sameness which would result from uniformity of surface, exposed to regular amount of solar radiation at different seasons of the varying year, is counteracted by special modifications of our dry land and ocean; and hence the variety of climate, and corresponding diversity in the vegetation clothing the earth, and in the living beings that people it.

The atmosphere near the earth's surface, or in contact with it, is, as a whole, much warmer in the vicinity of the equator than at the extreme polar regions. This hotter and higher air has a tendency to ascend, and the colder and heavier, an equal tendency to rush in from all sides and supply the place of the former. To such differences of temperature may generally be referred all those atmospheric currents which constitute the different winds.* The direction of these currents towards the equator might be uniform if the earth did not rotate, and if its surface were level. The currents from the vicinity of the pole have little rotatory motion, but in

* For some ingenious speculations on this subject, we would refer to Lieut. Maury's recent and excellent work on the Physical Geography of the Sea.

their progress toward the equator they reach successively portions of the earth's surface, which revolve more and more rapidly, and thus leave them behind, (if we may so speak,) and then they appear to blow in a direction contrary to that of the earth's rotation. Hence the current from the north becomes converted into a north-east, and that from the south into a south-east wind. Such is the origin of those regular winds called the Trades.

The land and sea breezes of warm climates depend on the same general cause ; the cold air from the sea during the day flows in to supply the place of the air which is more rapidly heated over the land, (and consequently ascends,) the converse happening at night.

The aerial currents spoken of, and their more regular modifications, also exercise a greater or less influence upon the ocean surface, giving rise to interchanges in its parts. There is a similarity in the effects produced by heat upon the sea, to those produced by the same agent on the aerial ocean. The warmer waters of the equatorial sea have a tendency to flow towards the poles, the colder and heavier portions forming an under current toward the equator. Differences in the amount of saline matter, occasioned by excessive evaporation at certain points, or by the influx of large rivers, producing differences in the specific gravity of the ocean water,* necessarily also give rise to currents. Whatever power, however, sets the water in motion, the direction of the current is variously modified by the contour of the land.

Moisture is being continually evaporated in an invisible state, and mixes with the atmosphere ; an absolutely dry air is therefore almost an impossible occurrence, though there may be endless modifications in the amount of moisture depending on various causes. The

* We would again refer to Lieut. Maury's work for details on this interesting subject.

quantity differs according to elevation above the earth's surface; the diminished density of the air upwards is accompanied also with decrease of the absolute amount of vapour of water contained in it. In the vicinity of the equator the suspended vapour is abundant, owing to the excessive heat, and the extent of water surface; it diminishes toward the poles; it is generally greatest over the open sea, and decreases from the coast to the interior of continents.

From this brief account some idea may be entertained of the remarkable relations between the genial beams of the sun reaching us from a distant point in space, and the atmosphere, dry land, and water of our world. These, again, have a connexion with the distribution and well-being of the animals and plants which have been distributed over its surface with bountiful hand.

We may now briefly examine some of the consequences of the present arrangements of the earth's surface. Not the least remarkable of these is determined by the general position of the highest elevations. The concentration and grouping of the high and extensive mountain systems towards the equator tend to reduce the temperature of that region; and the great extent of its water-surface contributes to the same effect. If the equatorial surface had been all land, and that land all plain, it is obvious, for reasons already stated, that the whole of that part would have presented the character of a parched desert, and, in reference to animal and vegetable life, would have been a dead waste. One of the agents necessary to the development of living organisms, namely, heat, would have been supplied in excess, and another, no less essential, namely, moisture, would have been withheld. By the complicated, but nicely adjusted, arrangements we have already described, the present constitution of the earth's surface determines enough of the agents in question for the wellbeing of vegetable and animal life.

If the elevated mountain ranges had been all grouped toward the higher latitudes, eternal snows and ice would have debarred animals and plants from a large extent of surface at present occupied by both. A combination of all these arrangements, namely, extensive flat land at the equator, and high land at the poles, would have necessarily limited the range of living forms, which must have been chiefly confined to a comparatively narrow zone between the two extremes.

Even when we consider the present aspect of limited portions of the earth's surface, we are struck with the beauty of the adaptations. Mixtures of two masses of air of different temperatures, and with dissimilar amount of moisture, will occasion condensation of that moisture in the form of mist or rain. The ascent of the hot and humid air of the equator brings it in contact with strata lower in temperature, and condensation of moisture is the result. The same may happen when it moves on as an overflowing current towards the north and south. Nor is it to be forgotten that there is another condensing agent ; we refer to land of high elevation. Moist winds meeting with such an obstacle to their flow, have their onward progress arrested, and their horizontal changed into an ascending course ; the consequence is, that the mass of air, becoming cooled by contact with other and colder air, and with the land surface, loses its power of retaining the same amount of vapour, and condensation of moisture is the result. In the words of Guyot,—"The mountain chains are the great condensers, placed here and there along the continents, to rob the winds of their treasures, to serve as reservoirs for the rain waters, and to distribute them afterwards, as they are needed, over the surrounding plains. Their wet and cloudy summits seem to be untiringly occupied with this important work. From their sides flow numberless torrents and rivers, carrying in all directions wealth and life."*

In the new world, the chain of the Andes—its "great backbone"—is situated not far from the western border; to the east of this vast range are extensive plains, with interspersed secondary mountain ranges; and this peculiarity of conformation has a most important and necessary relation to its climatic peculiarities. The trade-winds from the Atlantic, in their progress first reach the eastern slope, where the secondary chains of mountains condense part of the moisture in refreshing showers, and, finally coming in contact with the great and elevated principal range, the air is robbed of most of the vapour which remains. Hence a continual flow of water down the eastern slope, clothing that fertile region with the richest vegetation, and giving it the largest river systems in the world. A necessary result of this influence exerted on the moist trade-wind in its progress to the west, is, that by the time it reaches the western side of the Andes nearly all its moisture has been lost, and a line of coast on the Pacific presents the character of an arid desert. The extent, however, of this region of draught is very small, compared with that which profits at its expense. The advantage derived from the arrangement on the one side of the Andes, far more than compensates for the disadvantage, and then this latter is still farther lessened by local peculiarities, for the Chilian desert would have presented greater latitudinal extent, if the Cordilleras toward the north had been higher, or the continent of greater breadth.

Imagine a different arrangement of surface; the great

* Guyot's Earth and Man, p. 144.

mountain chain, for example, transferred to the eastern, instead of occupying the western side ; the consequence would have been that the Atlantic trade-wind must have had its progress arrested, and its vapour condensed, at a comparatively early part of its course ; the ocean giving up a portion of its waters to the passing wind, would have received them back again at no great distance in space, and after a short lapse of time ; no extensive river systems could have possibly existed as at present ;—in a word, the whole influence of the genial wind would have been lost, the descent to the west would have been far more extensive, and the change in the land surface, and the resulting effects on climatic peculiarity, would have resulted in a very different distribution of organic forms, would have given rise to new features in the zones of animal and vegetable life, and changed the habitations of man, and the relation of one part of mankind to another.

We may now direct our attention to another part of this wide subject, to modifications which have respect to the waters of the ocean and their currents. It has been already stated that there is a tendency to a general transference of the warmer equatorial waters to the north and south, and of the colder polar waters towards the equator, subject to modification in consequence of the earth's rotation. Now the configuration of the land surface determines peculiarities in the distribution of the great currents, which exert no mean influence on the distribution of organic forms. The great equatorial current of the Atlantic has the largest mass of its waters bifurcated by the projecting point of Cape San Roque, one part being deflected to the south, along the coast of Brazil, hence called the Brazil current ; while the remaining and largest passes into the Gulf of Mexico, and then issues from the north-east extremity of the same, under the name of the Gulf Stream, and at a temperature exceeding 80° of Fahrenheit's thermometer. At its exit from the narrow passage between the point of Florida and the island of Cuba, and for some distance beyond, its flow is comparatively rapid and northwards, till the cold currents from the north, and the change in the contour of the coast line, produce such an influence that its direction becomes north-east.* Nevertheless it still retains a high temperature ; in lat. 41° N. it is at 72·5° F., and 63·5° F. on the outer border of the stream. Its influence is admitted to extend to a large part of north-western Europe, and it bears with it evidence of its presence, and of the regions whence it flows, in the form of tropical seeds and fruits, &c., which are stranded on the shores bathed by its waters, and this even as far as North Cape.

The effect of such a body of warm water (at Cape Hatteras, Professor Bache found its temperature little altered at a depth of 3000 feet) upon the distribution of marine animals and plants might be expected ; but this influence extends also to the lands along whose shores it moves. The late Professor E. Forbes has shown its effect as regards the distribution of animal forms on the British coasts, the general Fauna of the German Ocean being different from that of the Atlantic border-line. This difference we have shown to be not less marked in regard to marine vegetation ; certain species of sea-plants abundant on the Devonshire coast, range also along the Atlantic border as far as the Shetland Islands, while most of them are wanting over a large proportion of the

* This explanation is not deemed sufficiently satisfactory by some, and we would refer to the remarks on this subject, in Lieut. Maury's work already quoted. We have chiefly to do with the course of the current.

coasts washed by the German Ocean.* The general mildness of the western coast of Britain, as compared with the eastern, is mainly to be attributed to the comparatively warm water of the Atlantic. The influence extends to the land vegetation of the continent; the consequence being that the line of cultivation extends nearly to North Cape, and barley may be grown as far as 70° N. latitude.

It appears that while there is a general plan regulating the relations between our earth's surface and the influence of the central luminary of our system, there are modifications affecting the more local distribution of heat and moisture; and these are associated with certain features of organic life, inasmuch as there is a relation between the amounts of the necessary agents and the constitution of animals and plants. We cannot avoid coming to the conclusion that there are indications—at least in our hemisphere, that great centre whence civilization has extended—of suitable physical conditions, which were not brought about by mere chance.

Knowing the connection which exists between the nature of the surface, whether land or water, and the influence of the sun's rays on the temperature of our atmosphere, is is quite legitimate to speculate regarding alterations of climate as related to changes of surface.

Those great revolutions which have taken place at different epochs of our earth's history, and the corresponding phases which have occurred in animal and vegetable life, are among the more interesting points which occupy the attention, and are revealed by the investigations of the geologist and of the palæontologist. In man's comparatively brief period, such have not been distinctly exhibited on any great scale; nevertheless with no inconsider-

* See Dr. Dickie's Paper in Proceedings of British Association for 1852

able degree of certainty, the physicist can show what general climatic changes would follow the submergence of a continent, and the increase of water surface, or the converse. Farther, the average height of any portion of land above the level of the sea, can be shewn to exercise a distinct influence on the climate of the region, and consequently, on the beings which inhabit it. Sir Charles Lyell in his "Principles of Geology," has shewn how the numbers and distribution of animals and plants are affected by changes in the physical geography of the earth, and that these changes may also promote or retard migrations of species, or alter the physical conditions of the localities which they inhabit. "There are always," says he, "some peculiar and characteristic features in the physical geography of each large division of the globe, and on these peculiarities the state of animal and vegetable life is dependent."

Mr. Hopkins, in his introductory address to the meeting of the British Association at Hull, has very clearly shewn the relation between the climate of northern and western Europe, and the present configuration of the American coast line, in reference to the direction of the great Gulf Stream. He remarks—"It is to the enormous mass of heated water thus poured into the colder seas of our own latitudes, that we owe the temperate character of our climate and not only do the maps of M. Dové enable us to assert distinctly this general fact, but also make an approximate calculation of the amount to which the temperature of these regions is thus affected. If a change were to take place in the configuration of the surface of the globe, so as to admit the passage of this current directly into the Pacific, across the existing Isthmus of Panama, or along the base of the Rocky Mountains of North America into the North Sea—a change indefinitely small in comparison to those which have heretofore taken place—our mountains, which now present to us the ever-varying beauties of successive seasons, would become the unvarying abodes of the glacier, and regions of the snow-storm; the cultivation of our soil could be no longer maintained, and civilisation itself must retreat before the invasion of such physical barbarism."

We are anxious not to stretch the argument beyond what it can bear. Where the relations are so many and complicated, we are not entitled to say that no other system could have served the same ends; but we think that we can discover proof that there is a system. We can see that certain changes unless counterbalanced by other changes, would have been fatal to many of the animated beings on the earth's surface. We can see, too, that the present condition of the globe is, in fact, suited to the existing distribution of organized beings; and we know of no means by which plants and brutes could have adapted themselves to an essentially different state of the earth. It is evident that every part is suited to every other. "The mind," says Lieut. Maury, "is delighted, and the imagination charmed, by contemplating the physical arrangements of the earth from such points of view as this which we have now before us; from it, the sea, and the air, and the land appear each as a part of that grand machinery upon which the wellbeing of all inhabitants of earth, sea, and air, depend; and which, in their beautiful adaptations, afford new and striking evidence that they all have their origin in one omniscient idea, just as the different parts of a watch may be considered to have been constructed and arranged according to one human design."

We fully acknowledge, in regard to man, that he is capable of suiting himself to a variety of conditions and circumstances, but, in this respect, he stands almost alone in creation ; and we cannot view him apart from animals and plants, for his existence is intimately linked to theirs.

His range in latitude is certainly very extensive, from the snows of the Artic lands—where those outposts of humanity, the Esquimaux, pass their lives between the extremes of satiety and starvation—to the tropical zones, where their swarthier brothers are exposed to the heat of a meridian sun. But it is not to be forgotten that while he can exist in such widely different circumstances, there are certain terrestrial conditions necessary to the development of his higher nature and qualities. "The distribution of man," says Guyot, "over the surface of the globe, and that of other organized beings, are not founded on the same principle. There is a particular law which presides over the distribution of the human races, and of civilized communities, taken at their cradle in their infancy ; a different law from that which governs the distribution of plants and animals. In the latter, the degree of perfection of the type is proportional to the intensity of heat, and of other agents which stimulate the display of material life. The law is of physical order. In man the degree of the perfection of the types is in proportion to the degree of intellectual and moral improvement. The law is of moral order. . . . Here is the reason that the Creator has placed the cradle of mankind in the midst of the continents of the north, so well made, by their forms, by their structure, by their climate, to stimulate and hasten individual development, and that of human societies."

When God gave the earth to the children, He meant it to be to them a source of something more than mere sustenance. There are scenes spread all over its surface which have delighted or roused the soul of man, and helped to shape his character and his history. The fertile field, the pleasant dale, the murmuring rill, the gently-flowing stream, the rugged mountain, the bold headland, the thundering cataracts, these have all been the means of soothing, of exciting, or awing the spirit of man. The vegetable productions enhance and vary the effect by the lightness and gracefulness of their forms and harmony of their colours, by their tangled luxuriance in our meadows and by our rivers' banks, or by the sombreness of their hue and depth of shade which they furnish. These aspects of nature have all had their influence in raising up new ideas and fresh feelings in man's soul. The physical characters of a region, the nature of its surface whether flat or hilly, its soil and minerals, the size and flow of its rivers, the mountain chains which cross it, and the bays of the sea which indent it, the clearness or cloudiness of its atmosphere—all these have moulded to some extent the psychical peculiarities of man, and determined his tastes, his pursuits, and his destiny.

And there are still higher views to be taken of humanity. "God hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation." As the drama of our race's history is only being acted, we cannot see the issue ; but we are convinced that in this allotment there was a reference to the development of man's mental faculties, and ultimately to his moral and religious elevation.

We should leave a wrong impression if we did not here state our belief that our earth, while adapted to man, is adapted to him as a being fallen, frail and depraved. Our earth had a paradise upon it only for a brief period, and within a narrow range ; and, truly, an Eden would not be suited to man with his present character. We frankly acknowledge that we could not comprehend the suitableness of many of the physical conditions and actions of our globe, of its waters and its vapours, if we regarded man as a pure and holy being, who did not require to be restrained from evil by physical barriers, who needed not suffering to punish and to purify. Our earth, while it affords nourishment to man, yields it in such a manner that man must toil for it, and, in toiling for it, is kept from much sin. Physical geography announces, as clearly as Scripture, that man must eat bread in the sweat of his face. Not only so, our soil and atmosphere have chilling damps, and unwholesome heats, and deleterious ingredients, which breed and cherish disease, and help to bring man to the grave. These are essential parts of the economy of things in which man is placed. In short, our earth was prepared for man as possessing sinful inclinations, and needing to be exposed to suffering. Let us add, that it has been prepared as the scene of the action and passion of Him who must "needs suffer many things," and who had to say, "the foxes have holes, and the birds of the air have nests, but the Son of man hath not where to lay his head."

But "unto us a child is born, unto us a son is given," and "this same shall comfort us concerning our work and the toil of our hands." We are convinced that not a few of the conditions of the earth have a reference, more or less direct, to the diffusion of Christianity as the only element fitted to regenerate our world. As the leaven is only yet leavening the mass, we cannot discover its full relations to the agents among which it is placed. But as the past condition of the earth was an anticipation of the present, so the present points on to the future. We do not believe that the present is the consummated state of the earth. Just as among the old geological vertebrates, there were members which had not unfolded all their capabilities, so, in our present earth, there are agencies at work which have not completed their office. A grand plan of prophecy is advancing both in the physical and moral world, and we live in the expectation of a coming era, when the streams which have run for ages alongside of each other will unite, and yield, at the same time, a nobler condition of the earth's surface, and of the spiritual character of its human inhabitants. "They shall not labour in vain, nor bring forth for trouble," "Instead of the thorn shall come up the fir-tree, and instead of the brier shall come up the myrtle-tree." "The child shall die an hundred years old."

CHAPTER XIII.

THE HEAVENS.

SECT. I.—ORDER IN THE MOVEMENTS OF THE HEAVENLY BODIES.

THE ancients appealed with great confidence and evident delight, to the heavens, as fitted above almost everything else, to prove that there is in nature, or above it, a presiding Intelligence. The spectres of which they stood in awe were either a grim fate or an unsteady chance, and from these they felt that they could be most readily delivered by the light which shone from the heavenly bodies. The argument was perfectly conclusive of the end proposed by those who advanced it, and it was so, notwithstanding that they were not able to shew whence the order to which they pointed proceeded. They observed that the movements of the celestial bodies were harmonious; that there was, in consequence, a beneficent succession of day and night, and of seed-time and harvest, summer and winter, cold and hot; that the motions of the very stars, which they styled planetary or wandering, were orderly—their apparent regularities obeying a higher law of order; that there was a cycle for eclipses, whose return, therefore, could be predicted;—and they argued, we believe legitimately, that the "music of the spheres" had been arranged as certainly as the concord which comes from a concert of musical instruments. We are justified in inferring that there has been intelligence exercised in the production of the harmonies of music, whether we are or are not able to shew how the tones are produced ; and, on a like principle, we are entitled to conclude that the harmony of the heavens does not arise from the concurrences of chance, even when we cannot unfold its nature with perfect accuracy. Theology has not been employing this argument so frequently for the last age or two, but it is because the old spectre, raised in the darkness of heathenism, has disappeared, and it is now more terrified by another delusion, that of pantheism, which has originated in the deception of the eye when gazing on a brighter light. But the argument drawn from the heavens is as conclusive as it ever was, and can now be expounded more fully and satisfactorily. We mean, in the brief survey which follows, to begin with the Solar System, and thence rise to the region of the Sidereal Heavens.

In all, about seventy planetary bodies—planets, planetoids, and satellites—are moving round the sun, or round each other in the most regular manner. Each of them is of an oblate spheroid shape ; rotates round its own axis ; moves in an elliptic orbit, with a sun or a planet in one of the foci ; has a fixed length of day, that is, time of rotation on its axis ; and a fixed length of year, that is, time of making a revolution round its primary. The rotatory motions and the revolutionary motions of the planets round the sun, and of the primaries round their secondaries, are all, with the exception of those of the satellites of Uranus, in one and the same direction, from west to east. All these bodies are held in their spheres by a central force, of which Newton gave us the proportional expression. These may not be the ultimate expression of the laws of nature, but they are the obvious forms in which they present themselves to human observation.

We have spoken of the orbits and movements of the planets as being regular, but this is true only approximately. There are irregularities in them all, and apprehensions were at one time entertained that these might go on increasing, till the whole system became hopelessly deranged. But it was shewn, by the eminent continental philosophers of last century, that all these are periodical, or balanced one by another. The earth's orbit, at this present time, is approaching nearer the circular figure ; but it has been demonstrated, that after a time it will become more elongated, leaving the length of the year and the mean temperature of the earth unchanged. The obliquity of the ecliptic—that is, the inclination of the earth's axis to the plane of its orbit—is at present lessening ; and as the seasons depend on this obliquity, which allows the sun to shed his full radiance on different portions of the earth at different times, it was feared that they, and all on the earth which depends on them, might be seriously affected by the change ; but it can be shewn that the obliquity will, in course of time, begin to increase, and that the variation, whether of increase or decrease, cannot sensibly affect the seasons. The moon's mean motion has for some time been increasing ; this is due to the diminishing eccentricity of the earth's orbit ; but in the course of time the eccentricity of the earth will begin to increase, and the moon's mean motion to diminish. The planes of the planetary orbits vary in their positions, but all the variations are periodical, and can lead to no inconvenience. When these questions were still unsettled, the apprehensions of derangement arose chiefly from the perturbations of Jupiter and Saturn, each of which is as large as all the planetary bodies then discovered put together. Long and anxious calculations were instituted on this subject by Lagrange and Laplace: these cannot be detailed without the aid of the highest mathematical analysis, but the result may be given. Laplace found that "there existed in the motion of Saturn an inequality, the period of which is 929 years, and in the motion of Jupiter a corresponding inequality, which is affected with a contrary sign, and whose period is nearly the same—the difference between the two scarcely amounting to a degree in a thousand years. This was balm to the apprehensions of philosophers, for all fears as to the probable disorganization of the frame of nature evaporated, and the explanation of Laplace produced the true ἀποκατάστασις, by which astronomers signified the restitution of things to their former state."* It is thus proven that, looking to the law of gravitation, and the disposition of the various planetary bodies in reference to the sun and each other, the solar system has a remarkable principle of stability in the midst of constant change.

Connected with the Solar System there is a still greater number of comets. These used to be regarded even by astronomers with feelings of alarm, as apparently disturbing rather than harmonizing agents. Byron speaks of

> "A pathless comet and a curse,
> The menace of the universe."

The impression was that they appeared and disappeared in the most capricious manner, and that the earth might regard itself as fortunate if it did not come within the sweep of their tails, which at times spread themselves

* Smyth's Celestial Cycle, vol i., p. 264.

through a space of 180,000,000 miles. But it has now been demonstrated of some of them, and may be inferred of all, that they obey laws as constant as those of the planets themselves. They seem to consist of floating vaporous matter through which the stars can easily be seen. It has been ascertained that forty of them move in elliptic orbits. Some of these are comparatively small, being within the orbits of the known planets; others extend much farther into space. Neptune revolves round the sun at a distance thirty times that of the earth; but the great comet of 1680 moves in an orbit exceeding that of Neptune nearly as much as it exceeds that of the earth—the distance of the comet being 853 mean distances of the earth. The period of the revolution of a number of them has been ascertained, and the time of their return can be predicted. It should be added that a few of them seem to move in hyperbolic curves, while a large number are said to have curves sensibly parabolic. Though we do not know the ends contemplated by these wanderers into space, nor, indeed, by comets generally, yet we know that they obey the same law as the planetary bodies, and reasoning from analogy we may conclude with Newton, that they carry with them, and dispense through wide regions a beneficial influence.

We are now to pass on from the sun and planets to the contemplation of the stars. The distances of some of the nearest of these stars has been ascertained, and shew us that in going from the outer planet to the nearest body of the sidereal regions, we have leapt across an inconceivable void of twenty-one billions of miles. Others are supposed to be so far distant, that light, which travels from the sun in eight minutes, would require millions or even thousands of millions of minutes to come from them to our earth. It follows that the stars which we now see are stars as they existed many long ages ago. There is thus opened to us a glimpse not only of regions of space, but of periods of time stretching far into infinity. The telescope shows within its range one hundred millions of self-luminous bodies like our own sun. These are collected in many cases into groups with regular shapes, and, in not a few cases, are in binary, or ternary, or multiple combination with each other.

We can discover even by the naked eye that the stars in some places are gathered into clusters. Thus six or seven stars are seen by the naked eye as forming the Pleiades. The telescope shows that in this constellation there are nine or ten times the number of stars collected together and separated from the rest of the heavens. The number of such clusters is very great, and they may be discovered by artificial glasses, here and there, over the whole surface of the heavens—but more numerous in some places than in others, more numerous in particular in the northern than in the southern hemisphere. The stars in so many of these clusters are so many that they cannot be counted; but on a rough calculation it would appear that many of them must contain ten or twenty thousand stars, in an area not more than the tenth part of the moon's apparent disc. Some of these groups are of an irregular shape, which it is difficult to classify, or even to describe; but a large number of them assume such regular forms, as to show that there is some principle of order or combination among them.

The most common form is stated by Sir J. Herschel to be the circular, or the elliptic of various degrees of eccentricity, from moderately oval forms to ellipses so elongated as to be almost linear.* Dr. Robinson, in describ-

* Outlines of Astronomy.

ing the discoveries made by Lord Rosse's telescope, says they may be separated into three classes; those which

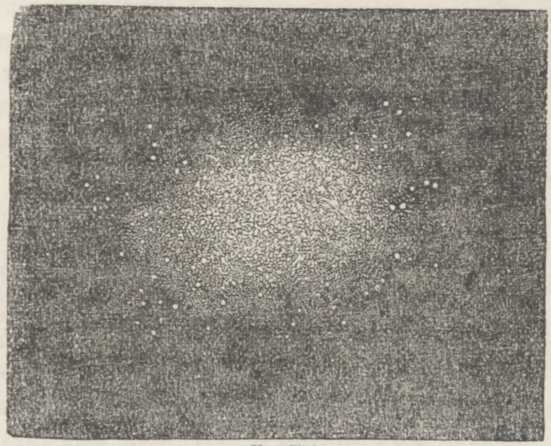

FIG. 75.*

are round, of nearly uniform brightness; those which are round, but appear to have one or more nuclei; and those which are extended in one direction, so as to become long stripes or rays.† It should be added, that although there can be no doubt as to the regular character of the forms assumed by distant groups, yet as wonderful changes are made in their appearance by higher optical powers, we are not at liberty to assume that we have ascertained their forms with perfect accuracy. Thus some of the nebulæ which presented

FIG. 76.‡

* FIG. 75. Cluster in Hercules.
† Transactions of Royal Irish Academy, 1847.
‡ FIG. 76. Annular Nebula in Lyra.

the appearance of a spherical body to Sir John Herschel's eighteen-inch reflector, have been transformed by Lord Rosse's six-feet speculum into a luminous spiral of unequal convolutions, which are prolonged at both extremities into granular globules. "Almost every new observation appears to confirm the fact of that curious tendency to spiral arrangement in these nebulous masses, of which mention has been so frequently made."*

Sir John Herschel discovers in these aggregations of stars the operations of physical laws. "Their round form clearly indicates the existence of some general bond of union of the nature of an attractive force, and in many of them there is an evident acceleration in the rate of condensation as we approach the centre which is not referable to a merely uniform distribution of equidistant stars through a globular space, but marks an intrinsic *density* in their state of aggregation greater in the centre than at the surface of the mass."† The same distinguished astronomer‡ regards it as a general law in the constitution of extended nebulæ, that their interior or brighter strata are more nearly spherical than their exterior or fainter, their ellipticity diminishing as we proceed from without inwards, a character which he represents as favouring, though not conclusively, "the idea of rotation on an axis, in the manner of a body whose component parts have such an amount of mutual connexion as to admit of such a mode of rotation, and of the exertion of some degree of pressure one on another." Some of the late disclosures of Lord Rosse's telescope, in regard to the prevalence of the spiral form in nebular groups, may so far effect these speculations, but in doing so they open to our view a more wonderful harmony, the law of which has not been determined.

* President's address to British Association, 1853.

† Outlines of Astronomy, p. 593. ‡ Observations at Cape, p. 8.

The Milky Way, which spans our heavens so conspicuously, is not a cluster of stars, but a succession of clusters. Our sun is one of the stars composing this system, and is supposed to be placed not far from the centre, but nearer the one side than the other, and in one of the poorer or almost vacant parts of its general mass. Sir

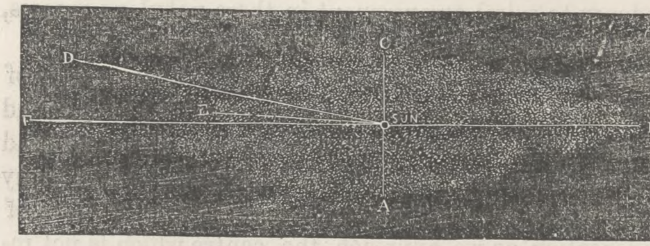

Fig. 77.*

W. Herschel thought he was able to number eighteen million stars in this girdle, and his son speaks of it as consisting entirely of stars, scattered by millions like glittering dust on the background of the general heavens. That there is some sort of concentration in this zone is evident from the statement of Struve, that there are nearly thirty times as many stars in the centre of the stratum as in the regions near the extremities.

On looking into the concave of the heavens, there are perceived at unmeasurable distances, luminous masses which look like fleecy clouds, and have been called nebulæ by astronomers. Upwards of two thousand of these "world islands" have been discovered in the northern, and upwards of a thousand in the southern hemisphere, by the telescope employed by the Herschels. According to Sir W. Herschel's estimate in 1811, they cover $\frac{1}{270}$th part of the whole heavens. They were at one time sup-

* Fig. 77. Herschel's section of the Milky Way. The Milky Way appears more brilliant in the direction of F, of D, of B, than in that of E, C, and A.

posed by certain speculators to consist of a sort of luminous matter, or *star-dust*, out of which worlds are being made even now by general law. This supposition has not been confirmed by later speculation. Within these few years, not a few of these nebulæ which were regarded as being most certainly luminous vapours, have been shewn to be stars. The magnificent telescope of Lord Rosse, not long after it began to be used, shewed that the great nebula in Orion, which was supposed to be one of the most unresolvable of them all, consisted of clusters of distinct stellar bodies. Since that time, nebula after nebula has been resolved by Lord Rosse's telescope, and another of less power but in a finer climate, at Cambridge, in the United States. In 1850, Sir J. Herschel was prepared to declare it as being almost certain, since Lord Rosse's telescope had resolved, or rendered resolvable, multitudes of nebulæ, that all the rest could be resolved by a farther increase of optical power, and the language might be made still stronger and more decisive, in consequence of what has been accomplished by that magnificent telescope since that date. The nebulæ may now be confidently regarded as clusters of stars, and give evidence of order, combination, and law in the extreme boundary of that sphere of immeasurable magnitude which constitutes the universe as knowable by us.

It is worthy of being mentioned, as illustrative of order and law, that there are to be seen in the expanse of heaven, in many places two or more stars which are apparently near each other, and which have been shown to be mutually connected as part of one system. It not unfrequently happens that a centre of light, which appears as only one star to the naked eye, is turned into two or more stars by a telescope of very ordinary power. Sometimes the relation is merely optical, and not real, that is, stars at a great distance from each other may seem near, because though the one be far behind the other, they lie nearly in the same line of vision to the eye. But the number of double stars in the heavens, being about 6000 in all, is far too numerous to be referred to any such cause. Among these, according to a table published in 1849, 650 are known in which a change of position can be incontestably proved.* Besides it has been ascertained in regard to considerably more than 100 double stars, that they revolve about each other in regular orbits. In some cases there is a smaller star joined to a large one, in other cases there are two or more stars of

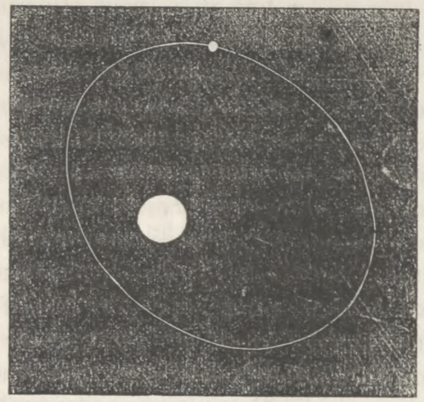

FIG. 78.

nearly equal size revolving round a common centre of gravity. The orbit in which these connected stars move is ascertained to be elliptical. These phenomena lead Sir J. Herschel unhesitatingly to declare the stars to be subject to the same dynamical laws, and obedient to the same power of gravitation, which govern our sys-

* Humboldt's Cosmos, vol. iii. p. 280, Otte's Translation; additions being made every year by the labours of Argelander, Sturve, &c.

† FIG. 78. Binary star, that is, two stars revolving round a common centre.

tem. The period of revolution of some of these combined stars has been determined, and is found to vary in different binary and multiple systems from 30 to upwards of 700 years. We have thus glimpses opened up to us in the depths of the sky, not of planet revolving round sun, but of sun moving round sun.* In the solar system we have satellite rolling round planet, and planet around sun, and double, triple, and multiple stars revolving round each other, and thousands of millions of stars grouped together in a common system.

In consequence of having ascertained, as is supposed, the distance of some of these binary stars from the earth, it is not difficult to calculate, with an approach to certainty, what are the dimensions of their orbits. These combined stars seem to be at a much greater distance from each other than the farthest planet of our system is from the sun. The distance of the two stars of 61 Cygni from each other, is 44 times the distance of the sun from the earth. The distance of these double and triple suns from each other is thus greater than the distance of the planets from the sun, in nearly as high a proportion as the distance of the planets from the sun exceeds that of the satellites from their primaries. All this gives the appearance of a regulated order in the relative distance of satellite from planet, of planet from sun, and of sun from sun, so as to allow them to move freely, each in its own sphere, whether a wider or narrower.

The region which we have been surveying used to be called that of the fixed stars; but it has been shewn that the language is inapplicable. Every star is in motion:

* It is most interesting to notice that many of the double stars have colours which are complementary the one of the other. The larger star is commonly of a ruddy or orange tinge, and the smaller one appears blue or green. "No green or blue star of any decided hue," says Sir J. Herschel, "has ever, we believe, been noticed unassociated with a companion brighter than itself."

absolute rest is unknown in the material universe. Our sun, with its retinue of planets, is travelling through space at the rate of 422,000 miles a day, towards a point near the constellation of Hercules. The mind grows dizzy in contemplating such velocity, but everything, meanwhile, is as stable as if all were at rest. It is evident that arrangements have been made to produce equilibrium among powers, each of which, acting alone, might work only destruction, and stability among objects which are never for one instant at rest.

Even before the construction of Lord Rosse's telescope, it was thought that astronomers had sounded space to nearly 500 times the distance of Sirius, that is, ten thousand billions of miles. "Hence it seems as if, were the world island, in which our system is placed, viewed from the cluster in the hand of Perseus, it would probably appear as an assemblage of telescopic stars, ranged behind each other in boundless perspective ; from that of Andromeda, it would diminish to a milky way, or pure nebulosity." It may be asserted, without any risk of contradiction, that nowhere within this wide knowable space, do we discover even the semblance of chance, confusion, lawlessness, or oversight. Nay, it may now be most confidently affirmed, that nowhere within this extensive region, or in the long ages opened up to us by the time which light requires to travel from different stars, do we discover any traces of a chaos now existing, or ever having existed, or of worlds being formed by natural law, or of worlds only half formed or in the course of formation, or of any object overlooked, or out of place, or not in harmony with all the rest. As far as the telescope can carry our vision, or enable thought to carry out its calculations, we find all the bodies already formed, already in harmony, moving on in their spheres as if performing some great and good office, and all so perfect, that our feelings are in harmony with the declaration of their Maker, when He is represented as proclaiming them "to be all very good."

SECT. II.—SPECIAL ADJUSTMENTS NEEDED IN ORDER TO THE HARMONY OF COSMICAL BODIES.

It is very manifest that every one part of the visible universe is intimately connected with every other. There are certain agents which seem to operate through the whole of it;—there is gravitation attracting all the bodies to each other; there is light flowing from millions of luminaries; there is heat radiating everywhere from the warmer to the colder regions; there is probably, also, a universally diffused ether; and possibly, also, some others of no less extensive influence, such as electricity and magnetism. We are now to shew that all these require an adjustment in order to their beneficial operation.

First, Gravitation.—The planets move in nearly circular orbits round the sun, and the satellites round their primaries, and binary and multiple stars round each other, in consequence of the balanced adjustment of the velocity of the moving body and the central attractive force. Without a nice adaptation of the one to the other, two opposite but equally deleterious results might have followed. Had the velocity been beyond its proper proportion, the body would have rushed away in a hyperbolic curve into space, to run the risk of collision with other bodies, and certainly to derange every other well-arranged system into which it might intrude. On the other hand, had the centripetal force been in excess, the separate existence of the bodies would have been lost in a mutual collapse and embrace, which must have destroyed every existing arrangement upon their surface. In a calculation of probability in a previous section, (pp. 48-50,) we have referred to two circumstances as needful to the stability of the mundane system: first, that the planets have a motion round the sun in the same direction; and have orbits with very little and scarcely-varying eccentricity, in planes with very moderate differences of inclination. There are conditions absolutely necessary to the continuance of the system;—as the invariability of the major axis of the orbits of the planets, proved by lengthened investigations, in which the highest powers of the infinitesimal calculus were employed, by the most distinguished mathematicians of the latter half of last century; as the long periodic change of the eccentricity of Jupiter and Saturn, which together amount to nearly a thousandth part of the mass of the sun, and which might have deranged the whole system under a different arrangement; and there is the farther circumstance, that the planetary revolutions have among each other no common measure. Change any one of these essential conditions, and the issue, sooner or later, would be a fearful conflict, in which every existing cosmical arrangement, with the planetary inhabitants, such as animals and plants, would inevitably be destroyed.

But here we must allude to the attempt which has been made to turn aside the force of this argument, by a scheme of ingenious cosmogony suggested by Laplace. According to this hypothesis, the whole solar system has been formed out of floating matter rotating round an axis, and which, being at first greatly heated, has, in the process of cooling and condensation, given off the planets one by one, beginning with the outer; which planets, again, being thrown off in the form of rings, have, in their condensation, given off the satellites. We do not mean to enter upon a minute examination of this hypothesis. It was connected with, and received much of its support from, the supposed existence of unformed nebulous matter floating in space. Lord Rosse's telescope has dispelled these clouds, and the theories, light as clouds, which were built on them.* It may be acknowledged that there are some of the peculiar phenomena of planetary movements which can thus be accounted for. But there are other facts beyond its power to explain, as that the satellites of Uranus should move in a direction opposite to that of all the other planetary bodies. "The satellites," says Professor Nichol, an ardent supporter of the hypothesis, "present farther a curious anomaly, or rather peculiarity. So far as we know, they all rotate on their axis, like our moon, in the exact period of a revolution in their orbits. This mode of rotation is evidently that of the original ring, but why the satellites have preserved that period is a mystery."† This theory has been subjected to a searching examination by Sir J. Herschel. "If," says he, "it is to be regarded as demonstrated truth, or as receiving the smallest support from any observed numerical relations which actually hold good among the elements of the planetary orbits, I beg leave to demur. Assuredly, it receives no support from the observation of the effects of sidereal aggrega-

* Some may urge that the hypothesis has been corroborated by certain experiments of Plateau as to the phenomena of a free liquid mass withdrawn from the action of gravity. In speaking of the division of liquid masses into parts, Plateau had compared the minute masses to satellites; but in a subsequent paper he corrects the misapprehensions to which his language had given rise, as if it favoured Laplace's cosmogony. "It is clear," he says, "that this mode of formation is entirely foreign to Laplace's Cosmogenic Hypothesis; therefore, we have no idea of deducing from this little experiment, which only refers to the *effects of molecular* attraction, and not to those of gravitation, any argument in favour of the hypothesis in question, an hypothesis which, in other respects, we do not adopt."—Taylor's Scientific Memoirs vol. v.

† Planetary System, p. 241.

tion, as exemplified in the formation of globular and elliptic clusters, supposing them to have resulted from such aggregation. For we see this cause, working out in thousands of instances, to have resulted, *not* in the formation of a single large central body, surrounded by a few smaller attendants, disposed in one plane around it, but in systems of infinitely greater complexity, consisting of multitudes of nearly equal luminaries, grouped together in a solid elliptic or globular form. So far, then, as any conclusion from our observations of nebulæ can go, the result of agglomerative tendencies *may*, indeed, be the formation of families of stars of a general and very striking character, but we see nothing to lead us to presume its farther result to be the surrounding of those stars with planetary attendants."*

But let us admit, for argument's sake, the truth of this hypothesis, and we still urge that numberless adaptations, and these of a very remarkable description, are needed in order to admit of this loose floating matter being formed into the harmonious and beneficent results which fall

* Opening Address, British Association, 1845. There follows a severe criticism of the pretended verification of that hypothesis by M. Comte, which had been quoted with approbation by the author of the Vestiges of Creation, and by J. S. Mill in his Logic. "If, in pursuit of this idea, we find the author first computing the time of rotation the sun must have had about its axis, so that a planet situate on its surface, and forming part of it, should not press on that surface, and should therefore be in a state of indifference as to its adhesion or detachment; if we find him, in this computation, throwing overboard, as troublesome, all those essential considerations of the law of cooling, the change of spheroidal form, the internal distribution of density, the probable non-circulation of the internal and external shells in the same periodic time, on which alone it is possible to execute such a calculation correctly, and avowedly, as a short cut to a result, using, as the basis of his calculation, 'the elementary Huygenian theorems for the evaluation of centrifugal forces in combination with the law of gravitation,'—a combination which, I need not explain to those who have read the first book of Newton, leads direct to Kepler's law; and if we find him then gravely turning round upon us, and adducing the coincidence of the resulting periods, compared with the distances of the planets, with this law of Kepler, as being the numerical verification in question;—where, I would ask, is there a student to be found, who has graduated as a Senior Optime in this University, who will not at once lay his finger on the fallacy of such an argument, and declare it a vicious circle?" &c.

under our notice on the earth, and which may be presumed to exist also in the other planets. Whence, for example, the striking adaptation of the gravitating, chemical, galvanic, and electric powers to each other? Whence the plants and animals which cover the face of the earth? Whence animal instincts and the human soul? Whence the correspondence between all these, and the atmosphere, and the light of the sun? All this is wonderful on any system, but becomes vastly more incomprehensible when it is supposed that it originated in certain nebulous matter. The cosmogony referred to has never been carried out into details; but if it had, we could have taken these up, and have proved that every one of them implies an adjustment. But dealing with it in its present vague form, it may be maintained that either the properties of this cosmical matter must have been such as in their own nature to imply a designing mind in the formation of them, or adjustments must have been made in order to their beneficent operation; and on either supposition we have evidence of intelligence, and the hypothesis leaves the theistic argument where it found it.

We go on to mention another beautiful arrangement which should be regarded as equally striking, whether we adopt or reject the hypothesis of Laplace. In the annual motion of the earth round the sun, its axis is inclined from the perpendicular to its orbit at an angle of twenty-three degrees, and remains constantly parallel to this direction. By this arrangement the changes of temperature on the earth's surface, and of the seasons, are produced. Had the axis of the earth, instead of being so inclined, been perpendicular to the plane of its orbit, as is the case in Jupiter, the sun would always have been vertical to the same line of places, the equatorial regions would have been parched by the heat, while the regions called teemprate in the present arrangement, would have been consigned to utter desolation. By the existing disposition, the various parts of the earth are brought more fully under the solar influence, and we have all the delightful and beneficent effects which flow from the variety of climates.

Again, the earth is nearer the sun at one season than at another, and without some counteracting influence there would be an inconvenient increase both of the cold of winter and the heat of summer in the southern hemisphere, and the climates of the two hemispheres would be rendered altogether unlike each other. But any injury which might arise from this cause is made to disappear chiefly by means of the circumstance that the point of the earth's orbit which is nearest the sun is that over which it moves with the greatest speed. "It follows," says Poisson, "from the theory of Lambert, that the quantity of heat which is conveyed by the sun to the earth, is the same during the passage from the vernal to the autumnal equinox, as in returning from the latter to the former. The much longer time which the sun takes in the first part of his course is exactly compensated by its proportionably greater distance, and the quantities of heat which is conveyed to the earth is the same, whether in the one hemisphere or in the other, north or south."*

Second, *The Universal Diffusion of Light.*—Under this head we are called first to admire the wisdom of the arrangement by which a luminous body is placed in the centre of a solar system; there being no physical necessity, so far as we can discover, for such a disposition. Some astronomers have supposed (it has not been confirmed by later investigation) that there are binary and multiple stars moving round central bodies which are

* Humboldt's Cosmos, vol. iv. p. 460.

not luminous; it is evident that if our earth had been made to circle round such a body, or round a body similar in constitution to itself, most of the living objects upon its surface would have become extinct. There is an evident harmony between the force or amount of light coming from the sun and the organism of plants and animals, for the life of both of which light, and this in a certain measure, is requisite. Had the light been much stronger than it is, it would have dazzled and blinded the eyes of animals, and stimulated to an excessive extent the growth of certain plants, while it would have utterly destroyed others. On the other hand, a diminution to any great extent of the luminiferous power of the sun would have imparted to our earth a dull and murky appearance, and have rendered it impossible for the plants of the earth, deprived of their needful stimulus, to subsist. If our earth, with its present vegetable covering and animal tenants, had been as far removed from the sun as Uranus or Neptune, or even Jupiter, it is certain that a large portion of the species of living beings would long before this have ceased to exist. Taking the intensity of light upon the earth as one, the proportions in the other planets will be as follows:—

Mercury, .	6·674.	Jupiter, . .	0·036.
Venus, . .	1·911.	Saturn, . . .	0·011.
Mars, . . .	0·431.	Uranus, . .	0·003.
Pallas, . .	0·130.	Neptune, . .	0·001.*

It is very evident that the earth could not have been placed in the room of any one of the other planets without endangering the existence of the greater number of the organized objects upon its surface. It may also be mentioned here that there is a beautiful harmony instituted between light and the gaseous envelope surround-

* Cosmos, vol. iv. p. 461

ing our earth whereby the sun's rays are diffused through the atmosphere, and are reflected upon us from every point of the concave heavens, in the infinitely varied hues of sky and cloud, instead of all streaming with burning power from the sun alone, and leaving the rest of the hemisphere black as if it had been clothed in mourning attire.

It is also worthy of being noticed, that in consequence of the comparatively small eccentricity of its orbit, much the same quantity of light falls upon the earth at all times. In this respect it may be compared with some of the other planets.

While the earth, in perihelion, is		1·034, it is in aphelion		0·967.
Mercury,	....	10·58,	....	4·59.
Mars,	....	0·52,	....	0·36.
Juno,	....	0·25,	....	0·09.

If the earth's eccentricity had been as great as that of Mercury or Juno, it is certain that not a few of our most useful and beautiful plants would have altogether disappeared, or rather could never have existed.

Thirdly, The Universal Diffusion of Heat.—There is need of a number of harmonious adjustments in order to the beneficent operation of this agent so powerful for good but also for evil.

It will be readily acknowledged that there must be a uniform temperature on the surface of the ground in order to the continuance of organized beings upon it. We know, as a matter of fact, that the earth's surface has had much the same temperature throughout historical ages. The paintings and inscriptions on the monuments of Egypt shew that in that country much the same plants were cultivated, and that they ripened about the same season between 3000 and 4000 years ago, in the ages of the Pharaohs, as at this day. The plants of

Canaan at the time of Moses and Joshua were not different from what they are now. But the sustaining of this equable temperature depends on a combination of circumstances. *First*, there are various sources of heat, and, in particular, there is the internal heat of the earth, which is known to be much greater than that of the exterior, and increasing as we go farther down, and there are the beams of the sun daily taking the circuit of the earth. Were these influences operating alone, the temperature of the earth's surface would soon be inconveniently or rather destructively heated. But to counterbalance them, we have the earth's surface and its atmosphere radiating heat into the circumambient regions of space, which are ascertained to have a very low temperature, being lower than the freezing point of mercury. Our earth has thus, on the one hand, powerful fires to heat it, and, on the other hand, an extensive reservoir of cold to keep it cool ; its surface is warmed by the internal heat, and by the heat of the sun ; and its temperature being thus rendered higher than that of the vault of heaven, it is ever radiating heat towards the regions of space according to the beautiful law of the universe, whereby all things tend towards an equilibrium. The uniform temperature of the earth from year to year, and from age to age, necessary to the continuance of the races of plants and animals, is sustained by the harmonious adjustment of agents which seem to be distinct from, and independent of, each other, except in the original collocation of all things. An increase in the internal heat, or in the heat streaming from the sun, would speedily scorch the ground, and burn up the plants which grow upon it. The same dire effects would follow, were the cool celestial regions not ready to receive the heat from the sun-warmed face of our earth and atmosphere. On the other hand, were there not sources of heat within or without, the temperature of the earth would speedily sink below zero, and the whole globe be as much ice-bound as the north or south poles. It is to be remembered that the temperature of the celestial regions is dependent, if not in whole, at least in part, on the temperature of the innumerable bodies which move in them. We are thus led to see that we are dependent for our continued existence, and our everyday comforts at home and abroad, on the disposition through millions of years of millions of bodies, removed from us millions of miles.

On the earth we are dependent for our very artificial fires, and for the mechanical power which can be generated by them, upon influences which have descended from heaven in ages long past. We are using coal formed of vegetables fostered in former geological eras by the sun's rays. Allusion is made to these and to some other beneficial effects of the solar rays in the following passage from Sir John Herschel's Treatise on Astronomy:—"By the vivifying action of the sun's rays, vegetables are enabled to draw support from inorganic matter, and become in their turn the support of animals and of man, and the sources of those *great deposits of dynamical efficiency* which are laid up for human use in our coal strata. By them the waters of the sea are made to circulate in vapours through the air, and irrigate the land, producing springs and rivers. By them are produced all disturbances of the chemical equilibrium of the elements of nature which, by a series of compositions and decompositions, give rise to new products, and originate a transfer of materials."

The far-reaching truth here enunciated has opened the way to experiments, calculations, and speculations, which all tend to shew how intimately connected every one part of the visible universe is with every other. "We must look, then, to the sun," says Professor W. Thomson, "as the source from which the mechanical energy of all the motions and heat of living creatures, and all the motion, heat, and life derived from fires and artificial flames, is supplied. The natural motions of air and water derive their energy partly, no doubt, from the sun's heat, but partly also from the earth's rotatory motion, and the relative motions and mutual forces between the earth, moon, and sun. If we except the heat derivable from the combustion of native sulphur and of meteoric iron, every kind of motion (heat and light included) that takes place naturally, or that can be called into existence through man's directing powers on this earth, derives its mechanical energy either from the sun's heat, or from motions and forces among bodies of the solar system."

Such results having been attained in regard to the source of the heat and mechanical energy called forth on the earth, the question is started, Whence does the sun get the heat and light which he sheds? There are insuperable scientific difficulties in the way of supposing that the sun is a heated body losing heat, or that the sun is a great fire emitting heat due to chemical action; and it has been surmised that "the sun's heat is probably due to friction in his atmosphere between his surface and a vortex of vapours, fed externally by the evaporation of small planets in a surrounding region of very high temperature, which they reach by gradual spiral paths, and falling inwards, in torrents of meteoric rain, form the luminous atmosphere of intense resistance to his surface."*

* See Professor W. Thomson's Paper in Trans. of Royal Society of Edin., 1854, and abstract of same in Edin. New Phil. Jour., January, 1855.

Fourthly, Indications of some other Universally Operative Agents. Possibly all those we have been considering and those we are now to contemplate, may be modifications of one and the same force: this is a favourite idea of not a few living men of the very highest scientific eminence, and it may be granted without affecting our argument. For if there be only one force, what a variety of adjustments must have been made in order to its producing such a number of results, so different from each other and so beneficent in their character! Our conclusion follows equally from the admission of a number of forces suited to each other, or one force with an infinite number of adjusted collocations. But at the present stage of science, we are not entitled to say that all the forces of nature are one; they present themselves to us as diverse, but all correlated, and capable of exciting each other. Meanwhile, we must look at them in the forms which they assume, and besides those which have been already before us, there are the magnetic and chemical powers.

It has been ascertained that there are periodical variations in the magnetic forces on the earth depending on the solar day and the time of the year, and pointing to the sun as the cause. It has also been discovered that there is a variation in the direction of the magnetic needle, going through all its changes exactly in each lunar day. "It would seem, therefore, that some of the curious phenomena of magnetism, which have hitherto been regarded as strictly terrestrial, are really due to solar and lunar as much as terrestrial magnetism.*" It has also been supposed that there is a connexion between the period of the recurrence of the sun's spots and

* President's (Mr. Hopkins) Address to British Association 1853.

the period of the variation of magnetism on the earth's surface. The maxima of the sun's spots occurred in 1828, 1837, and 1848, the minima in 1833 and 1843; and it has been shown that the cycle of the variations in the earth's magnetic intensity is also about ten years, and bears a relation to the other cycle. These discoveries open up curious glimpses of relations between things on the earth and things in the sky, such as men have not been inclined to believe in since science expelled astrology from human credence.

We know further, that in the sun's rays there is a chemical (actinic) as well as a luminiferous and calorific potency. These principles have each, in its own way, an influence on the germination and growth of the plant; and it is affirmed that all are in harmony with the seasons, and that each is strongest relatively at the time when most needed for the function which it has to discharge in fostering the vegetable. Actinism is needed in order to the healthful germination of seed; light is required to excite the plant to decompose carbonic acid; and caloric is necessary in order to develop and carry out the reproductive energies of the plant. "It is now," says Mr. Hunt, "an ascertained fact, that the solar beam, during spring, contains a large amount of actinic principle, so necessary at that season for the germination of seeds and the development of buds. In summer, there is a large proportion of the light-giving principle necessary to the formation of the wooden parts of plants. As autumn approaches, the calorific or heat-giving principles of the solar rays increase. This is necessary to harden the woody parts and prepare them for the approach of winter. It is thus that the proportions are changed with the seasons, and thus that vegetation is germinated, grown, and hardened by them. We have these statements on the authority of Mr. Hunt.* It is affirmed that every flower has its own peculiar power in reference to heat, and that different plants take the different temperatures needed in order to their health, by reason of their different colours, which also determine the relative amount of dew deposited on the leaves.

Fifthly, Traces of an all-pervading Ether. The existence of such a medium between the various cosmical bodies had long been suspected, and has now been established to the satisfaction of most scientific men. The resistance offered by it to the comet of Encke is the cause, it is believed, of the acceleration of the period of the revolution of that body, by causing it to fall nearer the sun. The acceleration is appreciable, being about two days in each revolution, which occupies about $3\frac{3}{10}$ years, and it has been observed during a number of revolutions. But we know too little of the nature of this ether to admit of its being turned to much use in such a treatise. It may be legitimately argued, however, that if light—according to the prevailing theory in the present day—consists in vibrations in an ether, we must call in an important class of adaptations, the absence or alteration of any one of which would disturb the economy of the universe. The three rays, the violet, the yellow, and the red, must each have ether waves of different lengths; and they must each make a different number of vibrations in a second, upon which circumstance the character of the coloured rays depends. The number of vibrations in the second is approximately as folows :—

Violet, 699 billions. Yellow, 535 billions. Red, 477 billions.

It needs no lengthened statement to show how liable

* Report on Chemical Action of Solar Radiations, British Association, 1850. We are by no means at the bottom of this subject. Farther investigation is evidently needed in order to put us in possession of the exact facts, and we are not yet within sight of the rationale of them.

such a complicated system is to go wrong, and how nice must be the continued adjustments so as to admit of our distinguishing stars and the colours of stars, so distant that light must require thousands of years to travel from them to us. For, on looking abroad on the face of the sky, we cannot be said to be looking on the stars as they now exist, but on these stars as they existed many years, it may be thousands of years ago. We have perfect confidence that there is no deception in all this, but in order to our trust being well founded, it is needful to suppose, if there be any truth in the prevailing scientific theory, that the ether has retained its laws and collocations through both immeasurable ages of time and regions of space.

Before closing this subject, we must refer to a most important class of facts, and speculations founded upon them, which have come into great prominence in the present day. The calculations of Lagrange and Laplace in regard to the stability of the solar system, (see p. 390,) proceeded on assumptions which later science has shewn not to be warranted. In particular, they pre-supposed that the planets moved *in vacuo*. But the prevalent opinion at this stage of advancing science is, that they move in an ether, the effect of which must be to lessen the velocity, and bring all the planetary bodies nearer and nearer the sun. The influence thus exercised in a brief period must be very small, but acting constantly, as it does, it must, in the course of ages, produce appreciable effects, and tend to break up the solar system.*

Other facts, not reconcilable with absolute stability

* The demonstration of the French mathematicians proceeded on the further assumption that the planets are solid throughout, and not fluid. But our earth, whatever may be the case with the other planets, has the largest portion of its surface covered with waters ever agitated by tides produced by the gravitation of the moon. Now, it is well known that when there is water in a boat, the motion of the boat is retarded by the agi-

have come into view. Sir J. Herschel says that the breaking up of the Milky Way affords proof that it cannot last for ever, and equally bears witness that its past duration cannot be admitted to be infinite.

Certain very important conclusions, tending in the same direction, have been established on following out the modern doctrine in regard to heat. Heat is now regarded as, if not identical with mechanical power, at least the means of producing it. As has been already stated, we are at present taking advantage of the mechanical energy excited on our earth, and laid up in store for us during the age of the coal formation. As this dynamical agency is being dissipated and wasted, we have here another disturbing element. The following are the conclusions drawn by Professor W. Thomson, who has deeply studied this subject:—"I. There is at present in the material world a universal tendency to the dissipations of mechanical energy. II. Any *restoration* of mechanical energy without more than equivalent dissipation is impossible in inanimate material processes, and is probably never affected by means of organized matter, either endowed with vegetable life, or subjected to the will of an animated creature. III. Within a finite period of time past, the earth must have been, and within a finite period of time to come, the earth must again be unfit for the habitation of man, as at present constituted, unless operations have been, or are to be, performed which are impossible under the laws to which the known operations going on at present in the material world are subject."*

All this does not in the least detract from the skill

tation of the water; and on the same principle (a scientific friend assures us) the tidal agitation of the waters on the surface of the earth exercises a disturbing influence on the movements of the earth in its orbit. Can any counteracting power be detected?

† Transactions of Royal Society of Edinburgh, 1852.

displayed in those wonderful adjustments and counterpoises which were brought to light by the analytic dexterity of the French mathematicians ; but it brings into view an overlooked set of agencies which must, in the course of ages, change the present system of things, provided always that they are not corrected by some well-adjusted counterbalancing arrangements. Professor Thompson says that there is not in nature any counteracting agency. Without dogmatizing on so difficult a subject, it may be confidently asserted that science at its present stage cannot point out any means of restoring the lost energy. Even though it could be restored by natural means beyond the ken of man, it must be in consequence of a wonderful adjustment planned by intelligence. In either case, we are made to feel the dependence of all physical nature upon a higher power either to keep things in their present stable condition, or, in the event of some great change, such as seems not obscurely pointed to in the Word of God, to render that change beneficent. Doubtless the world is stable, (for "the earth abideth forever,") but it is by means of forces, each of which would make it very unstable, and which are made to produce stability by counteracting each other, so that there is a truth in that part of the theogony of Hesiod which represents Eros, the healer of divisions, as the world-forming principle. All this balancing is fitted, we should say intended, to carry up our minds to Him who holds the balances in His hands. Our confidence in the permanence of things must be made to rest, after all, on the purposes of a God who has ordained all things from the beginning, and who, when He changes any existing state of things, changes them in the development of one and the same mighty plan.

We are now in circumstances to estimate the amount of truth in a statement of Paley, which has been quoted with approbation by others,—" My opinion of astronomy,' says he, " has all along been that it is not the best medium through which to prove the agency of an intelligent Creator; but that this being proved, it shews beyond all other sciences the magnificence of his operations."* Now, it may be admitted that astronomy does not display so many cases of special adjustment as the animal kingdom, so beautifully illustrated by Paley. The reasons are not difficult to find: First, we do not know so much of celestial bodies as of objects on the surface of the earth; we know little or nothing of the internal structure of the planets; we know absolutely nothing of the composition of the sun or stars; we do not know for certain whether any one of them is inhabited; and so we cannot expect to be able to unfold such adaptations among them as among the objects with which we are familiar. Then, secondly, and more especially, there is no necessity for such special adaptation in the case of inorganic bodies as is required for living bodies, and more particularly for animals requiring provision to be made not only for their existence, but for their comfort. It will be found as a general rule, that we discover the clearest examples of special adaptation where our knowledge is most extensive and minute, and that they are more abundant where we see they are most required, in the frames of organized existences, especially of animated beings capable of pleasure and pain, and the most abundant of all in the frame of man, the being who needs the greatest number and complication of organs to enable him to fufill his high destiny. But it is satisfactory to observe, that we are able to detect a number of striking examples of special adaptation among the celestial bodies in general, and the

* Paley's Natural Theology, chap. xxii.

planetary bodies in particular, and it is an instructive circumstance, that in consequence of the advance of knowledge, we are able to unfold a greater number than could be developed in the days of Paley. There is no just ground, then, for the scoffing remark of the haughty and eccentric Frenchman, (who denies that he is an atheist, seeing that he adores himself and has set up a formal worship of his system,) that the heavens cannot now be appealed to as a proof of the existence of Deity, or for the inference drawn by him, that the time will speedily arrive when organized objects will be in the same condition ; for while, for the reasons stated, animals and plants must ever furnish the most striking examples of design, it is still true that "THE HEAVENS DECLARE THE GLORY OF GOD, AND THE FIRMAMENT SHOWETH HIS HANDIWORK."

BOOK THIRD.

THE INTERPRETATION OF THE FACTS.

CHAPTER I.

THE ARGUMENT FROM COMBINED ORDER AND ADAPTATION.

We are now to estimate the force of the influence of two streams, which we have hitherto been contemplating as flowing in parallel channels.

The principle of Order has been scientifically expounded only in modern times, and in regard to the animal and vegetable kingdoms only within these few years. But it existed from the creation of the world, and had been noticed in a general way since the creation of intelligent being. Science in its latest advances is simply coming up to, and explaining, the spontaneous suggestions of human thought, which as it muses upon the universe is at once struck with the model forms and correspondences which everywhere prevail. The late discoveries in regard to homotypes, homologies, and we may add homœophytes, or parallel developments in animal and vegetable structures, is but the scientific exposition of what all along impressed intelligent observers, without their being able to give an account of it. Nor are these remarkable facts of an isolated or exceptionable character; on the contrary, they are merely striking examples of what is universal, and they have their homotypes, analogues, homologues, and parallels, in every department of nature.

The principle of Special Adaptation, or that of particular conformity to the position of the object and function of the organ, has also been noticed all along by minds addicted to reflection. Socrates is represented by Xenophon as delighting to dwell upon it. So strong, indeed, was this tendency in the ancient world, and in the middle ages, that Bacon felt himself called on to remove the inquiry from physical science, where it hindered the discovery of physical agents, to metaphysics, where it might have a legitimate scope. Bacon was right in saying, that the propensity to discover final cause had sometimes come in the way of the discovery of physical cause; but he is altogether wrong in affirming that it is barren of results in scientific inquiry, for in certain departments of natural science, such as physiology and comparative anatomy, it is a most powerful instrument of discovery, and such eminent men as Cuvier and Sir Charles Bell delight to inform us that they have proceeded on the principle of final cause in all their researches.

It is not difficult to discover the beauty and the appropriateness of both these principles.

On the one hand, the mind discerns the need and appreciates the propriety of the principle of Order. Without some such governing principle, nature would be incomprehensible by human intelligence, and this because of the very number and multiplicity of the objects of which it presents, each eager to catch our notice; and the mind in trying to apprehend them would have felt itself lost, as in a forest through which there is no pathway, or as in a vast storehouse, where the seeds of every species of plant on the earth's surface, are mixed in hopeless confusion. By what means is it that man is enabled to arrange into groups the objects by which he is surrounded, and thus acquire a scientific knowledge of them, and turn them to practical purposes? Plainly, by reason of the circumstance that there are numberless points of resemblance and correspondence between them. Scientific men have so long been familiar with this process that they are not impressed by it as they ought, and seldom do they inquire into the ground on which it proceeds. It is only when something new, such as the discovery of homologies in the animal kingdom, comes to light, that they are led to reflect on what has been too common to be specially noticed. But if they but seriously reflect on the subject, they will find that it is because of the universal prevalence of points of resemblance and correspondence that man is enabled to grasp the infinity of objects which fall under his view, into classes and subclasses, which can be comprehended by the intellect, and treasured up in the memory.

No doubt the mind has in itself a power of forming classes altogether independent of any special arrangement in order to aid it; but such groupings, though they may at times help the memory, are of no intellectual or scientific value. But there are means in nature of guiding the mind to the formation of classes which have a deep and far-reaching significance. It is true, in an important sense, that classes are already formed for us in nature. Man will find it expedient, in all cases, to attend to these arrangements made to his hand, and he must attend to them, provided he represent his classification as a natural one. It may illustrate our general subject to show what are the distinctive marks of natural classes, that is, of classes having the sanction of nature.

And first, we may take a classification which is not of this description. It is conceivable that a person might arrange all animated beings according to their size. He might put all animals of a certain height in one class, and all animals below that in another class. Every one sees how arbitrary, in short, how contrary to nature, such a distribution would be. It would often separate animals belonging to the very same species, while it would put in one confused group bird and fish, mammal and insect. And why, it may be asked, does the naturalist at once reject such a classification? Perhaps it is answered, because he is seeking a natural arrangement. But this answer, though correct so far as it goes, does not go down to the depths of the subject, for we immediately ask, Is not the distinction of size a natural one? He who would really sound the depths of this subject, and not skim over it, must be prepared to state what is the difference between an artificial and a natural classification.

All natural classes will be found to have not merely one, but an aggregate of common attributes. It follows that, when objects are classified according to a natural arrangement, the possession of any one characteristic is a mark of a great many others. Thus, when an animal is described as a reptile, we know that its blood is cold, that its heart consists of three cavities, and that its young are produced from eggs; and when we hear an animal called by the name of mammal, we know not only that it suckles its young, but that it breathes by lungs, that its blood is warm, and that its heart consists of four compartments. In short, when we have fixed on a truly natural arrangement, the presence of any one characteristic becomes a sign of others, commonly of very many others, at times of an inexhaustible number of others. The co-existence of these characteristics in one object, and their invariable co-existence in all objects possessing any one of them, is a clear evidence that such an arrangement has been purposely made. A class with such an aggregate of qualities as its ground, is said to be one of "Kinds." There are some valuable remarks on this subject in the Logic of Mr. J. S. Mill. "There are some classes, the things contained in which differ from other things only in certain particulars, which can be numbered, while others differ in more than can be numbered, more than even we need ever expect to know. Some classes have little or nothing in common to characterize them by, except precisely what is connoted by the name; white things, for example, are not distinguished by any common properties except whiteness, or if they are it is only by such as are in some way dependent upon or connected with whiteness. But a hundred generations have not exhausted the common properties of animals or of plants, or of sulphur, or of phosphorus; nor do we suppose them to be exhausted, but proceed to new observations and experiments, in the full confidence of discovering new properties, which were by no means implied in those we previously knew. It appears, therefore, that the properties on which we ground our classes sometimes exhaust all that the class has in common, or contain it all by some mode of implication; but in other instances, we make a selection of a few properties from among not only a greater number, but a number inexhaustible by us, and to which, as we know no bounds, they may, so far as we are concerned, be regarded as infinite."*

We now see wherein lies the essential distinction between an artificial and a natural class, and the superiority

* Mill's Logic, B. I. c. vii. 4

of the one to the other. In an artificial arrangement, we seize on a quality—not arbitrarily, it may be, but still for mere convenience' sake—and our arrangement does not yield us any farther information on the subject. In a natural classification, on the other hand, we fix on qualities which are invariably accompanied with certain other qualities, and which are, therefore, signs of them. All that an artificial class can do is to aid the memory, by having the innumerable objects put into a convenient number of groups. Even for this purpose a natural arrangement, if we can seize it, will be vastly more useful than an artificial one, as it will be found, in fact, that no artificial arrangement can embrace all the facts, and enable us to carry them about with us in convenient groups. But a natural classification does more than help the memory, it imparts positive knowledge, inasmuch as one property is a sign of the presence of a vast number of others. The most fundamental of all groups in Natural History, that of species, is always one of Kinds. It is formed on the principle that all the animals included in it might have proceeded from a common parentage; but all animals belonging to the same species are found to have a great many other points of resemblance besides their belonging to one stock. The same is true, to a greater or less extent, of all other natural groups, such as genera, orders, and kingdoms. In all such natural classes, the presence of some one attribute is a means of informing us of the presence of others. Thus, the power of speech is one of the characteristics of humanity; but there are many others, so many others, that physical and metaphysical science cannot be said to have fully exhausted them, and the presence of the power of speech is a sign of all these others. A traveller has lost himself in a deep forest, amidst wild birds and beasts, whose cries all raise within him feelings of alarm; suddenly he hears a human voice, and that sound at once announces that there is intelligence at hand, and probably also a compassionate heart, and the power and disposition to aid him. All the marks of a natural class are significent, in the same way, of an indefinite number of other attributes.

This invariable collocation of characteristic qualities in certain objects, so that the one is a sign of all the rest, is a clear proof that classes do exist in nature—that is, that objects are gathered into classes. This, we doubt not, was at least one of the truths which led to the mystic doctrine of Plato about Ideas or Types, above individual things and prior to individual things, and in mediæval times to the doctrine of Realism, according to which, universals or classes have an existence as well as individuals. There is a great truth at the basis of these theories, now exploded, but entertained in former ages by some of the deepest thinkers which our world has produced. This truth was not correctly seized, was very imperfectly, indeed, often very erroneously represented, but still it is deep in the constitution of things. All natural objects, and especially all organic objects, are fashioned according to type, and operate according to unchanging laws. The individuals all die, shewing how insignificant they are, whereas the genus and species survive. The flowers of last summer are all faded, but in the coming summer, other flowers will spring forth to continue the same form. Amidst the flux and reflux of all individual existences, the laws which they obey are permanent. In particular, classes, genera, and species, have as certain an existence in nature as the objects which are classified.

There is no new thing under the sun. The modern doctrine of organic correspondences is but the distinct articulation of what thinking minds have ever felt—but the scientific interpretation of the unconscious musings of deeper thinkers, as they have been gazing on the cryptic symbols of nature, ever since the time when inward reflection was awakened by outward objects. Nay, it is, after all, but the extension, into a new field, of the principles on which scientific classification has all along been resting. The facts on which the new doctrines are founded are the homotypes and homologues of the facts on which ordinary classification proceeds. The classification into genera and species proceeds on correspondences among a vast number of individuals. The doctrine of homotypes takes its rise from the correspondences in many parts of the same individual. Homologues are corresponding members in different individuals. We may add that homœophytes are corresponding stages in the development of different organic kingdoms.

So much, then, in regard to the fitness of the one principle—it enables mankind to make a practical and scientific use of the objects by which they are surrounded; and, as some one remarks, nature was made to be enjoyed by brutes, but to be contemplated by man. It is still more necessary that the other principle, that of Special Adaptation, be attended to ; for if the comprehensibility and beauty of the universe depend on the one, the very existence of the objects in it, and especially of animated beings, depends on the other.

And here it may be important to remark, that *the principle of special adaptation assumes two distinct forms.* So far as the efficient powers, the dynamical energies, the active properties of matter, are concerned, the adaptation consists in their adjustment so as to produce a general law, or it may be also an individual effect of a beneficent character. It is thus that the centripetal and centrifugal forces are adjusted to yield the harmonies of the planetary system; thus that the relation between the earth's orbit and the sun are arranged to yield the seasons of the year. In organic bodies, again, where the law is one of type or structure, we find the special adaptation taking a somewhat different form. We now meet not with an adjustment of forces to produce a law, but a modification of a general type, or a departure from it on one side or other, and this obviously to enable the part to execute its office. Under the first of these forms the adaptation is necessary in order to the very existence of general order; under the second, it bends the general order to the accomplishment of special ends.

It is in this second form that adaptation appears in the structure of animated beings. Not only the comfort of the animal, but its very continuance upon the earth, depends on every organ being made to serve its special function. And here it is satisfactory to find, that while attention is paid both to order and special end, the most uniform regard is had to the latter. There are cases, as we have seen, in which the general plan, if not sacrificed, is at least kept in abeyance, so that it is very difficult to detect it. It is of all pretensions the most absurd, in certain naturalists to profess to be able to see the general homologies, which are often very obscure, and yet regret that they can never discover special modifications to serve a given end, which are often so very clear. It is satisfactory to find that the wellbeing of the plant and the happiness of the animal are never sacrificed in following out the typical form. The general often gives way to the special, but the special never gives way to the general. It cannot be said of any animated being, that its individual comfort has been sacrificed in the attention paid to some general law or model shape. It is a circumstance worthy of being noted, that the typical form is most clearly exhibited in the lower animals, whose wants and functions are fewest; and that the principle of teleology is carried out to the farthest extent in animals higher in the scale, whose organism is the most complicated, and has the most numerous and varied functions to perform; and, farthest of all, in man, whose frame is so fearfully and wonderfully made to enable it to become the fit instrument of that spiritual nature to which it is united.

When we take an enlarged view of these two principles, we shall find that they are not inconsistent with each other, but rather that they depend on each other. There is an adaptation necessary in order to those regular successions of events and model forms which come so frequently before us. The regular flow or periodic recurrence of such phénomena as the tides, the seasons, is the result of arrangements many and varied. The forms assumed by plants and animals is evidently the contemplated issue of a multitude of forces made to combine to this end.* On the other hand, the general order, in some

* When the action of the combination of powers necessary to the development of an organ is interfered with, we have a *Monster*. In monstrosities the principle of order is not accommodated to the usual special end. They are always comparatively few in number—in short, the exception. But we are not to conclude that they are *failures*, or that they have no end to serve. A world in which they were the *rule* would certainly be a failure; but, as *exceptions*, they are as instructive as the rule. They help man to discover the nature of those agencies which combine to form typical organs, and they shew how derangements which, when few, work no evil, would have been fearful if they had been frequent. Teratology, which treats of natural monstrosities, has now a place among acknowledged sciences. Single monsters are produced by arrest of development; double by the union of homologous parts, as of veins to veins, and arteries to arteries. The aberrations of monstrosity do not exceed certain limits. They have their distinctive characters, and long ago there were noticed five orders, twenty-three families, and eighty-three genera. So far as these monstrosities do not produce pain, they are not evils any more than an irregularly-formed crystal is. So far as they are the means of entailing suffering and humiliation among mankind, they carry us into the profoundest of all mysteries (which we cannot here discuss)—the existence of evil.

cases, accomplishes very useful purposes; as when the mathematical law of the increment of the shell enables certain molluscs to ascend and descend the water at will; and when the spiral arrangement of the leaves and buds all round the axis exposes them equally to the light and to the air. In all cases the general order is adapted to the intellect of those who are expected to contemplate it.

Everything has, after all, a final cause. The general order pervading nature is just a final cause of a higher and more archetypal character. In the special principle, we have every organ suited to its function; in the more general principle, we find all the objects in nature suited to man, who has to study and to use them. Professor Owen has declared, that his practical assistant found himself greatly aided, in setting up the bones of the skull, by proceeding on the principle that they were constructed on the vertebrate type. Lecturers on anatomy find their students following them much more readily when they expound the skeleton on the archetypal idea. It is only by proceeding on some such method that the nomenclature of comparative anatomy can be retained by the memory. Without some such principle, there would require to be one set of names for the bones in man, another set for the bones in quadrupeds, and a third and a fourth set for the bones of birds and fishes. By the discovery of homologous parts running through all, it has been found possible to devise a common nomenclature, admitting of application to all vertebrate animals. But let it be observed, that it is not the unity of the nomenclature which gives the unity to nature, but it is the unity of nature which has given a unity to human science, and the nomenclature which science employs.

These correspondences are admirably fitted to make creation comprehensible by the human faculties. The more obvious points of resemblance enable man to recognise the nature and end of the objects by which he is surrounded. The more fixed points allow him to arrange them into classes in due subordination. The repetition of parts permit of his at once taking an intelligent glance along the whole length, and over the whole frame, of the animal and plant. The answerable parts permit of his discovering unity among organs that serve very diverse purposes. The members with similar functions invite him to observe a universal final cause. The parallel development points to a unity of arrangement in the forces by which all these correspondences are produced. The prophetic system of geology entitles him to look on the earliest past as a foreshadowing of the future, and on the present as the fulfilment of what has gone before.

Before the time of Geoffroy St. Hilaire, the undeveloped rudimentary organs were frequently thrown away as useless in the Museum of Comparative Anatomy in Paris. But it is rash, it is wrong to declare that any part of nature is useless. Geoffroy restored these organs, and thus led the way to grander generalizations of organic objects than had ever been formed before. We have now before us a sufficient final cause of typical forms. We may rise above a special adaptation of parts to an archetypal adaptation of the whole to the constitution of intellectual beings. We have here a most beautiful correspondence between the laws of external nature and the laws of the mind, between the laws of things and the laws of thought.* While the special modifications or adaptations investigated so carefully by Cuvier, are intended to promote the wellbeing of the particular species of animal, the archetypal plan investigated by Owen is fitted

* This is so interesting a topic, that we are to devote the next chapter to it.

to make the animal intelligible by the intelligent creation. Owen has developed—to some extent perhaps unconsciously, but to a far greater extent consciously—a teleology of a higher order than Cuvier.

Viewed in this light, the two principles, though evidently differing from each other in many respects, and requiring to be separately treated, come to be very much alike, may be seen to be analogous—that is, different organs fulfilling a similar function. The special adaptation proceeds on a general principle of beneficence, and the general principle is an example of adaptation to a special end. There is a general plan in the purpose, and a purpose in the general plan. The teleology is a homology, and the homology is an example of teleology.

There are some who prefer a somewhat different religious interpretation of the model forms of nature. Order and law, they say, are the natural methods of the Divine procedure, the ways in which God's nature and character spontaneously exhibit themselves. We need seek, they say, no other explanation than this of the typical forms in heaven and earth, they are just the manifestation of the divine ideas. And, as to man's recognition and appreciation of these laws and models, it is to be accounted for by the circumstance that he was made in his Maker's image. We are indisposed to advance a single word against this view; possibly it may be as true, as it is certainly striking and sublime. It is certainly a doctrine which cannot be disproven: we may venture to doubt whether it admits of absolute proof. Do we know so much of the Divine nature as, *a priori*, to be able to affirm with certainty, how that nature must manifest itself in creation? There may even be presumption implied in declaring, in some cases, that the harmonies of nature are after the taste or character of

God; for example, that complementary colours are more beautiful to His eye, as they are to ours, when seen in collocation, than non-complementary colours. But while we cannot predicate much, *a priori*, of the character of God, there is much that we can affirm, *a posteriori*, of the character of man, of his intellectual aptitudes and his tastes. We do know that correlations among objects are needful in order to his being able scientifically to arrange them, and practically to use them, and that he has tastes implanted within him, which are gratified by objects without him; for example, the ability to receive gratification from the complementary colours of animals and plants. We have here a firm ground to stand on, in reasoning from "what we know," and as there is a correspondence between man's constitution and the scenes in which he is placed, we cannot be wrong in inferring that God, by His nature and character, is led to accommodate the external world created by Him, to the intellectual nature of man, also created by Him. There is sense, then, and this a sense as grand as it is true, in which we are justified in representing these types as proceeding from the very ideas of God, from His eternal wisdom, impelled by His eternal love. Nay, we are inclined to think that as there are homologies among organic structures, so there may also be correspondences among spiritual natures, and that other intelligences, differing in many respects from man, may resemble him in this, that they also delight in these laws and patterns; while God, over all, may be conceived as rejoicing in all His works together.

As taking this view, we are not inclined to admit that the doctrine of final cause has been set aside, or shaken, or even damaged, by late discoveries in natural history. It is true that some of those engaged in making these discoveries did not see their consistency with teleology. Oken, as a pantheist, admitted, so far as we know, no final cause into his system. Geoffroy St. Hilaire reckoned it presumptuous in man to discover any end designed by the Creator. Cuvier was led to reject the doctrine of the unity of the vertebrate skeleton, partly by the practical turn of his mind, partly by the fear that it would interfere with the doctrine of final cause. Some, we suspect, have supported the doctrine of a physical uniformity of parts, because it seemed to deliver them from the necessity of calling in a personal God to account for the economy of nature; while not a few have regarded it with suspicion, because it seemed to be atheistic or pantheistic in its tendency. But amidst all these exhibitions of presumption and of fear, the doctrine of final cause stands as firm and as impregnable as ever, assailable by no known fact, consistent with every established truth.

Physiological research has, we admit, established a truth which cannot be reduced to final cause in the narrow sense of the term, but that truth is not inconsistent with final cause—it is an illustration of a higher form of final cause. We blame Cuvier because he would not attend to the evidence which his own discoveries supplied in favor of unity of composition. Not being of a speculative turn of mind, he would attend, he said, to nothing but facts, and content himself with classifying them. But we must also blame Geoffroy St. Hilaire, when, after condemning Cuvier for narrowing the field of science, he professed to be incapable of discovering final cause, and bids us remain "historians of what is."* Final cause is, to say the least of it, as certain as unity of composition. It is surely as certain that the eye was made to see, as

* Vie, Travaux et Doc. Scien. de Geoffroy St. Hilaire, par son Fils, p. 304.

that it is the homologue of the whisker of a cat.* We give little credit for sincerity to those who acknowledge that they have overwhelming evidence in favour of the former truth, but no convincing proof in behalf of the latter.

Again, there are metaphysicians who think that they have undermined the whole doctrine. We must reserve to a separate section the examination of any plausible considerations which they can urge. Meanwhile, let it be observed that their objections proceed on principles which would undermine all other objective truth, and leave us only a series of connected mental processes. The principles by which they would set final cause aside have not half the evidence in their favour which the doctrine of final cause has. We are sorry to find an accomplished and devout writer saying, "The argument from first or final cause will not bear the tests of modern metaphysical inquirers. The most highly educated minds are above them, the uneducated cannot be made to comprehend them."† The modern metaphysical speculators who have rejected final cause, have great need to review their own principles when they are opposed to a truth so obvious and so supported by scientific research. The argument from final cause is one which the uneducated universally feel, though they are incapable of explicating it logically, or illustrating it scientifically. The educated can feel that they are above it only in so far as they are elevated by the intoxicating fumes of German speculation, which would make man believe that he is a god, and that he creates from the stores of his own mind the final cause, which he simply discovers. Verily there are

* In the animal body the following parts are admitted to be all homologous;—Tactile Corpuscles, Pacinian bodies, Savian bodies, Muciparous ducts of fishes, Vibrissæ (whiskers) of cat and others, the eye, the ear.

† Jowett on Epistle to the Romans; Natural Religion, p. 410.

metaphysicians whose heads have been so dizzied with the turnings and windings of their own cogitations, that realities swim before them and they cannot distinguish between them and phantoms. Living forever in a region of pure, or rather very impure and cloudy speculation, they do not, as the physical investigator is ever doing, meet with stringent facts to restrain and control them; they have become utterly incapable of weighing ordinary evidence, probable and moral; they cannot see that the thoroughly established truths of inductive science are in the least degree more certain than the last spawned, *a priori*, theory of the universe; nay, some of them (such as Hegel) are prepared to deny the doctrine of gravitation itself, because it will not fall in with their theory. No wonder that final cause cannot stand the tests of such inquirers, for these tests need themselves to be tested.

As taking so enlarged a view of final cause, we have no objection to the general statement laid down by some eminent scientific men, that there are parts of the vegetable and animal frame which have no respect to the functions of the plant and animal. "There is yet another law," says De Candolle, "to be understood to enable us to judge properly respecting the nature of organs. In innumerable instances there appear forms similar to those which are connected with a definite function, but which do not fulfil that function, and nature, in these instances, as in the animal kingdom, seems to produce forms which are completely useless, merely for the sake of a harmonious and symmetrical structure. The appearance of filaments with empty anthers in flowers which are altogether female, and of female parts in flowers wholly male, the structure of filaments in other forms where they resemble nectaries, the false nectarothecæ in such orchidæ as have no nectaries, these are all formations which can only be explained by the law of nature we are now illustrating." Professor Owen uses similar language :—"I think it will be obvious that the principle of final adaptation fails to satisfy all the conditions of the problem. That every segment and almost every bone which is present in the human hand and arm should exist in the fin of the whale, solely because it is assumed they were required in such number and collocation for the movement of that undivided and inflexible paddle, squares as little with our idea of the simplest mode of effecting the purpose, as the reason which might be assigned for the greater number of bones in the cranium of the chick, viz., to allow the safe compression of the brain-case during the act of extrusion, squares with the requirements of that act."* And again, "The attempt to explain by the Cuvierian principles the facts of special homology on the hypothesis of the subservience of the parts so determined to similar ends in different animals—to say that the same or answerable bones occur in them because they have to perform similar functions—involves many difficulties, and is opposed by numerous phenomena. We may admit that the multiplied points of ossification in the skull of the human fœtus facilitate, and were designed to facilitate, childbirth ; yet something more than such a final pnrpose lies beneath the fact, that most of these osseous centres represent permanently distinct bones in the cold-blooded vertebrates. The cranium of the bird, which is composed in the adult of a single bone, is ossified from the same number of points as in the human embryo, without the possibility of a similar purpose being subserved thereby in the extrication of the chick from the fractured egg-shell. The composite structure is repeated in the minute

* On Limbs, p. 40.

and prematurely-born embryo of the marsupial quadrupeds. Moreover, in the bird and marsupial, as in the human subject, the different points of ossification have the same relative position and plan of arrrangement as in the skull of the young crocodile, in which, as in most other reptiles, and in most fishes, the bones, so commencing, maintain throughout life their primitive distinctness. These, and a hundred such facts, force upon the contemplative anatomist the inadequacy of the teleological hypothesis."*

It might be argued, if not with truth, at least with considerable plausibility, that some of these statements go farther than science warrants. It might be maintained that we are not entitled to affirm that an organ has no use, merely because we are not able to detect it. Science, as it advances, is ever shewing that organs which were at one time regarded as useless, have most important uses in the animal and vegetable economy. Who will venture to affirm that the bones of the skull of the young chick, have no reference, directly or indirectly, to animal instincts? or that the division in the parts of the fin of the whale do not the better enable the female to carry the cub under her arm when she is pursued by an enemy?† But, while we throw out this caution, we are inclined to admit that certainly in the vegetable, and probably in the animal kingdom, there are parts retained for the sake of symmetry which are not necessary to the mere function of the organ. In making such an admission, we are not, so far as we can judge, weakening the great principle of final cause, so long as we call in a higher final cause, and affirm that these part are fitted, in some cases, to give instruction to mankind, and, in other cases, to gratify their higher tastes.

* Homologies, p. 75.

† See Scoresby, Arctic Regions, vol. i p. 471.

In Civil Architecture there are four principles, it is said,* to be attended to:—1*st*, Convenience; 2*d*, Symmetry; 3*d*, Eurythma, or such a balance and disposition of parts as evidences design; and, 4*th*, Ornament. It is pleasant to notice that not one of these is wanting in the architecture of nature. The presence of any of them might be sufficient to prove design; the presence and concurrance of them all furnishes the most overwhelming evidence. Upon taking a combined view of the whole, we feel as if we have proof of much more than of the existence of law or a pinciple of order; we feel as if we have distinct traces of a personal God planning minute and specific ends. We do not know whether to admire most the all-pervading order which runs through the whole of nature, through all the parts of the plant and animal, and through the hundreds of thousands of different species of plants and animals, or the skillful accommodation of every part, and of every organ, in every species, to the purpose which it is meant to serve. The one leads us to discover the lofty wisdom which planned all things from the beginning, and the enlarged beneficence reaching over all without respect of persons; whereas the other impresses us more with the providential care and special beneficence which, in attending to the whole, has not overlooked any part, but has made provision for every individual member of the myriads of animated beings.

* See Lectures in connexion with opening of Great Exibition.

CHAPTER II.

CORRESPONDENCE BETWEEN THE LAWS OF THE MATERIAL WORLD AND THE FACULTIES OF THE HUMAN MIND.

SECT. I.—THE FANTASY, OR IMAGING POWER OF THE MIND.

It is Mind that is to be the special object of contemplation in this chapter;—not mind in its essence, of which we can know but little, but mind in its actual operations; mind looking out by the senses on the world without, and studying and admiring it; mind making the past to reappear, and imagine the absent as if present; mind analyzing the complex structure of nature into its elements, and discovering resemblances which group all nature into a few grand systems; mind rising from the effect to the remote and unseen cause, arguing from the known past to the unknown future, and discovering, by cogitation, new planets before the far-penetrating telescope had detected them: it is this mind which is to exhibit a few of its varied powers and movements to our view. Natural philosophy does not unfold laws of a wider sweep, chemistry does not disclose more curious combinations, nor natural history a more wonderful organization, than this ever active and living mind. There is a gradation from the inanimate, up through the plant and the animal, to mind, as the crowning object.

The motion of the planet in its elliptic orbit is no doubt beautiful to contemplate, but having enjoyed a higher existence, we would not choose to run, year after year, in that one unvarying orbit. If the choice were given us, we would rather be a plant than a planet—we would rather be a lily, expanding its petals in the sunshine—we would rather be the oak, shooting out and ramifying at will, and facing the buffetings of the storm. If the option were allowed us, there is a higher life that we would prefer. An eminent man, on seeing the sea-fowl career from the wave to the cliff, and sweeping from the cliff to the wave, expressed the momentary feeling, "Well, I should not dislike to be a sea-bird—I would have such a variety of life in water, in air, and on land." But having enjoyed by our Maker's beneficence, a still higher life, we would not descend to these lower states of existence. For this mind with which we are endowed, or rather, which constitutes our true self, can, in its thoughts, run a wider orbit than the planets, and wander into infinity; it can, in the midst of sunshine and of storm, grow on and on in knowledge and in love, and in all that is great and good throughout eternity; it can take in more than earth and sea and air and all the elements, and rise, by contemplation and purification, to gaze on infinite perfection embodied in the character of God. Surely this mind, with its laws and operation, is worthy of our careful study. We are to shew that, while it is vastly above them all, it is yet suited, by its structure and its organs, to all the objects by which it is surrounded, and which it is expected to contemplate and to use. When man appears on the earth, which had been so long in preparation for him, he comes with powers and aptitudes fitted to the scene in which he is placed. We have now before us a correspondence of a higher kind than any previously contemplated. It may be called the Archetypal correspondence connecting Homology with Teleology.

In illustrating this subject, we are to use mental faculties and laws, which, under one name or other, are treated, or at least referred to and incidentally sanctioned, in every system of mental science. There are, doubtless, differences of opinion as to the nomenclature best fitted to set forth these laws and powers; we are to avoid the difficulties arising from this source, by employing as little technical language as possible. Even those who regard our classification as not the best, and our analysis too refined or not sufficiently refined, will yet be prepared to acknowledge, that the powers of which we treat are in the mind of man, either as original or derived; and this is all that needs to be admitted in order to our being entitled to use them as we do in this chapter. We begin with the Imaging or Pictorial Power of the Mind.

The reader will be able to discover what is meant by this power, if he but observe, that whatever is recalled or imagined by the mind comes with an image more or less distinct. We call up, let me suppose, some incident of our childhood. We remember the day on which we were sent to school, and how we set out from our parents' roof with strangely mingled feelings of hope and apprehension. As we bring back these scenes, mark how everything appears with a pictorial power. We have a vivid picture, it may be, of the road along which we passed; we see, as it were, the school-house both externally and internally; we hear, as it were, the master addressing us, and the remarks which the children made upon us. Or more pleasant still, we remember a holiday trip undertaken by us, in the company of a pleasant companion or kind relative, to a scene interesting in itself, or made interesting by its historical associations; or, what we felt to be still more agreeable, the visit was paid to the house of a kind friend, who had a thousand contrivances to please and entertain us. How vivid the representation before us of the events of the journey, of the little incidents which befell us, of the amusements which were provided for us, and of the persons, the countenances, the voice and words of those who joined us in our mirth, or ministered to our gratification! We not only remember that there were such events, but we, as it were, perceive them before us; this imaging of them is, as it were, an essential element of our remembrance. Wordsworth is painting from the life when he speaks of

> "Those recollected hours that have the charm
> Of visionary things; those lovely forms
> And sweet sensations that throw back our life,
> And almost make remotest infancy
> A visible scene on which the sun is shining."

Or possibly there may be scenes which have imprinted themselves still more deeply upon our minds, which have, as it were, burned their image into our souls. Let us cast back our mind upon the time when death, as an unwelcome intruder, first entered our dwelling. We remember ourselves standing by the dying bed of a father or mother, or sister or brother, and then we recollect how a few days after we saw the lifeless body put into the coffin, and, within a brief period after, saw it borne away to the tomb. How terribly vivid and distinct do all these scenes stand before us at this instant! We, as it were, see that pallid countenance looking forth from the couch upon us; we, as it were, hear that voice becoming feebler and yet feebler; and then we feel as if we were looking at that fixed gaze which the countenance assumed after the spirit had fled; we follow the long funeral as it winds away to the place of the dead, and we hear the earth falling on the coffin as the dust is committed to its kindred dust.

And we would have it remarked, that not only are we able to represent these sensible scenes, we are farther able to picture the thoughts and feelings which passed through our minds as we mingled in them. Not only do we remember the road along which we travelled, and the building into which we entered, we can recall the feelings with which we set out from our parents' house, and those with which we walked into the school. Not only do we recollect the amusements which so interested us, but the feelings of interest with which we engaged in them. Not only can we picture the chamber in which a relative breathed his last, we can call up the mingled feelings of anxiety, of fear, and of hope with which we watched by his dying bed, and the emotions of grief which overwhelmed us as we endeavoured to realize the loss which we had suffered. We can set before us the feelings which passed through our minds as we sat by his corpse, or when we returned to our dwelling and found all so blank and melancholy. We are obliged to use metaphorical language in describing these recollections, but it is language which embodies and expresses important truth:—we speak of being able to image, to picture to ourselves not only the outward events which called forth the feelings, but the very feelings themselves.

This mental power we are disposed to call the Fantasy. It is a phrase used by Aristotle, and explained by Quintilian—"Quas φαντασίας Græci vocant nos sane visiones appellamus: per quas imagines rerum absentium ita representantur animo ut eas cernere oculis ac præsentes habere videamur." Lord Monboddo defines it, in his

Ancient Metaphysics, the power "by which the images of things presented to the mind by the senses are preserved." But this definition is too narrow for our purpose, for the mind can represent not only what has been presented by the senses, but all that has been before the consciousness, all that has been under the eye of reflection. We think it of moment to make this remark, because the grand object of higher education, and especially of religious discipline, is to lift the mind above material to the contemplation of spiritual images.

Every one sees how these mental pictures are fitted to enliven existence and increase enjoyment. They help us, too, by their vividness, to carry on trains of thought. Those nominalists are altogether mistaken who suppose that man reasons solely by means of words, or artificial signs of any description. We are far, indeed, from denying the utility of language as an instrument of thought. Language is a sort of stenography, by which we can abbreviate thought, and it helps us especially in those more recondite processes, in which our more refined abstractions or wider generalizations could be represented by no fantasy, or where images could mislead by their fulness of detail, or their vividness. But man thinks primarily by mental symbols, by pictures remembered or created by the image-forming capacity of the mind. So far from oral or written signs being primarily the object of thought, the first artificial signs are commonly outward pictures of the inward image. The earliest words and writings coined by man were hieroglyphic, and it was by degrees that they were refined into the highly analytic expressions furnished by our more advanced languages, such as those of ancient Greece, or those modern ones formed out of the debris of old tongues. But language, if used as the sole representative sign, has its defects as well as its excellences. The thoughts thus represented have, on account of their remoteness from reality, no interest to vast multitudes; these dried plants do not excite half the amount of emotion which collects around the natural ones with the life circulating in them. The most popular employers of words are those who use them to set before us vivid pictures. In the ages and nations in which dead symbols are most resorted to, and serve the highest purposes, we must still go to nature for our fresh and living symbols. Need we say that nature is ever presenting them to us in infinite number and variety, in the forms of the animal and plant, in the mountains and plains of the earth, in the clouds and stars of the sky.

It is, indeed, of vast moment to have the mind stored with a variety of noble images to enliven and elevate it, to act as Quintilian says, "incitamenta mentis." This end is much promoted by an early training among natural objects which are picturesque; by travelling at a later period of life into foreign countries, and by the opportunity thus afforded of holding communion with nature in her grander forms, and of inspecting the noblest products of the fine arts. But, while gathering these material pictures, let the young man and the old man not forget that there are others which he should not be losing, and which, if he part with, his gain will be more than counterbalanced by his loss. For there are images which it is still more important to have treasured up in his mind; they are the images of domestic peace, the images of home and friends, of the affectionate mother (we can never have more than one mother) and devoted wife, of kind sisters and smiling children, and to these let us add, by personal intercourse with them, or by elevated reading, the images of the great and good, of heroic men, who toiled and bled for noble ends, and of equally heroic women, who lost sight of themselves in works of disinterested love and sacrifice. These are in themselves vastly more exalted, and ten thousand times more exalting, than all your statues, draped and undraped, about which connoisseurs so talk and rave ; they are fitted to become incitements to all excellence, and he who has been at the pains to collect them and hang them round the chamber of his mind, is like one dwelling in a portrait gallery, from which the forms of ancestors are looking down upon him with a smile, and exhorting him to all that is great and good.

And there is one other object of which it is more important still that we have a noble image. The fundamental evil of images, as used in the worship of God, does not lie in their being pictures, but in their incapacity to act as pictures. "To whom will ye liken God? or what likeness will ye compare unto Him?" The stars in their purity are not suitable emblems of His holiness; nor the moon, shining in beauty, of His loveliness ; the sun in all his splendour has his beams paled in the dazzling brightness of His glory. There can be no corporeal image of God, who is a spirit. One grand aim of Revelation is to lift us above such gross representations, and to lead us to worship a spiritual God in "spirit and in truth." Man in his first estate, not his body but his soul, was a sort of image of Him ; but man in his fallen state is a caricature of Him. But we have one perfect image of God set before us in His Word, as in a glass, (2 Cor. iii. 18,) in Him who is the brightness of the Father's glory—only seen under a milder lustre—and the express image of His person. By such a mediate representation, aided by the types and figures which the Old Testament supplies, our minds may rise to a somewhat adequate idea of a spiritual God, even as, by the redemption purchased by that same Mediator, we hope at last to mount to the immediate presence of God. "No man hath seen God at any time ; the only-begotten Son, which is in the bosom of the Father, He hath declared Him." We shall return to this subject before we close the treatise.

But speaking of the connexion pre-established between the laws of mind and those of matter, it is most interesting to notice, that the most correct memory, in recalling an object, seldom reproduces it with all its individualities. In coming up before the mind as a picture, it appears with only the more prominent qualities, features, and colours—only with those which most vividly impressed the senses, or which were most noticed at the time. The consequence is, that the recollection appears very much as a type of the object. In representing, for example, some animal that we have seen, say a deer, we drop from our view not a few specialties of the individual, and form a sort of general picture, which might stand for any other deer. There may be cases indeed in which we were so deeply impressed with every part of the object, that we see it as it were before us, with all its peculiarities ; but in most instances we so far generalize or idealize it. That this should be the law of the reproduction of what we have experienced, we cannot but regard as, in a negative sense, a most merciful dispensation, as it saves the mind from the distraction which would be produced by numberless minutiæ ever floating before it. But there is another and more positive advantage arising from this tendency of the mind to generalize its representations—*the mental image of natural objects becomes a type of the species or genus.* After we have looked at a number of natural, especially organized objects, the recollection will be found, in fact, to be not far from the type constituted in nature as the model after which objects are formed. With this generalized representation in our minds, we are the better prepared at once to refer the individual before us to its genus or species, and at the same time to notice the specialties of the new individuals which may come before us. There are thus preparations made, in the very structure of the mind, for the contemplation and recognition of natural substances and beings. The very mind and memory supplies a series of typical models, and he who has his mind furnished with such images, is like one walking in a museum filled with specimens to illustrate the natural orders. The mind is disposed, on the one hand, to give to every object a typical form in its representations; and on the other hand, it finds, in its actual experience, that types run through nature. We might almost say, that there are types in nature and types in the mind corresponding to each other, as an object does to its image in a mirror.

SECT. II.—THE FACULTIES WHICH DISCOVER RELATIONS (CORRELATIVE.)

The soul is endowed with powers called sense-perception and self-consciousness, by which it is enabled to know the material objects presented to it through the senses, and also to know self in its shifting moods and states. These simple cognitive powers supply us with the raw elements of our knowledge. The mind has also a set of powers which enable it to retain and reproduce the past. To this class belong the memory, which retains and recalls the past in the form which it assumed when it was previously before the mind ; and the imagin ation, which brings up the past in new shapes and combinations. Both of these are reflective of objects ; but the one may be compared to the mirror which reflects whatever has been before it, in its proper form and colour ; the other may be likened to the kaleidoscope, which reflects what is before it in an infinite variety of new forms and dispositions. The knowledge thus acquired and reproduced, though furnishing the materials of all that follows, would, however, be very valueless unless there were a higher set of faculties to work upon it. But the mind has a class of powers which elaborate the materials thus acquired, by discovering relations among the objects which have become known to it. By these faculties, the materials, all but useless in themselves, are turned into an infinite variety of cognitions and judgments. Nor is there a greater difference between the wool when stript from the sheep, and the beautiful garment into which it is woven ; between the flax in its raw state, and the fine linen of exquisite pattern constructed from it ; between the stone when taken from the quarry, and the marble statue into which it is wrought—than there is between man's primary knowledge through the senses and the consciousness, and those lofty comparisons, and refined abstractions, and linked ratiocinations, which he is able to construct by his higher intellectual faculties. There must be a correspondence between our simplest knowing powers and the objects known ; but these other, as the scientific faculties, are the powers which fall more especially under our notice in tracing the correspondence between the laws of the external world and the laws of human intelligence.

The relations which the human mind is capable of discovering are very many and very varied ; Locke describes them as infinite—they are certainly innumerable. It is necessary, in consequence, to classify them. We are far from thinking that the arrangement which we are about to submit is perfect. It is possible that a better division might be made; but it is sufficient for our purpose that the powers of which we are to treat, by whatever name they may be called, and however they may be arranged, have actually a place in the mind. The mind is able and disposed to discover at least three distinct classes of relations:—First, that of Whole and Parts; secondly, that of Resemblance and Difference; thirdly, that of Cause and Effect. Every one who has ever seriously reflected on the operations of his own mind, will be prepared to acknowledge that it has the power and the inclination to notice these various relations. We could show that the faculties which discover them may be found, under one name or other, in almost every treatise on mental science written in modern times. By the first class of faculties we are able to separate the complex objects which fall under our notice into parts; by the second, we discover the varied points in respect of which the objects around us correspond; by the third, we can connect the present with the past and the future. By the first, we can, in some measure, penetrate into the composition of the objects by which we are surrounded; by the second, we see how objects are related to others existing at the same time—how plant, for example, is related to plant, and animal to animal; by the third, how the past has produced the present, and how the present will produce the future. By the first we have our abstract notions; by the second, our general notions; by the third, our notions of causal relations.

Before proceeding to illustrate them individually, we would have it observed regarding them generally, that *each has an aptitude and a tendency to seek and to find the relations which it is its function to discover.* We believe that there is a tendency in every faculty, with which man is endowed, to operate, and that there is a pleasure attached to the exercise of it. The eye having the power to see, delights to be employed in seeing, and light is pleasant to the eyes. There is a similar enjoyment felt in the action of all the mental powers. In particular, there is a tendency on the part of all the faculties under consideration, to exercise themselves, and an enjoyment in their exercise. We have not only a desire to know individual things as they present themselves, we have a propensity to discover relations subsisting between them. When any new object falls under our view, the question forthwith presents itself, How is it related to other objects known to us? On noticing any concrete or complex object, there is a strong intellectual tendency in our minds to analyze it, to take it to pieces. If it be a city or island that is brought under our notice, we immediately ask in what part of the world, in what country or ocean it is situated. If it be a new plant or animal that is submitted to us, we ask what is its genus or species. As strong as any of these, is that which we feel on witnessing a strange phenomenon, to ascertain its cause. Let us look at these faculties with the view of ascertaining how far they are fitted to enable us to comprehend the laws of nature.

I. The Faculty which discovers the relation of Whole and Parts; in other words, the Faculty of Abstraction and Analysis.

When we look abroad on this world, we find it, as a whole, presenting a very complicated appearance; it is a mighty maze, though not without a plan. When we inspect individual objects, we find them all more or less complex. Almost all the natural substances we meet with in the world are compound. Air, water, earth, and fire, which were regarded by the ancients as elements, have been shown to be composites. This piece of magnetized iron has a magnetic property, hence it will turn to the pole; it has a gravitating power, hence it falls to the ground if unsupported; it reflects certain rays of light, hence its colour; it has certain chemical properties, and hence it will chemically combine with one substance and not with another. What a vast number of powers of attraction, of chemical affinity, of electricity and vitality, are in action in every organism that falls under our eye!

As the objects which thus press themselves upon our observation are so complex, we see how needful it is to have a power of separating a part from a whole in mental contemplation. But this is a power possessed in a lower or a higher degree by every human being. On a complex whole being brought before the mind, it feels a pleasure in dividing it into its parts, and tracing the relation of the parts to the whole. It is to this principle, in part, that we must refer the tendency of children to take their toys to pieces; it is in order to discover all the parts, and how they are connected with one another. On seeing an ingenious machine, we have a strong inclination all our lives to have its parts taken asunder, that we may see how they co-operate. We feel it to be painful to stop in the midst of an important problem, or theorem, or discussion, or process; we are anxious to know how it may issue. We feel, indeed, as if our knowledge of objects must be very obscure till we have taken it down and resolved it into its elements, till we have logically divided it, or physically partitioned it. We feel as if we required to count over our wealth in order to estimate its value aright, to travel over our property, field by field, in order to know how much is comprised in it.

This mental power deserves to be noticed by us, because it furnishes an example of the adaptation of the mind to the objects by which it is surrounded, and which it is called to investigate. In consequence of the complication of nature, all science must begin with analysis. "But induction," says Bacon, "which will be useful in the invention and demonstration of arts and sciences, ought to divide nature by proper rejections and exclusions." "Analysis," says Whately, "is the form in which the first invention or discovery of any kind of system must originally have taken place." We have thus, on the one hand, the need of such an aptitude, and, on the other hand, the tendency working strongly and spontaneously. The retort in the laboratory of the chemist is not more obviously an instrument for decomposing the substances lying around, than the faculty under consideration is for decomposing the complex structure of the world in its parts, so as to bring them under scientific observation and experiment, and thus render their relation intelligible by the intelligent nature of man.

II. The Faculties which discover the Relations of Resemblance and Difference; in other words, the Comparative Faculties.

When a resemblance is discovered, it is between two or more objects in respect of certain attributes. This class of faculties may be subdivided according to the qualities in respect of which the agreement is noticed, whether they be those of Space, of Time, of Quality, or Active Property.

(1.) *The Faculty which discovers the Relations of Space, or, in other words, of Locality and Form.*—

There is a tendency in all minds, and a very strong tendency in some minds, to discover spatial relations. The commander of an exploring expedition sent to the Arctic regions, reports that he has seen a hitherto undiscovered portion of the ocean stretching away in a particular direction, and the question is immediately discussed, How does it stand related to the parts of the ocean previously known and described? A star-gazer reports a new planet detected by the telescope, and the eager question is put, What is its orbit, and what its relation to the orbit of the known planets? We at times experience a painful feeling because we cannot discover the connexion between two localities. We are carried over night, let us suppose, from a district of country which is known, to another which is entirely unknown to us. When morning dawns, and we go forth to survey the new region our first inquiry will be, How is it located in reference to the region which we left, and with which we are acquainted? We know that some persons have been positively distressed till they found out the relation of the two localities, that into which they have been carried, and that which they had left. The naturalist experiences a similar feeling of pain mingled with his joy, on discovering a new animal or plant which he cannot refer to its typical species or family. *There* is the plant before him, he sees its form and all its parts; and what more, we might be tempted to ask, could he wish to know of it? But the naturalist is not satisfied, he feels as if he wanted something, till such times as he has discovered its relation in respect of shape and structure to other natural objects, and has been able to allot to it its proper place in the classification of organic objects.

We have shewn, in the second book of this Treatise, that the most careful regard has been paid to the relations of space in the structure of the universe. The heavenly bodies have definite shapes and move in definite orbits. Most inorganic objects on the earth's surface assume, in certain circumstances, a regular mathematical form. Every organic object has a typical shape Every kind of bird builds its nest according to a plan of its own, and lays an egg of a peculiar size and shape. We have found it interesting to notice, that the horns which adorn the heads of certain animals have a sweep which differs in every family, and that every kind of tree has its own curve for its branch and leaf-vein, and the outline of its coma and leaf. Animals have been arranged according to type ever since the days of Aristotle, and the latest investigations have been disclosing new relations of form, which are scientifically named homotypes and homologues. Morphology is now acknowledged to be the fundamental department of botany, and opens the way to every other. Locality is the principle to be attended to by those who would study the geography of plants and animals. Relative position is the governing principle in the stratification of the earth and the bearing of mountain chains, as investigated in geology and physical geography. But we have now seen that the mind has a native aptitude to observe such relations as these. The two thus correspond, as a formed substance to its mould, as a portrait to its original. It is an eminent example of those striking adaptations between two things having no necessary connexion, which shew that both have been formed by an Intelligent Being, who fashioned the one to be contemplated by the other.

(2.) *The Faculty which discovers the Relations of Time.*—There is a natural inclination among all men to notice how events are connected in respect of time, and this becomes, in the case of many, a strong and vehement passion. On hearing an incident related, When did it happen ? is the question on every one's lips. On some historical event being disclosed by the casting up of a long-lost record, the inquiry is instantly made, In what age did it occur ? Hence, when Layard dug from the mounds in which they had long been concealed, the marble slabs which lined the palaces of ancient Nineveh, there was instantly awakened an intense desire to know the age at which these palaces were built, and the connexion of the historical events represented on them with the known events of Jewish and Egyptian history. The mind of the historical narrator feels in a state of painful anxiety till such time as his relation shall have been discovered. To aid this faculty, chronology has fixed on certain great leading events, and set them up as landmarks. Thus, in Sacred History, we fix on the Flood, on the call of Abraham, the Exodus from Egypt, the Reign of David, and the Babylonish Captivity, and distribute all other incidents in the intervening periods. To aid this same aptitude, we have artificial chronometers, which we set up in our dwellings, or carry about our persons.

Such circumstances as these prove that there is a strong intellectual tendency on the part of mankind, to observe the relations of time. But we have seen in previous portions of this Essay, that attention is evidently paid to Time in the economy of natural objects and the occurrence of natural events. The heavenly bodies have their definite times of rotation and revolution. Every organized object has a normal age allotted to it for its existence on earth. There is a periodical return of days, and months, and years, which admits of our systematically arranging our plans and anticipating the future. We measure the ages of the past by the movements of the heavenly bodies and the epochs of geology. Time is thus divided for us, by great physical events, into regular seasons, and all that we may number our days and apply our hearts unto wisdom. The connexion between the timepiece on earth and the motion of the sun in the heavens, is not more clear than is the relation between man's capacity and disposition to observe time, and the wonderful periodical arrangements which everywhere fall under our eye in nature.

(3.) *The Faculty which discovers the Relations of Quantity.*—These are equivalent to the relations of proportion mentioned by Locke, and those of proportion and degree mentioned by Brown; they are the relations of less and more. The faculty which discovers them proceeds upon the knowledge previously acquired by the mind of individual objects; and very frequently, also, upon the judgments pronounced by the other faculties of comparison. Upon discovering that objects resemble each other in respect of space, time, and property, we may proceed to notice how they have less or more of the common quality in respect of which they are related. There is an aptitude in all minds, and a very strong aptitude in certain minds, of a mathematical turn, to observe, to search for, and prosecute these relations. We feel as if our ideas of objects were very loose and inadequate, till we have made some sort of calculation as to their number. The mind delights to discover numerical repetitions, or proportions, or cycles among the objects falling under its notice; hence the propensity among all nations to trace significant numbers among natural phenomena, and to group historical events into periods of three, or four, or seven, or ten, or forty, or a hundred years. This talent, running waste, has wrought out the most fanciful and extravagant theories as to the power of numbers ; this talent, used as it ought, has constructed branches of mathematics, often long before they could be turned to much practical account.

But we have shewn, in earlier parts of this work, how much attention is paid throughout the whole of the physical universe to the relations of number. So far as we can go down to the elementary construction of matter, we find numerical proportions appearing, and, as we ascend upwards to compound and organic bodies, we still find a significance in numbers, and it is the ambition of physical science to reduce all its laws to a quantitative expression. The circumstance that arithmetical calculations and geometrical propositions admit of such an extensive application to it the laws and structure of the universe, is a clear proof that quantity is one of the principles which impart to its order and stability. It is pleasant to notice that He who hath given to quantity so important a place in the structure of His works, hath also allotted to the faculty which takes cognizance of it an equally high place in the constitution of man. There is not a more obvious correspondence between a weighing machine and the goods to be weighed out by it, between a measuring vessel and the articles to be measured by it, than there is between the mental capacity to discover the relations of quantity, and the significant numbers and proportions which everywhere occur in nature.

(4.) *The Faculty which discovers the Relations of Active Property.*—We cannot, as it appears to us, know either mind or matter, except as exercising properties. Mind exists "only as it energizes." In looking into the soul at any given time, we find it ever changing, ever busy. In all our apprehensions of matter, whether original or acquired, it is known as moving or as exercising some active quality in reference to us or to other objects.

Proceeding on this original knowledge, we are impelled by a native faculty to compare the various active operations of material substance, and are thus enabled to discover what its properties are, what is their nature, and their rule. As we detect the relations between the various actions, we refer one set of them to the law of gravitation, another set to the laws of chemical affinity, and a third set to the vital forces. Taking some one of these, say the law of chemical affinity, we proceed to farther distinctions and classifications, and we arrange substances into groups according to their more prominent properties. It is interesting to notice that we have now types and homologies of a deep meaning in chemistry as well as in natural history. The importance of the mental capacity under consideration is greatly magnified by the discovery, in our day, by Mr. Grove and others, that all the physical forces, light, heat, chemical action, electricity, galvanism, and magnetism, are correlated, and have mutual actions and re-actions.

As the result of the exercise of these faculties of comparison, we have—

Generalization.—The number of particulars presented to our notice in the world, if they cannot be described, with Plato, as infinite, may at least be said to be innumerable, and the mind would feel itself distracted were it obliged to carry them about with it; and so says Locke—"To shorten its way to knowledge, and make each perception more comprehensive, the mind binds them into bundles." In doing so, it notices how certain objects are alike in this respect, that they possess certain attributes in common;—they are of the same shape, or they are spread over the same time, or they are alike in respect of number, or they are of the same colour, or have some other property in common. The things thus resembling each other, thus correlated, are put into a group or class, which will include an indefinite number of other objects, indeed all others possessing the common attribute or attributes. "To be of a sort," says Dr. Thomas Reid, "implies having those attributes which characterize the sort, and are common to all the individuals which belong to it. There cannot, therefore, be a sort without general attributes, nor can there be any conception of a sort without a conception of those general attributes which distinguish it."

There is a strong disposition in all minds to notice the agreement of objects, and to give a unity to the many, by assorting them into groups; and in the case of some, and these usually the minds of noblest mould, it becomes a strong passion. "This impulse of the human mind to generalize," this "inductive propensity," as Sir John Herschel calls it, is a characteristic of the higher scientific intellects which often, indeed, carry it too far; still, as Bacon, who warns them against these excesses, remarks, "those who are sublime and discursive put together even the most subtle and general resemblances."

There is thus, on the one hand, a tendency in the human mind to observe relations, and especially resemblances, and by them to group objects into classes. But, on the other hand, the phenomena around us have many and comprehensive relations one towards another, affording befitting exercise to the intellectual faculty, and inviting it to dispose all individuals into systems, and connect all nature into series. Among all natural, but especially among all organic objects, there are groups or classes formed, altogether independent of a mind to observe them. There are species and genera, and orders and kingdoms—there are homotypes and homologues in nature, whether we take notice of them or no. In constructing natural science, we are not to create classes by an exercise of our own ingenuity ; classes are already formed, and we are to discover and not invent them. In every department of natural science, it is imperative on us to look to the natural grouping. An arrangement which does not proceed upon it, however ingeniously contrived, may be characterized as artificial, even when it is not denounced as arbitrary and capricious, and will seldom turn out to be of much scientific or practical value. But when the naturalist has been able to seize the dispositions made for him by nature, or rather by the God of nature, his classifications being natural, will also turn out to be available for the accomplishment of a great number and variety of ends. Every character in such an arrangement will be significant, that is, the sign of a great many other qualities with which it invariably co-exists ; and the arrangement will be found not only to be convenient, but instructive ; not only aiding the memory in retaining what we know, but disclosing other truths, and widening immeasurably the boundaries of our knowledge.

This account of the correspondence between the classifying aptitude of the mind and the classes in nature, is fitted to save us from both of two opposite extremes. It shews us, on the one hand, that the mind is not a mere mirror, reflecting the objects passing before it simply as they pass before it. The mind brings with it to the investigation high capacities, a power of separating the most complex objects into parts for more especial contemplation, of discovering resemblances among objects very dissimilar in most respects, and of devising hypotheses to account for the phenomena which present themselves, usually in the most scattered manner or in most singular combinations. The relations which unite the objects in nature are often of the most recondite character, and it requires the very sharpest subtlety to bring them forth to view, and the highest invention to propose the truth which is to solve the enigma. But, on the other hand, we are never to look on the mind, in the construction of science, as creating laws which are not in nature itself. Dr. Whewell everywhere speaks of the mind, in scientific inquiry, as "superinducing" upon the facts, "from its own ideas," something that is not in the facts. "The facts are known, but they are insulated and unconnected, till the discoverer supplies, from his own stores, a Principle of Connexion. The pearls are there, but they will not hang together till some one provides the string."* To us it appears that the true statement rather is, that the mind is so constituted as to be able—which is often very difficult—to discern all that is in the facts. The law is in the facts, whether we observe it or no, but it often requires much trained sagacity to detect it. True, the class cannot with propriety be said to be in the individual phenomena; it is the law of a large body of phenomena which have an aggregate of common qualities, each one of which is a sign of all the others. We have in nature not only the "pearls," but the "string," otherwise they would not hang together as they do; but the string is often of a very subtle nature, and only to be discovered by the most penetrating intellect. The account which we have given shews us, on the other hand, how vain all attempts must be to reach the secrets of nature by *a priori* cogitation. The mind, in its widest range, is a creature, not a creator; it is cognitive, and not creative. It has an eye fitted to see; but if that eye will go beyond its office, and produce what is not to be seen, that

* Whewell's Philosophy of the Inductive Sciences, vol. ii. p. 48. See also Aph. xi.

which is thus conjured up will be a phantom, an illusion, deceiving the eye which created it. True, it can devise, and ought to devise hypotheses, but it should only be to bring them to the test of facts. It has faculties which often enable it to make shrewd guesses and long-sighted anticipations, but these are to be regarded as chimerical, unless they are in conformity with realities. The beauty of the correspondence between the internal faculty and the external object lies in this, that the faculty can come to the knowledge of the object with its subtle qualities and its far-ranging relations.

Three great truths are now before us:—First, all things are conformable to a law of order: Secondly, man has mental principles and powers which enable him to trace and apprehend this order: Thirdly, he can discover the order only by a careful induction of facts. The laws exist in the things, otherwise man could not find them, he would simply feign them, and there would be no correspondence between his inward cogitations and the external world. Science is not the creation of human reason; it is simply the exposition of a rational system, which proceeds from the Divine Reason. Newton did not make nature rational, he found it rational; and his system was rational, because the expression of rational laws. But, on the other hand, there must be human reason discovering the traces of Divine Reason in nature. Nature, as nature, is unconscious of its rational character. Its phenomena are usually so involved, one with another, that it requires the very highest reason to unravel their threads, and follow each to its separate source. The scattered events assume a scientific form, not as they present themselves to the empirical observer, but when subjected to analysis and generalized by human intelligence. But the intellect, all the while, dare not, except at the peril of being hopelessly lost, set itself above observation; it can merely act upon what it observes, and its most comprehensive laws are inductions from experience.

Profound thinkers, in all ages, have observed some one or other of these truths, but have too frequently dissevered it from its connexion with the rest. There was a truth shadowed forth by the ancient Pythagorean doctrine of numbers, and the music of the spheres: God's works have a numerical order, and are formed, as was fabled of ancient Thebes, by the power of harmony, Plato bodied forth a great truth in his Eternal Ideas, which had been in or before the Divine mind from all eternity, and to which as patterns, all things in heaven and earth are conformed. Aristotle saw that there was not a little mysticism in these lofty speculations of his master, and so rejected some of his views, but retained the grand central truth, under the nomenclature of Forms, which are as necessary as matter to the construction of the universe. Plato is right when he speaks of Ideas being in the Divine mind prior to their exhibition in sensible objects. Plato is in the right, too, when he represented sensible objects, which are ephemeral, as being constituted after eternal models. Herein, too, Plato was farther right when he talked of these ideas being, in a sense, in human intelligence, and requiring only to be called forth. Herein, too, Aristotle was right and Plato was wrong, for these ideas are not to be awakened by inward cogitation, as the great master taught, but by the induction of particulars, as the equally illustrious pupil affirmed. Even in the scholastic ages, all artificial though the minds of scholars had become, by a too exclusively formal training, there was a profound truth retained by those who set forth the doctrine of genera, species and universals, as having an existence in nature prior to, and in a sense above the ephemeral existence of individual things; for while the individual lily and rose perish, the species abide, and are exhibited in new roses and lilies bursting forth every spring and summer. But these speculations were, after all, one-sided and imperfect, till Bacon supplied the complementary truth necessary to the perfection of the others, and, passing far beyond Aristotle, unfolded the very process by which man might certainly discover the laws, and, as he hoped, the "forms" of nature, which he represents as the final aim of all observation and all science. Herein, too, the physical inquirers who profess to follow Bacon are in the right when they declare that man must collect facts, in order to know the law of the facts. But the great German schoolman, Emanual Kant, is no less in the right when he recalled the modern mind to the subjective laws necessary to enable us to find the objective order. And herein, too, that great but presumptuous thinker erred in supposing that the subjective mind created the symphonies which it was created to discover and unfold; and these errors of his opened the way to the airy speculations which later German metaphysicians devised in order to turn the correspondence between the inward and the outward into an identity. In our own country, in the present age, there is an uneasy clashing between the German metaphysics on the one hand, and the empiricism of the French physicists on the other, and our thinking youth are ever swinging, like the pendulum, past the point of rest.

There is a *Mundus Sensibilis* and a *Mundus Intelligibilis*, and the relation in which they stand to each other seems to be as follows. To us there is first the Mundus Sensibilis, and this when human intelligence contemplates it, becomes the Mundus Intelligibilis. But when things are considered in themselves, the order, as Aristotle showed long ago, is reversed; to us there is first the particular, and then the general; in the order of things, however, there is first the general, and then the particular. There is first the Mundus Intelligibilis in the mind of the eternal Logos; this, in the fulness of time, becomes the Mundus Sensibilis, (in a sense the word becomes flesh,) which is once more reproduced as the Mundus Intelligibilis, in the mind of intelligent creation. We are reminded that in redemption there is a similar development. In the History of man there is first the earthly, and then the spiritual. But in the counsels of the Godhead there is first the Eternal Word; then the Eternal Word becoming Flesh; and finally, the Eternal Word reproducing himself in the sanctified humanity of the Redeemed.

III. The Faculty which discovers the Relation of Cause and Effect.

Every one will acknowledge that man has a capacity and tendency to observe this relation. On a new event being brought under the notice, the mind immediately inquires, What is its cause? A house is seen to be on fire, and the question on every one's lips is, How was it ignited! We hear of the death of a friend, and our natural impulse is to ask, What was the disease which cut him off? When it can not discover the cause of any important event, the mind feels pained and distressed. There are certain historical events, the producing circumstances of which have not been found out, and there is a renewed attempt to discover them in every succeeding age. There are physical phenomena the causes of which are unknown, and again and again do scientific inquirers return to the investigation, bent on unveiling the mystery.

There is a power exercised in the performance of the ordinary duties of life, and it is the faculty required above all others by the philosopher, and this whatever be his particular walk, whether in abstract speculation, in history, science, or the fine arts. The ordinary investigator is satisfied when he can find an answer to the question, *What is it?* When it can be answered that it is so and so, he is contented. But it is different with the philosopher. When this question is answered, he has another to put—*How is it so and so?* He is not satisfied with knowing the *What*, he must also know the *How*. An answer to the second of these inquiries can be furnished only by the faculty under consideration, which may be regarded as the loftiest, and most far-ranging of all our intellectual powers. It enables us from the effects now visible to go back to the causes of these effects, and the causes of these causes, into a distant past, and from the causes now in operation to anticipate the effects of these causes, and the effects of these effects, on to a distant future.

As this faculty has an important place in the constitution of the human mind, on the one hand, so it is found on the other hand, that all the events, both of the mental and material world, obey the law of cause and effect. Our mental anticipations or expectations are ever found to be realized ; they are realized in our familiar experience ; they are also realized in the most remote ages and worlds of which we can obtain any knowledge. As far as geology carries us back, it shews us effects of causes then, as still, in operation ; as far as the telescope carries us out into space, it shows light obeying the same laws as it does in our own mundane system.

In order to arrive at such a conclusion, it is not needful to determine very precisely the nature of the mental capacity which prompts us, on discovering an event, to look for its cause. All that is necessary for our argument is, that the talent and inclination be regarded as native, and this it shows itself to be by its universal operation, and its constant craving. The majority of thinkers deserving the name of philosophers, have regarded the mental prlnciple as not only an original capacity and disposition of the mind, but as a fundamental law of the intelligence, which insists not only that all effects known to us have in fact had a cause, but that *every given effect must have had a cause.* This view seems to us to be the correct representation. On the discovery of any particular effect the mind is led intuitively to look for a cause.* This is not a principle gathered from experience, it is rather the principle on which we proceed in gathering experience. Some may say that having invariably observed that every event has had a cause, we generalize our experience, and conclude that every effect has had a cause. But the inference would by no means be legitimate. Suppose our experience to be that we had seen a spark ignite gunpowder one hundred times, there would be a mighty gap between this and the conclusion that it must do so the one hundred and first time, and the one thousandth time, and so on for ever. A finite, though it be a uniform experience, cannot authorize us to rise to a universal and necessary truth. The experience of all civilized men for ages, that swans are white, did not entitle them to argue

* We put the axiom in this form, because we do not believe that causation rises up instinctively in the mind as an abstract or general notion, or that it is consciously before the mind as a general axiom or principle; it is in the mind simply as a law of its operation leading it, on an individual effect being presented, to seek a cause. (See Method of Divine Government, 4th edit. p. 508, and Appendix.) The objections current in England against original mental principles, apply merely to certain extravagant doctrines about innate, or *a priori* ideas.

that all swans are white, and must be white, and accordingly there was nothing inconsistent with previous experience in the discovery of black swans in Australia. All human experience shows that crows are black, yet there is no law of our mental nature leading us to believe that crows must be black in the planets Juno or Jupiter. But it is very different with the belief in causation, (as we have explained it above ;) there is something in our very intelligence which prevents us from believing, or so much as thinking, that anywhere, in any planet, or sun, or star, or nebulous matter, there can be an event without a cause. We have only carefully to notice the operations of this native principle, to find that there is a feeling of universality and necessity attached to all its exercises. And as the mind, on the one hand anticipates and expects that every effect must have a cause, so it finds on the other hand, in its experience, that all things in earth and heaven are in unision with the internal principles. The intuitive expectation has ever a correspondence in the external reality.

The account which we have given of the intuitive belief, shews us at once that the internal principle does not entitle us to proceed in the investigation of nature by *a priori* speculation. For while intuition impels us on the discovery of an effect to anticipate a cause, it does not reveal to us what that cause is. The actual cause must be detected by experience, and thus we are thrown back upon induction as the only means, after all, of penetrating the secrets of nature.

Such, then, is the account which we are disposed to give of the relation between the laws of our intellectual nature and the laws of the external world. The German metaphysicians have discovered this correspondence between the subject and object, as they express it, and they have often dwelt upon it, but they have given, as it appears to us, a mistaken representation of it. Some of them are accustomed to speak of it as an antithesis, an antithesis between subject and object, between matter and form, between ideas and experience. They are very fond of comparing it (I think very unhappily, as the two are very different) to the polar forces which are found to operate in the material world, and they call the one the positive and the other the negative pole. When thus stated, we have a dualistic view of nature. But a bolder set of thinkers, following out the same method, have found out a synthesis to reconcile this antithesis. Discovering a relation between the two poles, they have reduced the duality to a unity, and resolved all things up into one Absolute Existence. The general result of all this heterogeneous combination proceeding from a confusion of thought, is a hideous pantheism, in which the existence of God is affirmed, but His existence separate from the universe is denied. These speculators would account for the correspondence between the internal operation and the outward objects by supposing them to be correlated parts of one whole. Fichte represents the internal power as creating the external object, which, according to our view, it simply observes. Schelling conceives them to be necessarily parallel developments of one ethereal essence developing itself, whereas they appear to us to be parellelisms produced by Him who hath instituted both. Hegel resolved them into a unity of logical forms, whereas they are one simply by reason of the unity of the Divine Counsel. We must return to this subject, and devote a separate section to it. These views, under whatever form they may appear, and however imposing the nomenclature in which they are clothed, and however formidable the array of logical forms in which they may be set forth, are the wanderings of great minds, which will not condescend to proceed in the method of induction, and, having set out in the wrong way, and with principles not carefully inducted, are going the faster and the further wrong, the quicker and more vigorous their march.

There is, undoubtedly, a relation between the internal and external, between the subjective and objective, but it is not a relation of antithesis but correspondence ; and this correspondence is to be traced, not to any identity, not to any connexion in the order of things, not to any logical connexion, but to the adaptation of the one to the other by Him who hath created both, and, in creating both hath suited the one to the other. The mind, as the contemplator, is so constituted as to be able to attain a knowledge of the thing contemplated, and the thing contemplated is so formed as to suit itself to the intellectual nature of the being who has to contemplate it.

There is here a correspondence between two things, so far independent in themselves, which I can ascribe only to the unity of design on the part of Him who hath created both, and given to each its nature and its laws. and these in exquisite adaptation the one to the other. We can conceive a world without any such correspondence, a world in which the intellects of the inhabitants might have no capacity to discover relations among the objects falling under their notice, or in which relations among the objects might in no way correspond to their intellectual aptitudes. It is conceivable, on the one hand, that the relations might have existed in all their significance, but have remained unknown characters—like the mysterious writings on the rocks of some eastern countries, which no living man can read—in consequence of no one having the capacity to decipher them ; it is conceivable, on the other hand, there might have been the intellectual power and inclinations, and yet that such relations might not have been found in nature, or found only to show that they are of no significance. In the one case, there would have been an inscription without the means of deciphering it, in the other, a key with nothing to interpret by it. In the co-existence of the two, we have, on the one hand, a power of reading the symbols, and, on the other hand, a wondrous book spread out before us full of the highest instruction. The consequence to man is, that instead of being a stranger, a wanderer, and an outcast, as he must have been in a world in which there was no such correspondence, he feels himself to be so far at home in every domain of nature, with faculties fitted, if only he exercises them properly, to discover those laws which give its unity and connexion to the Cosmos, and help him, if he have faith, upward to the contemplation of Him who hath instituted them in an all-comprehensive wisdom. "This also cometh forth from the Lord of hosts, who is wonderful in counsel, and excellent in working."

SECT. III.—THE ASSOCIATION OF IDEAS.

Every one has an easy mode of satisfyiug himself that his thoughts do not succeed each other at random. Let him, by an act of reflective memory, go back upon the ideas which have passed through the mind in any given period: he may take the time when they seem the most desultory and unconnected, and he will find that the one has led on the other, like a string of birds floating through the air. Or let him, by self-consciousness, watch the train as it moves along, and he will find that every thought is related to that which precedes it, not by a material bond, like the carriages on a railway, but still by ties which can be discovered. A few minutes ago he may have been musing on home, and friends, and comforts, but now his thoughts are in a far distant land, wandering amidst extended swamps, and burning heat, and fearful malaria. At first sight it might seem as if there could be no possible relation between the two mental states : it might look as if the mind had leapt from the one region to the other without an intermediate step. But he has only to recall the whole train to discover that there has been a continuous transition from the one to the other. He was meditating on home and friends; but one of those friends has been called away from this world, he went to a distant land to earn an honourable independence, and there he fell a prey to an unwholesome climate produced by heat and damps. And suppose that he allow this last thought to run on in its natural course, he may find it carrying him up to the heavens, there to indulge in meteorological speculations, and these suggesting scientific principles, which bring him back to his own land and to his younger years, when he was first made acquainted with these principles, and to the very friends of his youth, and the home whence he started on his wide excursion. Throughout the whole of this circuit, every thought has been in some way related to that which has gone before, and to that which has come after.

We owe to Aristotle the first attempt to classify the relations according to which our mental states succeed each other. According to the usual interpretation of his language, he represents our thoughts as associated by similarity, by contrast, and by contiguity.* To discuss

* According to Sir William Hamilton, (see Note D** appended to his edition of Reid,) Aristotle first announces one universal law, and then three subordinate ones. The one universal law is: Thoughts which have at one time, recent or remote, stood to each other

the various theories which have been propounded since his days, would carry us into very irrelevant matter. Without entering upon any subtleties or disputed points, we take up the associations of thought in the two forms in which they present themselves most obviously to our view, that of Repetition and that of Correlation.

In Repetition, a thought is followed by the very same thought with which it was previously associated. Thus, on the first line of a song with which we are familiar being recited, the mind is apt to run through the whole. This is the simplest and lowest form of the associative power. It is apt to be strongest in children, who are able, in consequence, to repeat what they have heard or read more readily than persons farther advanced in life, and whose thoughts are disposed to obey a higher law of succession. For there is a higher form assumed by mental association, less or more, in all minds, but most of all in minds possessed of firmer intellectual grasp. *Things between which there has been a relation discovered may suggest each other.* No matter what the relation has been, whether one of those mentioned by Aristotle or any others, it ever afterwards combines the things correlated in our minds, and the one tends to bring up the other. This is law of Correlation.

We have already given what appears to us to be, upon the whole, the best classification of the relations which the human mind can discover. It can discover, we have said, the relation of comprehension—that is, of the whole to its parts, and of the parts to the whole. Now, whenever such a relation has been noticed, the part will sug-

in the relation of co-existence or immediate consecution, do, when severally reproduced, tend to reproduce each other. This is explained by Hamilton as meaning: The parts of any total thought, when subsequently called into consciousness, are apt to suggest immediately the parts to which they are proximately related, and mediately the whole of which they were co-constituents.

gest the whole, and the whole the part; the substance will suggest the quality, and the quality the substance; the book will suggest certain of its contents, and certain of its contents will suggest the book; the sentence will suggest its words, and its words the sentence; a building will suggest some of the things contained in it, such as its doors and windows, while the doors and windows will call up the house. Again, the mind has the power of discovering resemblances among objects; and when a similarity, whether in respect of form, time, number, or property, has been detected between two things, the one will bring up the other. If a resemblance has been discovered between certain plants, or certain animals, or certain seasons, or certain substances, henceforth the presentation of the one may lead on to the thought of the others. The mind has also the power of discovering the relation of causality, and it is well known that the cause suggests the effect, and the effect the cause; a wound suggests the instrument that inflicted it, and a warlike instrument is apt to be associated with its murderous effects; and so the Quaker poet sings—

"I hate the drum's discordant sound
Parading round, and round, and round,
To me it talks of ravaged plains,
And burning towns, and ruin'd swains,
And mangled limbs, and dying groans,
And widows' tears, and orphans' moans,
And all that misery's hand bestows
To fill the catalogue of human woes."

If there is any truth in these remarks, we may notice the following interesting relationships:—

1. The intellectual powers are ever furnishing bonds of association to our ideas. The mind is for ever actively employed in discovering relations among objects pre-

sented to it by the senses, or by the memory. It is ever engaged in analyzing and compounding; in discovering analogies more or less obvious; in tracing up the effect to its cause, or following the cause onwards to its distant consequences. The activity of thought in these operations far exceeds the velocity of the most subtle material agents such as light and electricity. The number of relations discovered by the mind in a single day, or a single hour, or even, at times, in a single minute, far exceeds human calculation. It would require hours, on the part of the reflective philosopher, to spread out and analyze the judgments of as few moments of spontaneous thought. But every correlation discovered among objects may become the ground of their association by the mind at any future time.

2. The laws of association are adapted to the intellectual powers, and are the means of aiding them, and, in particular, of supplying them with illustrations, and enabling them to follow out their investigations. Whenever a relation has been discovered, it henceforth becomes a means of associating in our thoughts the objects related. The analysis brings up the synthesis, and the synthesis reproduces the analysis. The individual now calls up the species or the genus, and the species or the genus calls up the individual as an exemplification of it. The cause suggests the effect, and the effect the cause. The laws of suggestion thus carry out spontaneously the processes which, in the first instance, have required the more laborious exercises of the understanding. Our intellectual conquests are thus kept from being lost. Every discovered relation is made to re-appear with new confirmations, without limit and without end.

3. The links which bind our thoughts may be made so far to depend on our intellectual habits. We say "so

far," because associations may also be formed by casual circumstances or impulses, or may depend on the state of the bodily organism, or other things which cannot be directly regulated by the understanding. Still the associations formed, must so far depend on the intellect; man is not so helpless as he sometimes imagines that he is in the current of his thoughts. If the mind delight to discover high and important relations, then the ideas will be found to suggest each other agreeably to these noble relations. If, on the other hand, the mind is fond of tracing trifling relations, relations of mere accident, or mere verbal relations—as in certain kinds of wit—the links which combine the thoughts will also be of a trivial character and tendency. It is found here, as in many other cases, that as men sow, so must they also reap.

4. A provision is made for enabling the disciplined mind to conduct ultroneously its scientific pursuits. Natural objects, we have shewn, are related according to relations of class and cause. The mind, as we have also seen, is furnished with talents specially fitted to enable it to discover these relations. And now, we have seen that objects, between which a relation has been discerned, will be brought up in their correlation again and again. Provided persons have only made the analyses required in chemistry, or traced the classes in natural history, or the causes determined by natural philosophy, they will fall in every day with illustrations and confirmations. Nay, in thoroughly trained minds, the suggestive faculty at times strikes flashes of light which illuminate the darkest subject, and disclose the way to new and brilliant discoveries.

Besides these Primary Laws of Association, there are Secondary Laws (as they have been called by Brown) detemining which of the primary laws should operate at any given time. We have not anywhere a complete enumeration of these secondary laws. In the few remarks which we have to offer, we are to limit ourselves to the two which stand out most prominently.

First, Those objects are recalled most readily and frequently to which we have attended, or to which we have attached an act of the will of any description. How speedily, for example, does the striking of the hours of the clock vanish from our memory when there has been no particular circumstance to call our attention to it! On the other hand, when we have deliberately revolved any particular topic in our minds, it will more readily come up before us at all future times. The will has an antiseptic power, and keeps whatever has been embalmed by it from being destroyed.

Secondly, Our minds will often be directed towards an object when our feelings are interested in it. There is a locality, for example, which has been much before the minds of multitudes during the past year or two. Some of us had scarcely ever heard of it before; it possesses in itself no great interest; it consists of rocky and barren heights sweeping down to an indented shore. Yet how often have our thoughts been turned of late to that place! With what eagerness did fathers and mothers, sisters and children, lover and friend, look for tidings of beloved ones toiling and fighting on these cold and bristling eminences! There are thousands upon thousands who can never forget that spot, many to whose view it will rise up every day of their future lives, and some to whom it will henceforth appear every waking hour of their existence on earth—for there it was that a son, or brother, or husband was smitten, as amidst flying balls and bursting shells, he rushed to fight the enemies of his country. There are children, whose first lessons in geography, learned from a mother's lips, will be about these wild heights, and the blasting storms which raged around them—for there it was that the father breathed his last. And why do men's minds wander so often to these scenes ? it is because their feelings have become interested in them, and emotion has the power of preserving, as in amber, whatever has been imbedded in it.

Now, let us mark how these two laws aid sciencific men in their pursuits. The attention which they have given to the subjects which engross them; their fixed determinations regarding them; the efforts which they have made to master the difficulties; their very disappointments and failures—all these tend to bring the objects more constantly before them, that they may fully exhibit themselves, and reveal all their truth. Then, their original tastes, and their acquired habits, the result of association, cause them to warm as they advance, and now their hearts are as much interested as their heads in their pursuits. The botanist comes to love the plants, the zoologist the animals, and the astronomer the stars, which he has often and anxiously watched, and scientific men generally feel, when engaged with their favourite pursuits, as if they were surrounded by friends and companions. But as, when we truly love our friends, we find ourselves frequently thinking of them, so, those who are engaged in the study of nature dwell habitually among their cherished objects, and the images of them start up everywhere to delight and instruct, to furnish new examples of old laws, and suggest new laws not previously discovered.

SECT. IV.—THE ÆSTHETIC SENTIMENTS.

It may be safely affirmed that no one has been able to give a complete account of the nature of Beauty. Pleasant are the glimpses which not a few have had, but to no one has she fully revealed her charms. We have many valuable contributions towards a correct theory, but we are yet without a thorough analysis or a full exposition. We are to attempt no systematic discussion of a subject so interesting from the nature of the objects at which it looks, and yet shewing itself to be so subtle and retiring when we would advance towards it. It is very obvious that, in the judicious treatment of the subject, there should be a distinction drawn between the object which calls forth the feeling and the feeling called forth. We are to content ourselves with shewing that there is a correspondence between the two, and the component parts of each. Here, as in every other province of God's works, we find the confluence of a number of streams; only, in the case of beauty, they are so blended that it is impossible to trace each to its source.

I. Vigorous efforts are being made, in the present day, to find out in what physical beauty consists. These attempts have so far been successful. It has been demonstrated that there are certain distributions of colours which are more agreeable than others. Certain colours, if placed alongside of each other in the decoration of a house, or a piece of dress, are felt to produce a pleasant impression. But we have shewn that these juxtapositions of colours are frequently met with in the plant, in the plumage of birds, and in the sky. There is here a correspondence between the external world on the one hand, and our organization bodily, and probably mental also, on the other.

Endeavours are also being made to find out the law of harmonious forms. Not having fully examined the subject, we are not prepared to say how far they have been successful. But we are persuaded that such inquirers as Dr. M'Vicar and Mr. Hay are on the proper route, and that, sooner or later, there will be detected certain laws of beauty in form, capable of mathematical expression. But it is to be carefully noticed, that even when scientific research shall have established all this, it has not fully explained the phenomena of beauty. For the mental sentiment, of which we are conscious, corresponding to the physical object which excites it, is as wonderful as the object which calls it forth ; indeed, the most remarkable feature of the whole phenomenon is the adaptation of the one to the other.

II. We are not to speak confidently on so intricate a subject, but it appears to us that there is a feeling of beauty resulting from certain exercises of the intelligence, (we are sure that there is a feeling of beauty awakened by certain moral ideas.) This emotion issues when the mind, in contemplating objects, discovers spontaneously, without will and without effort, a number of seemingly intended relations of one thing to another. There has been a striving after the expression of this truth by deep thinkers in different ages. According to Augustine, beauty consists in order and design ; according to Hutcheson, in unity with variety ; according to Diderot, in relations. Glimpses of the same doctrine appear and disappear in the writings of Cousin, M'Vicar, and Ruskin.* There is a sort of beauty in a large combination of independent means to accomplish one end, and in the co-agency of numberless causes to work one effect,—

* Cousin on the True, the Beautiful, the Good; M'Vicar on the Beautiful, &c., (1837;) Ruskin's Modern Painters, vol. ii. sect. i. chaps. v. v'.

provided always that the end be not malevolent, or the effect trivial. There is a beauty in certain well-arranged forms, perhaps also in certain recurrences and proportions. It is said that there is a beauty in certain regular rectilinear figures, such as the triangle, the parallelogram and square, and it has been shown that these regulate not a few forms of beauty. This seems to us, however, to be only a partial expression of the truth; we think that it needs a complementary truth to be added. The feeling of beauty is called forth only when, along with an observable regularity of figure, there is something to indicate that there has been more than mechanism at work. If the form be too evidently regular, there is little or no emotion excited. On the other hand, if the figure be irregular throughout, there is no feeling of beauty. But if there be a regular figure, such as a triangle, at the basis of the whole, with curvilinear departures to set it off, or if there be rhomboids set in spirals, as on the surface of cones, then the æsthetic sentiment is called forth.

This general view is illustrated and confirmed by the pleasure which is felt in rhyme and in verse of every description, indeed, in all forms of poetry, ancient or modern, eastern or western. All kinds of poetry agree in presenting repetitions, parallelisms, balancings, correspondences of some description. The mind is excited, and its admiration is called forth, when it finds the varied thoughts and feelings grouped under correlations of sound or sentiment, which exercise the intellect, and aid the natural flow of association, which proceeds, we have shewn, according to correlation. There is a similar pleasure excited by the tropes, figures, apposite allusions, comparisons, metaphors. contrasts, which are ever addressing themselves to us in more adorned prose, such as that of Plato, of Jeremy Taylor, and of Edmund Burke.

But the correlations of poetry are limited in range compared with those which meet us everywhere in the kingdoms of nature. In all organic bodies there is, along with more or less variety, a symmetry or likeness of side to side, and also a repetition of similar parts; and in higher organisms, there are more complex and recondite correspondences.

In plants, there are regular lines and definite angles in the framework, but meanwhile the bounding lines are always curves, all the more beautiful that they are not the more regular curves, but curves of great freedom of sweep. We have found it interesting to notice, that in the leaves of many plants there is a series of visible triangles. These triangles are formed in the upper part of the leaf by the midrib, by the lateral vein, and by a line drawn from the apex of the leaf to the top of the midrib. It has been affirmed that there is a peculiar significancy in the right-angled triangle; it exhibits most observably a unity with variety; and we have noticed that in many plants the angles formed by the lateral veins in the upper part of the leaf, and a line drawn from their apex to the apex of the leaf, is a right angle. There is a series of similar triangles in the upper part of the coma of many trees. Yet every vein and branch, and the outline of every leaf, and of the coma of every tree, is not a straight line, but a curve with a graceful sweep, that is, a sweep which still maintains an observable regularity. The triangle would be stiff and formal without the curve, and the curve would be eccentric without the triangle; the beauty arises from the union of the two.

There is beauty in the spiral arrangement of the appendages of the plant, and in the crossing of the spiral lines on the surface of the stem, and of many fruits. Of the more regular curves, the spiral combines in itself most evidently the two principles of unity with variety, that is, the greatest number of visible correlations; and it is interesting to notice, that this figure is perhaps the most universally prevalent regular figure in nature, being seen in shell-fish, in plants, and in the starry heavens. There is a visible beauty, too, in the regular flower-cup, with the petals all alike, surrounding and guarding a common centre, and each with curvilinear outline. There is no less beauty in the irregular flower, with one of its petals standing out from the rest, but this not by chance or by oversight, for in order to enable it to counterbalance the others, it has, we have shewn, a richer colouring.

In the animal frame the relations are more numerous, but at the same time, as becomes the higher subject, more manifold, and not so easily noticed. Whatever disadvantage might arise, from the latter source, to minds of limited intelligence, is counterpoised by the Life which distinguishes the animal from the plant. The plant being soulless, must have a meaning given to it by its regular shape and regular divergences. The soul of the animal, on the other hand, is sufficient to impart to it a concentration of purpose, with a never-ceasing activity and change.

Still there is a beauty in the forms of the animal. Mr. Hay thinks he has found triangles regulating the framework of the human body. But it should be carefully noted that no such angular figures strike the eye in the rounded body of man or woman. There are indeed ratios and proportions carefully attended to in the construction of the human frame, and perceived unconsciously by the mind, and these doubtless give the unity to the body. But these would not kindle a feeling of beauty, (they excite no such feeling in the skeleton or in Mr. Hay's plates,) unless they were relieved by rounded forms and flowing curves. The feeling of beauty is raised neither by the one nor the other, but by the happy marriage-union of the stronger with the more flexible.

It will not be understood from this statement that we look upon the perception of beauty as an intellectual exercise; what we mean is, that the intellectual exercise may lead on to it. That there is need of some intellectual perception in order to the sense of beauty, is evident from the circumstance that nations and persons low in the scale of intelligence have little sense of beauty, and what little they have is awakened by the simplest forms of beauty. The sense of beauty is a sentiment, and not an act of the understanding, but it is the reward which God gives to the intelligence when contemplating the noblest of His works. Not even that it issues simply from the intellectual act, it proceeds from the intelligence contemplating those designed relations which appear in the objects.

If there be any truth in these views, they lend an emphasis and significance to much that we have been establishing throughout this volume. The sense of beauty in the case of a vast number of organic objects is called forth by the very union of typical form and intended modifications; by the special end being in conformity with a general plan. Every one of the correspondences we have been tracing in the plant and animal may, when taken along with the designed departures, be the means of exciting admiration and a sense of beauty. Those who experienced the feeling, may not be able to lay bare the principle on which it proceeds, but nevertheless they perceived the plan and the end, and the emotion sprang up spontaneously.

And here it is instructive to notice how the class of æsthetic emotions are meant to lead on our minds from creation to the Creator. For it is only when there is such a correspondence among objects as might be designed that the emotions are awakened. The whole exercise of mind is thus fitted, and we believe intended, to draw us on to the perception of design. It is too true that the thoughts of many are arrested when they would run in this direction. The æsthetic emotions are cherished and cultivated by many who spurn away every sentiment of godliness. Alas, it is because a deeply seated ungodliness is staying the proper outflowing of the soul! But were it not that men "restrain prayer," every perception of the beauty of natural objects would express itself in a hymn of praise to the Maker of them all. The feeling excited by the beautiful is the fire which should kindle the sacrifice into a flame rising to heaven.

III. The theory of Alison, followed out and illustrated by the late Lord Jeffrey, which refers all beauty to association of ideas, was never favourably received by artists, and is now abandoned by all metaphysicians. But while the doctrine of association cannot explain every phenomenon connected with the perception of beauty, there is much that it can account for, and which can be accounted for in no other way. When living in a rural district, we hear on the Sabbath the sound of a bell rising in the midst of the stillness, and we say how beautiful; but we feel in this way not so much because of any pleasure which the sound may give to the bodily organism, (for the sound may rather be grating in itself,) but because it is associated with the idea of Sabbath peace, and the blessing which the Sabbath diffuses. The association of ideas alone can explain such a phenomenon as this, a sound or sight rendered pleasant by reason of the delightful feelings which cluster around it. There is a still more important part of the complex state of mind which can be accounted for in no other way; we allude to the prolonging of the pleasure, and the variety of the pleasure communicated by the image upon image, the feeling upon feeling, all agreeable and exciting, raised by certain objects, such as a cheerful countenance, a plain covered with grain, and a river rolling along amid fertile banks. It is in the union of the two, the original feeling of beauty, and the association with it of other pleasant feelings, that we are to find the full explanation of the phenomenon. By the one we account for what is fixed in æsthetics, for the uniformity of men's judgments in matter of taste; by the other, that is, by the difference of the associated feelings, we can account for what is variable, for what differs, in the case of different individuals. And we do not know whether to admire most that constitution of our nature, by which there are certain points of agreement in all men's tastes, which renders it possible for them to sympathize with each other, and by which a science of æsthetics is rendered possible, or that variety of tastes which gives to every man his individuality, which secures that all do not run after the same object, and that there is scarcely an object which may not be made attractive to certain minds.

But then, this very association of ideas in its special connexion with the beautiful, requires itself to be accounted for. The views which we have propounded may aid us in doing so. The feeling of beauty is awakened by means of discovered correlations, and each of these ramifies into collateral topics. Then all the correlations point to Design, and Design is a mental quality alluring on the mind to a thousand pleasant topics. Hence the retinue of thoughts ready to rise up, and prolonging the feeling as by answering echoes, and calling in images to aid it from every object in nature or in art, which may have fallen under the notice.

IV. We may notice some other and allied feelings, so far as they are awakened by objects in nature. Some maintain that there are plants and animals which may be described as ludicrous. If there be, it is because they are addressed to the sense of the ludicrous in us. The feeling of the ludicrous seems to us to be awakened by the discovery of an unexpected relation between objects in other respects totally dissimilar. This, too, seems to point, but in an opposite way, from the sense of beauty to design, to design in bringing things unlike into one category. There are, certainly, grotesque and fantastic objects, both in the animal and vegetable kingdoms, which call up the feelings of the ludicrous. We smile when we observe how like the owl is to an old man or woman with excessive pretensions to wisdom; how like certain orchids are to beasts, birds, or insects; and how admirably the monkey mimics the movements of humanity.

V. There are scenes met with on our earth which are expressively called picturesque. They seem to be peculiarly addressed to the imagining power of the mind; they are picture-like, and raise a vivid picture of themselves in the mind; such as the jagged mountain ridges, the peaked promontories, the perpendicular rocks. The mass of objects on the earth are not of this exciting character. Just as the ground colours of nature are soft, or neutral, so the earth's common scenes are irregular, or simply rounded in their outline. Yet here and there there arise picture-like objects from the midst of them, to arrest the eye and print themselves on the fancy. It may be noticed, that the grass and grain of the earth raise up their sharp points from the surface to catch our eye. A still larger proportion of objects above us, and standing between us and the sky, have a clear outline or vivid points. This is the case with the leaves and the coma of trees, and with not a few rocks and mountains. Rising out from quieter scenes, they enliven without exciting the mind, and tend to raise that earthward look of ours, and direct it to heaven, to which they point.

VI. Before closing this paragraph, we must allude to another kindred subject, the Sublime, so far as natural objects are fitted to raise the feeling. Visible things can here do nothing more than aid the mind, which uses them merely to pass beyond them.

The feeling of the Sublime is acknowledged on all hands to be intimately connected with the Idea of the Infinite. In the formation—or rather, in the attempt at the formation—of this idea, the mind shews, in a very striking manner, both its strength and its weakness. In expanding any image spatially, it finds itself incapable of doing anything more than representing to itself a volume with a spherical boundary. In following out its contemplation in respect of time, the image is of a line of great length, but terminating in a point at each end. But where the mind shews its weakness, there it also exhibits its strength. It can only imagine this bounded sphere and outline, but it is led to believe in vastly more. It strives to conceive the Infinite, but ever feels as if it were baffled and thrown back. But while the mind cannot embrace the infinite, it feels, at the place where it is arrested by its own impotency, that there is an infinite beyond. Looking forth, as it were, on the sky, it can see only a certain distance, but is constrained to believe that there is much more beyond the range of the vision—nay, that to whatever point it might go, there would still be a something farther on. "If the mind," says John Foster, "were to arrive at the solemn ridge of mountains which we may fancy to bound creation, it would eagerly ask, Why no farther ?—what is beyond ?" It is here that we find the origin and genesis of such idea as the mind can form of the infinite, and of the belief, to which it ever clings, in the boundless and eternal.

Now, whatever calls forth this exercise of mind and the feeling of awe awakened by it, may be described as sublime. So far as picturesque objects are concerned, the imaging power of the mind rejoices to find that it can print them upon its surface. But there are objects which it tries in vain to picture or represent; the imaging power is filled, but they will not be compressed within it. Everywhere in nature are there scenes which are

> . . . "Like an invitation in space
> Boundless, a guide into Eternity."

A vast height, such as a lofty mountain, is a step to help us to this elevation of thought and emotion. The revelations of astronomy awaken the feeling, because they carry out the soul into far depths of space, but without carrying it to the verge of space. The discoveries in geology extend the mind in much the same way, by the long vistas opened of ages—which yet do not go back to the beginning. Every vast display of power evokes this overawing sentiment; we see effects which are great, arguing a power which is greater. The howl of the tempest, the ceaseless lashing of the ocean, the roar of the waterfall, the crash of the avalanche, the growl of the thunder, the shaking of the very foundation on which we stand when the earth trembles—all these fill the imagination, but are suggestive of something more tremendous behind and beyond. For a similar reason the vault of heaven is always a sublime object when serene; we feel, in looking into it, as if we were looking into immensity. Hence it is that a clear bright space in the sky or in a painting, always allures the eye towards it; it is an outlet by which the mind may, as it were, go out into infinity.

But whatever may suggest the infinite, there is, after all, but one Infinite. The grandest objects presented to our view in earth or sky, the most towering heights, the vastest depths, the most resistless agencies—these are but means to help us to the contemplation of Him who is "high-throned above all height," whose counsels reach from eternity to eternity, and who is the Almighty unto perfection. They are fulfilling their highest end when they lift us above this cold earth, and above our narrow selves, to revel and lose ourselves in the height and depth, the length and breadth, of an Infinite Wisdom, lightened and warmed by an Infinite Love.

SUPPLEMENTARY SECT.—THEORIES OF THE CONTINENTAL PHILOSOPHERS AS TO THE RELATION OF THE LAWS OF NATURE TO THE LAWS OF INTELLIGENCE.

We have illustrated, to as large an extent as our plan allows, the facts which bear upon the relation of the subjective mind to the objective world. After such a survey, we are in circumstances to examine the theories of this relation which have been propounded by some of the deeper thinkers on the Continent of Europe, and especially by some of the German metaphysicians. It should be frankly acknowledged that we have derived much new material for thought from the importation into our land of the loftier speculations of German Philosophy; but it is not to be forgotten, at the same time, that there are principles lying at the basis of some of their systems which would go far to undermine, not only revealed, but natural religion in all its beneficent forms. Some of the gigantic systems, which are being eagerly studied by the ardent youth of our land, constitute the chief supports of a pretending pantheism which it is proposed to substitute for the doctrine of a God possessed of personality, that is, of a separate consciousness and an independent will. Before entering upon the discussion of these systems, it is proper to state that we are to examine them only so far as they relate to our own subject, and as they profess to adduce facts external or internal as evidence in their favour.

In order to understand these theories, it will be needful to trace them historically from their origin. It was a fundamental principle of Descartes—so distinguished for the originality and the independence of his thinking—that there existed in the universe two entirely distinct substances, spirit, whose essence is thought, and matter, whose essence is extension. In his days, it was a universally acknowledged principle that things which were like, and they only, could influence each other. This seems to be an unfounded, or rather a false principle. In this universe, things very unlike affect each other; in polar action, like repels like, and things unlike are attracted to each other. But, being then a universally recognized principle, we find it acting an important part, in the philosophy of the seventeenth century. In particular, it suggested a difficulty which greatly puzzled the school of Descartes;—How can mind influence matter, and matter mind? How does an object, presented to the senses, give rise to an apprehension of it in the mind? How is it, that when we will to move the arm, the arm moves? It does not appear that Descartes uttered a very clear or explicit answer to this question, but the reply was given, and this quite in the spirit of the master, by the disciples, and, in particular, by the ingenious and devout Malebranche. According to him, matter does not influence mind, nor mind matter; the action of matter in reference to mind, and of mind in reference to matter, is the mere occasion of the forth-putting of the Divine power, which is the true cause of the effects which follow. Thus, when we will to move the arm, a present Deity, the source of all power, actually makes the arm to move. This is the famous doctrince of Occasional Causes, as maintained by Malebranche. To us it appears that God has been pleased to give a delegated power both to mind and matter, and that there is no greater difficulty in supposing mind to act on matter, than in supposing matter to act on matter.

These principles and speculations, floating among the reading and thinking minds of that era, took a deep hold on the meditative spirit of a glass-grinder at Amsterdam, who had been brought up in the Jewish faith. The influence exercised by this man—despised and persecuted in his own day—upon the whole of the future history of speculation, is one of the most curious incidents in the whole history of modern philosophy. It is acknowledged, he argues, that if mind and matter are totally different substances, they cannot influence each other; but it is very evident, meanwhile, that they have innumerable points of connexion. It is not necessary to suppose them to be separate substances, they are to be regarded as modes of one and the same substance, a substance possessed both of thought and extension. In itself this one substance is *Natura Naturans*, possessing all power, and ever developing itself; in the universe it is *Natura Naturata*. This system recommended itself to the mind of Spinoza by its simplicity; it seemed to follow from the acknowledged principles of the day as to the nature of substance; and it accounted for the unity of operation which everywhere runs through nature. It is probable that Spinoza did not allow himself seriously to contemplate the fatal nature of the consequences flowing from a system which makes evil, even moral evil, a development or mode of the Divine Being, and denies to man all free-will, all personality, and accountability to a being different from himself. Still, he saw and avowed that such consequences did follow, and was willing to take them as the logical results of a system which had so much to recommend it to his reason, and which represented the universe as full of Deity.

Passing over inferior names, we now find the lofty genius of Leibnitz devoting itself to the solution of the same problems. Proceeding on the principle that mind could not influence matter, nor matter mind, he supposed that they co-operated so beautifully in consequence of a Harmony Pre-established between them. Rejecting the atomic theory of matter, which had found such favour with Bacon, Gassendi, and the majority of modern physicists, he substituted a theory of Monads. The ultimate principles of matter were not, according to him, sluggish atoms, but active powers. There are two distinct kinds of monads, the one unconscious, the elements of matter—the other conscious, the elements of mind. These could not be thought to operate causally upon each other, but still they acted in unison by reason of relations pre-established by God, the Supreme and Eternal Monad, between the inferior monads, whereby each monad acts according to its own principle, and yet acts in harmony with all around it. Some of these speculations of Leibnitz carry us into regions where we have really no light to guide us. We are far, at this day, from being able to determine what are the ultimate elements either of mind or matter. Some of the principles laid down by him are evidently wrong, as when he says that the monads, or powers of nature, cannot influence each other. The agencies of nature, whatever they be, are so constituted as to be able to operate upon, to affect, and modify each other. But, in these lofty discussions, there is a truth propounded which can never be set aside, but which will, on the contrary, appear more and more significant in every succeeding age. The principle in which we refer is that of pre-established harmony. We must, indeed, in the first place, affirm, contrary to the theory of Leibnitz, that the powers of nature, whatever they be, do stimulate and influence the one the other; but we must also, if we would account for the phenomena which present themselves, take along with us the other doctrine, that they are so constituted and collocated as to affect each other, not in a destructive, but in a beneficial manner. Their mutual action, which Leibnitz denied, implies in itself an adjustment, a pre-established harmony; and there are, besides, harmonies proceeding from a concurrence of independent causes; and both one and other carry up our minds to an Intelligent Being appointing, from the beginning, all things to act in concert.

Such was the state of speculation on this all-important subject when the profound intellect of Kant was led to meditate upon it. The relation between the internal and the external, between the subjective and objective, was his great theme round which his philosophy moved. In studying his system we have never been able to say whether we should yield to the feeling of admiration which the logical powers manifested everywhere, and the important truths unfolded in many places, naturally call forth, or whether we should not restrain all such sentiments as we deplore the erroneous and dangerous principles which he has been the means of introducing not only into German, but into European speculation.

Kant saw clearly that we cannot account for human knowledge by mere impressions from without, that it was needful to have a subjective power as well as an objective influence. It is his grand aim to unfold these subjective principles, and in particular, the synthetic judgments *à priori*, the judgments pronounced independently of experience, on objects known by experience. In all knowledge, he says, there is, on the one hand, an external impression, and on the other a subjective form; that the external thing which produces the impression exists, he acknowledges, but then it is an unknown something. It is at this point that his error begins. According to our natural cognitions or beliefs, as it appears to us, the mind is so constituted as to be able to attain a limited knowledge of the external thing as it is; but according to Kant, the external thing is unknown, and there is much in our cognition of it which is given to it by the mind as it contemplates it. Thus the mind, in looking upon the external world, perceives it always as in Space or in Time, which have no objective reality, but are mere forms of the Sense or Sensibility. Again, the understanding, in judging of the matters of Sense, unites them under such categories as Quantity, Quality, Relation, Modality, which are not to be understood as having any external or objective reality.

The relation between the subjective and objective may, we find him arguing, be conceived to spring from one or other of three causes:—*First*, From the objective determining the subjective; *Secondly*, From the subjective determining the objective; or, *Thirdly*, From a pre-established relation or connexion between them. He then shows how the first supposition, that of the school of Locke, (as he represents it, confounding it everywhere with the French school of Condillac,) which derives all our knowledge from sensation, cannot account for the internal facts. He dismisses the third doctrine, that of a pre-ordained adjustment, in a very summary manner, neither stating it accurately, nor examining it carefully. His objections to this middle way are, *first*, that no end can be seen to such an hypothesis, and *secondly*, that necessity would be wanting to the categories which belongs essentially to the conception of them.* In reply to the first, we maintain that the limit to the relation of the objective to the subjective, is to be ascertained and determined, like its existence, by inductive investigation; that is, we believe in the relation only so far as we prove it to exist, that is, find a natural aptitude in the mind on the one hand, and a corresponding operation of nature on the other. In reply to the second, we urge, that when there is a feeling of necessity in the internal principle, there is a universality in the external relation. This is one of the correspondences which we have traced. But having dismissed the other two, Kant finds himself shut up into that theory which makes the mind give its own laws and relations to the objective world. It is thus that he accounts for the relation of cause and effect, and the harmonies in the universe; they are not in the universe itself, they are merely in the mind, and are thence, as the forms, or categories, or ideas under which the mind knows all things, projected upon the world. In this system the doctrine of final cause, as founded upon the correspondence between the mind and nature, and upon the harmonies of nature, must necessarily disappear, for these are not correlations between independent things, but the result of one principle in the mind itself. It is not difficult, as it appears to us, to meet this subjective idealism. We are led by the very constitution of our minds to believe in the reality of external objects; and to believe in them not as things unknown, but as things so far known, and known as professing certain properties; and further to believe, that such relations as those of quality, and cause and effect, are relations in the things themselves. Kant acknowledges that the mind does not create the things, and on the same ground we maintain that it does not create the properties, the relations of things; it has a set of powers by which it is enabled to know them. Deny this, and we deny the very truths of consciousness—the truths sanctioned by the very constitution of our minds; and after denying these, we have no principle left on which to proceed on our speculations, no truth so certain as that which we have set aside. But if we believe in the existence of external things, and on the same ground in the reality of the relations of external things, we are obliged as Kant clearly saw, to believe also, in some "Preformation," between them. Not that we are therefore to set aside the influence of mind on matter; for matter is so constituted as to influence the nervous system, and the nervous system is so constituted as to excite mental action. Not that we

* Critick of Pure Reason. Analytic of Principles, close of Book I.

are to deny the separate potency of mind—all that nervous agency does is to call forth the activity of mind, which is so constituted as to know matter, and the relations of matter. Not that we are to deny the influence of matter upon mind in putting it in motion. We must admit, we think, all these agencies, the action of mind, the action of matter, and their reciprocal action. And in order to account for their harmonious action, we must call in a divinely-appointed adjustment of the two—an adjustment not independent, as Leibnitz supposed, of their mutual action, but an adjustment enabling them to act upon, as well as with each other, so as to produce consistent and beneficial results. We must, as most important of all, suppose that there has been a pre-ordained adjustment between the intuitive laws and beliefs of the mind on the one hand, and the actual relations instituted in the external world on the other.

There was but a step between the doctrine of Kant and that of Fichte, which professed to carry out the principles of Kant to their legitimate consequences. Kant admitted that there was an external world; but then he supposed that the mind gave to it its qualities and relations of Space, Time, Cause and Effect. It was no violent step in advance which was taken by Fichte when he alleged that the mind, which was capable of creating all the relations of matter, might form matter itself. The whole external world became in this philosophy a production of the Ego, all its laws, its order, its harmonies, being given it by the mind itself. In the progress of these speculations of Fichte, the Ego became expanded, in an unintelligible, inconceivable manner, into a kind of universal Ego, which constituted the Moral Order of the universe, and went by the name of God. Here there was an end, as in the system of Kant, to all final cause; but let it be observed that final cause was discarded on grounds which also set aside all objective truth. Here, too, there was an end to what had been carefully preserved in the philosophy of Kant, to the personality of man and to the separate immortality of the soul. It may have been a discovery of the connexion of this system with his own, which led Kant in his late years to pray to be protected from his friends. It is not necessary to subject this system to a critical examination; in doing so we should only be wrestling with a shadow. It sets itself against the fundamental principles of the mind, which announce to us that there is a reality, independent of ourselves, in the external world.

There was now in the system of Fichte a scheme of pantheism, with lofty pretensions, and enforced by great beauty of sentiment, set before the German mind. About this period, certain occurrences which arose out of a conversation of Jacobi with Lessing, who had a great admiration of Spinoza, and reported by the former, brought the system of the Dutch Jew also before the thinking mind of Germany. It was while the German philosophic mind was being fermented by the two systems of Fichte and Spinoza, that Schelling produced his theory, and irradiated it with the fascinations of a poetical imagination. According to him, it was absurd to suppose that the Ego could create all the harmonies of things; we must go farther back if we would account for the correspondences between the external and internal. Neither is this relation to be explained, as Spinoza supposes, by a universal substance possessed at one and the same time of thought and extension, for this would not account for the very diverse experiences of subject and object. We must, therefore, go a step higher, we must go back to the origin both of the subjective and objective, and there we shall find them identical and flowing out of one original, living essence, called by the name of God. This self-existent essence or being develops itself according to a law, and becomes on the one side the Ego, and on the other the Non-Ego; on the one side the subject, and on the other the object; on the one side mind, and on the other nature. Hence the harmony of the two; it arises from their identity. The subjective and objective are in such visible correspondence, because the developments of one and the same principle. Hence the statement that nature is petrified intelligence, and that mind is conscious reflective nature. The feeling of beauty in the mind corresponds to beauty in the world, because both are the unfolding of one eternal power which is at one and the same time God and the universe. God is lovely, the universe is lovely, man's soul loves the lovely in nature and creates the lovely in art, because all are manifestations of the ONE who is infinitely lovely. It would be a waste of thought to institute a serious refutation of this speculation, which, taken as a whole, is to be treated as a picture drawn by a brilliant fancy. In its fundamental truths it is inconsistent with our intuitive knowledge and belief, which announces to us distinctly that we have a separate personality, that we are not the same with God on the one hand, or nature on the other. Schelling appeals to an intellectual intuition, which is one with the Divine Intelligence, as capable of gazing on this identity of existence. But this intuition is acknowledged by him to be above consciousness; that is, as we reckon it, above the region to which man's knowledge can reach, that is, in a cloud-land where irradiated mists may be mistaken for solid bodies. Certain it is, that all the intuitions which we can discover by consciousness, set themselves against this identification of ourselves either with the Divine Intelligence or with nature, this identification of subject and object, of man and God. But with all its superlative extravagance it contains a truth, a truth not in the systems of Kant or Fichte; this is the correspondence between the subjective and objective, both being represented as real though not independent. Never was there so beautiful, and, let us add, so true a picture drawn of the harmony between the beautiful in the mind and the beautiful in nature, as that which we find in the writings of Schelling and of the disciples of his school. We have here a style of speculation to which the native British philosophy is a stranger, and which appears irresistibly attractive when presented to British youth of fervent intellect; and they are too often prepared, in their admiration of the mixture of truth contained in the system, to embrace the error with which it is associated.

It was felt in Germany that the system of Schelling, though exquisitely beautiful, was little better than a speculative rhapsody, when his friend Hegel, with a much more logical mind, set about amending and systematizing it. We do not propose to give an account of his system. We do not attempt to fathom its depths or expose its shallows; for it has depths in which the tallest intellects would lose themselves if allured into them, and it has shallows which the most superficial can see and point out. He is reported to have said, "There is only one person who understands me, and he does not understand me." Not having the honour to be this person, we make no pretensions to a thorough understanding of Hegel. Fortunately, we have to consider his system only in one aspect.

In the systems of Kant and Fichte, the relation between the subjective and the objective has disappeared, for the whole is the creation of the subjective. In the system of Schelling, the relation has reappeared, but has been accounted for in a most unsatisfactory manner. In the system of Hegel, the relation is all in all. The subjective has no separate existence, on the one hand, nor the objective on the other hand; they exist only in relation to each other. The relation is here acknowledged, but it is a relation which does away with the independent existence of the things related.

Abandoning the intellectual intention of Schelling as a mere gratuitous assumption, he attempts to show how all things are developed necessarily by a logical process which is not assumed, but is, in its development, a proof of its own reality. In following out this process, he begins with the most general and abstract notions, such as "Idea" and "Being," and thence develops nature and mind. In all this he reverses the natural order followed by intelligence, which begins with things individual and concrete as they present themselves, and thence rises to the general and the abstract. In doing so, it never for one instant supposes that the abstract or general, such as "Being," can exist independent of individual things. The abstract is a part, separately considered, of the concrete whole. The general is the aggregate of qualities in which individual things agree. It is to reverse the proper process of thought, to begin, as Hegel does, with the abstract, the general. It is to contradict the clearest declarations of thought to deny the existence of the individual, whether subject or object, and resolve all into a relation. The relations which the mind discovers are relations among individual things.

According to this system, the ALL presents a constant evolution of nothing becoming something, and we have to add, of something falling back into nothing. In the unfolding of this theory, he represents God as attaining to consciousness in man, and the whole history of the human race as a succession of incarnations. At his death, which was occasioned by cholera, some of his pupils apotheosized him as the noblest of all the self-conscious developments of Deity. It is easy to see how he accounted for the harmonies which the mind discovers in the universe. To philosophize on nature, he says, is to rethink the grand thought of creation—it is to reproduce, from the depths of the soul, the creative ideas of nature. In a journey which he made to Paris, he was greatly entertained, as he discovered everywhere—in nature and in art, in man as an individual, and in man united in society—confirmations of his system, which widened, like vapours, to embrace all the agreements and disagreements in existence.

It might easily be shown that this ambitious and arrogant system destroys all personality—that is, separate consciousness and will—in God, all personality in man, and that it is inconsistent with human responsibility, and the immortality of the soul as a separate existence. All this has been dwelt on by the schools which have set themselves in opposition to it in Germany. And this argument from consequences should have its weight, for any system which sets itself against these truths, cannot be supported by such evidence as *they* can adduce in their favour. Again, various gaps and inconsistencies have been pointed out in it, showing that it is not so solid a structure as it professes to be. But its fundamental error lies in this, that it denies the separate existence of individual things —of the subject on the one hand, and the object on the other. In professing to proceed according to the laws of thought, it begins with setting the clearest laws of thought at defiance, and must wander the more the farther it advances. It is acknowledged, even in Germany, to be a failure. It fails, in particular, to account for the correspondence between mind and matter regarded as separate existences.

It should be added, that Herbart met these idealistic views of Kant, Fichte, Schelling, and Hegel, with great vigour by a realistic scheme, in which final causes once more have their proper place. But his realism is professedly a rational system erected on certain philosophic principles, which may be assailed equally with the grounds taken by those whom he opposes, and will not find much favour among persons in our country who have become imbued with the spirit recommended by Lord Bacon, and followed out, though with but imperfect success, by Locke and Reid. It is only by proceeding in the inductive method that we can expect fairly to unfold the subjective laws of mind on the one hand, and the objective laws of nature on the other, and then discover the relation between them.

In the speculations of all these philosophers, notice is taken of a most important class of facts, which have very much escaped the attention of British writers. But while we acknowledge this, we are convinced, at the same time, that the correct explanation has not been given by the continental speculatists. In the days of Descartes and Spinoza, the questions discussed turned round the action of mind upon material objects, and the action of material objects upon mind. But from the time of Leibnitz, and still more from the time of Kant, a new set of questions came to be agitated in regard to the accordance between the laws of the mind within, and the harmonies of external nature without. Kant and Fichte referred this to the mind creating the order which it contemplated, Schelling and Hegel to the identity of subject and object, of the world within and the world without. But none of these hypotheses meets the full facts of the case, nor explains the whole phenomena. Leibnitz, indeed, had a glimpse of the truth, but failed to represent it fully and correctly. The facts admit of only one satisfactory explanation, and this an explanation in strict accordance with the doctrine of final cause, and implying a specific plan on the part of an intelligent being.

For mark, that we have, *first, a set of internal facts.* We have in the mind perceptions through the senses; we have certain intelligent aptitudes, such as the generalizing propensity, ever seeking to group the objects it meets with into classes, and causality, anticipating nature, and confidently looking for certain effects to follow agencies now in operation; we have instincts and affections craving for external objects on which to lavish themselves; and we have a sense of beauty, longing for scenes of loveliness and sublimity. We insist that these internal facts be not set aside, but that they be embraced and accounted for in any explanation which may be offered. It will not do to refer them, with certain French and British writers, to sensations and impressions from without. They are evidently powers, instincts, affections, fundamental laws in the mind itself, making their own use of the influences which may come in from the external world.

But, *secondly, there is a set of external facts.* As little are we at liberty to overlook them. In denying them, we are, in the very act, discarding the dicta of consciousness, and the very constitutional principles of intelligence in the mind; and after we have done so, there remains no ground on which we can reason on this or on any other subject. Here, in this world which we perceive, are bodies endowed with wonderful properties; are objects grouped into classes, and with interesting correlations subsisting between them; are events causally connected together; and scenes of beauty and grandeur. All this must be explained by a hypothesis adequate to meet the case obviously presented, and no part of all this can be accounted for merely by the inward principles of the mind, except on the ground which would make these very principles delusive and a delusion.

We have thus a series of facts in congruity with each other within the mind. We have also a series of facts in beautiful harmony with each other without the mind. But we have more, there is an accordance between the internal and external facts. We have the perceptions of one sense confirmed by those of another sense. We have instincts impelling to certain operations, and we find ourselves placed in a state of things in which these instincts are gratified, and in being so, perform acts necessary to our welfare and our very existence. We have affections general and special, and we fall in with objects to call them forth, and on which to lavish them. We proceed spontaneously to classify objects according to certain relations of shape, quantity, and proportion, and actually find them distributed into groups according to these very principles. We anticipate that the same cause will ever produce the same effect, and find our expectations realized every waking hour of our existence. We have æsthetic tastes, and everywhere there are harmonious colours, and graceful forms, and lovely scenes to gratify them. As it is not the sound which produces the ear to receive it, as it is not the eye which creates the light that falls upon it, so it cannot be the outward harmonies which create the inward desire to discover them, and the capacity to observe them; nor the internal faculties and feelings which create the outward harmonies. We are obliged, if we would account for the whole phenomena, to account for both classes of facts, and the relation between them. This can only be done by supposing that one Intelligent Being instituted both series of facts and their mutual accordance. The facts round which the German philosophy has been moving, are thus seen to bring us back to the old doctrine of our British Theology. It is only by calling in a God who designs and executes, that we can fully or rationally account for facts, which we cannot deny without denying our intelligence.

It thus appears that the doctrine of Final Cause, so far from being undermined or shaken by these speculations, is as secure as ever—nay, it stands forth with new illustrations and confirmations. We are brought back to what observant minds have noticed from the first, (though they had not always expressed it correctly,) a concurrence of independent agencies towards the production of a given end. Hegel is laying down an utterly mistaken doctrine when (not in words denying final cause) he speaks of the final cause of a thing being the inward nature of a thing, or a thing following its inward nature; final cause is the co-operation of a number of independent things to accomplish what is evidently an end. In particular, there is need of a correspondence of the external and internal in order to our inward knowledge, and to our experience of the outwad world. The phenomenon cannot be explained by an internal order projecting itself upon the external world; for, as Herbart asks, if it be by some necessary form of the understanding that final cause is imposed on things, how are we to account for the fact that we do not see the final cause in regard to every occurrence? How is it, in particular, that we discover it only in those cases in which we notice a concurrence of agencies acting independently of the laws of thought within ourselves? All this can easily be accounted for on the supposition that it needs objective evidence to lead us to discover final cause; but is inexplicable if the process proceeds from a merely subjective principle. But, without pressing this difficulty, we plant ourselves on ground from which we can never be dislodged, when we maintain that the outward is real and that the inward is real, and that there is proof of plan and intelligence in the correspondence instituted between them.

At the close of this review, we find ourselves shut up into a Pre-Established Harmony. But it is not the fanciful doctrine of Leibnitz. According to him, no one power or monad can operate upon any other, but each fulfils its function independent of all others, and yet in harmony with all others. This seems to us quite inconsistent with what we see everywhere, the action of objects on each other. The Pre-Established Harmony which we advocate, pre-supposes the action of matter on matter, of matter on mind, and mind on matter, and the harmony is manifested in the beneficence of their mutual operation.

This Pre-Established Harmony manifests itself in two forms.

First, Agents mental and material have powers or properties which fit into each other, and enable them to co-operate in producing consistent and bountiful results. So far from supposing that they do not act on each other, we affirm, that they do act, but act in harmony.

Secondly, There has been an original collocation of agents, whereby concordant results are produced without any reciprocal action. The lily that grows in one garden, assumes the same forms and colours as the lily which grows in another garden. The fish of the Old Red Sandstone epoch had the same general form as the fish which still swims in our seas. But these correspondences do not arise from any mystic or magnetic influence of the one upon the other, but because causes have been instituted and arrangements made, which produce the one in unison with the other. The comparison of Leibnitz here applies; the two correspond as two timepieces, not because of any mutual influence, but because each has been so constituted, that it moves in harmony with the other.

We cannot comprehend the harmonies of the universe without admitting and calling in both these principles.

CHAPTER III.

TYPICAL SYSTEMS OF NATURE AND REVELATION.

SECT. I.—THE OLD TESTAMENT TYPES.

IN looking at any one department of contemporaneous nature, we discover that all objects and events are conformed to a plan. Organisms differing from each other in their constituent elements have the same relations of parts, and differing from each other in use, are cast in the same general mould. Again, looking at certain departments of successive nature, we find that objects in one epoch are an anticipation or prediction of objects to appear at a later epoch. The science of embryology shows that there are systematic stages of progression in the formation of the young of all animals. In the Psalm which celebrates the omniscience of God, this remarkable language is employed :—"I WILL PRAISE THEE ; FOR I AM FEARFULLY AND WONDERFULLY MADE : MARVELLOUS ARE THY WORKS ; AND THAT MY SOUL KNOWETH RIGHT WELL. MY SUBSTANCE WAS NOT HID FROM THEE, WHEN I WAS MADE IN SECRET, AND CURIOUSLY WROUGHT IN THE LOWEST PARTS OF THE EARTH. THINE EYES DID SEE MY SUBSTANCE, YET BEING UNPERFECT; AND IN THY BOOK ALL MY MEMBERS WERE WRITTEN, WHICH IN CONTINUANCE WERE FASHIONED, WHEN AS YET THERE WAS NONE OF THEM." These two great truths are seen in beautiful combination in geology, which reveals a typical system, that is, all things formed after a type, in every age, and also a grand system of prophecy, in which the past ever points to the future, and the future appears as the accomplishment of the presentiments of the past. Lower animals appear as a prognostication of higher, and the higher come as the fulfilment of the prediction set forth in the lower, and this not by any physical emanation of the one from the other, but according to the eternal plan of Him who hath therein showed the immutability of His counsel. There is an order in successive, even as there is an order in contemporaneous nature; but as the one plant does not produce the other plant, which in the same type may be growing alongside of it, so neither does a species of animal in one age produce the homologous species in a succeeding age. In this divinely-predetermined progression man stands as the end or consummation of a process which had been going on since the dawn of creation.

Views like these have been floating before the minds of deep thinkers and large-minded observers for the last two or three ages, and were expressed by some who did not discover their true meaning. We find Herder writing, at the end of last century, " See how the different classes of creation run into each other! How do the organizations ascend and struggle upward from all points on all sides! And then, again, what a close resemblance between them! Precisely as if, on all our earth, the form-abounding mother had proposed to herself but one type, one proto-plasma, according to which, and for which, she formed them all. Know thou what this form is. It is the identical one which man also wears. It is more evident internally than it is externally. Even in insects an analogon of the human anatomy has been discovered, though, compared with ours, enveloped and seemingly disproportionate. The different members, and consequently also the powers which work in them, are yet undeveloped, not organized to our fulness of life. It seems to me that throughout creation this finger-mark of nature is the Ariadne thread that conducts through the labyrinth of animal forms, ascending and descending."* A similar passage, very probably suggested by that quoted from Herder, (but without any acknowledgement to this effect,) is found in Coleridge's Aids to Reflection.† "The metal at its height seems a mute prophecy of the coming vegetation, into a mimic resemblance of which it crystalizes. The blossom and flower, the acme of vegetable life, divides into component organs with reciprocal functions, and by instinctive motions and approximations seems impatient of that figure by which it is differenced in kind from the flower-shaped Psyche that flutters with free wing above it. And wonderfully in the insect realm doth the irritability, the proper seat of instinct, while yet the nascent sensibility is subordinate thereto—most wonderfully, I say, doth the muscular life in the insect, and the musculo-arteria in the bird, imitate and typically rehearse the adaptive understanding, yea, and the moral affections and charities of man. Let us carry ourselves back in spirit to the mysterious week, the teeming work-days of the Creator, as they rose in vision before the eye of the inspired historian of the operations of the heavens and of the earth, in the day that the Lord God made the earth and the heavens. And who that watched their ways with an understanding heart could, as the vision evolved still advanced towards him, contemplate the filial and loyal bee, the home building, wedded and divorceless swallow, and above all the manifoldly intelligent ant tribes, with their commonwealths and con-

* Metempsychosis. † Aph. xxxvi.

federacies, their warriors and miners, the husband folk that fold in their tiny flocks on the honey's leaf, and the virgin sisters with the holy instincts of maternal love detached, and in selfless purity, and not say in himself, Behold the shadow of approaching humanity, the sun rising from behind in the kindling morn of creation !" Nor are these the visionary dreams of a poet or a mystic, clothing nature in forms devised by his own fantasy; they are (after deducting one or two slight misapprehensions of fact) the results reached by the profoundest inductive science of our times.

Between this typical system in nature and our powers of intelligence, there is a beautiful correspondence. First, there is in the human mind an imagining faculty, which experiences a strange delight in reproducing what it has perceived under a kind of ideal or pattern form. We have seen, let us suppose, a particular plant, say the Victoria Regina, we cannot remember every insignificant particular connected with the number of its ribs or veins, but there is laid up in our minds a general outline of its shape, colour, and structure, which enables us on any other plant of the sort falling under our notice, at once to recognise it as belonging to the same species. The mind seems thus to idealize to some extent its very recollections. And then in the higher intellectual processes of abstraction and generalization, it abstracts the indifferent and retains the essential, and strives to group the innumerable objects which it meets with under a few heads, by means of their common qualities. The relations thus discovered, cause the classes and individuals to recur again and again to the mind according to the law of association, and even aid the mind in the perception of certain kinds of beauty.

These are the topics which have passed before us in the previous part of this Work. We are now to trace another correspondence—it is equally wonderful—between the typical system of nature, and the typical system of revelation, and to show that this second is as admirably suited as the first to the native capacity and tendencies of the mind.

It has long been known to divines, that the Word of God has a typical system. The types have not been always expounded in the exercise of a sound judgment, or in accordance with the principles which should govern all Scripture interpretation. Not unfrequently imagination has been allowed unreined to career in this field at will, and in all treatises of divinity, the word *type* has been changed from its scriptural to a theological sense. In other cases, the fanciful interpretations which have collected around the types of Scripture have led men of severe critical taste to reject the whole system as visionary. Still it is obvious that types run through the whole Word of God, and cannot be excluded from it without mutilating the Old Testament, and even parts of the New Testament, so as to deprive them of some of their most marked features. But now where such curious harmonies and prefigurations have been detected in the organic world, we may be able to show that no one is entitled summarily to reject Scripture types as being contrary to reason, or the analogy of things, and even to trace an analogy between the types of the Works and of the Word of God. Not that the two systems are the same; they are not identical, but homologous or analogous. If the principles which we have been unfolding are well founded, there should, with the uniformity, be also a diversity. The typical system of the animal kingdom is of a different order from the typical system of the vegetable kingdom; and when we rise from matter to mind, from nature to revelation, we may expect the typical system to be of a higher kind than that which pervades the organic world. There is the same method in all, and this suited to the intellectual tendencies of mankind, but it is varied to suit the end which each has to accomplish.

In the theological use of the phrase, the word *type* is confined to the prefigurations of Christ set forth in the Old Testament. In books of divinity we read of certain ordinances as the type, and Christ as the antitype. But this is not the sense in which the term is used in Scripture. Mr. Fairbairn, in his able work on Typology, says, that he understands the word in the theological sense, but adds, "as employed in Scripture it is used with greater latitude, as may be seen by consulting in the original the passages referred to," (Heb. viii. 5; 1 Cor. x. 6; Phil. iii. 17; 1 Thess. i. 7; 1 Peter v. 3; Rom. vi. 17.) But "the foolishness of God is wiser than men." We do not know what right divines have to construct a system of theological types, instead of a system of Scripture types. We are sure that had they kept to the Scripture use of the term instead of devising a theological sense, they would have been saved from much extravagance, and have evolved much more truth. The words employed in Scripture (τύποι, ὑποδείγματα) stand for pattern-figures, or examples; and persons living in ages widely different from each other, and events having no natural connexion, are represented as being constituted after the same type or model. There are typical occurrences mentioned in Scripture, and full of instruction, which have no immediate connexion with the person of Christ, and are in no way prefigurative of Him. Thus the judgments of God fell on the children of Israel in the wilderness as types or "examples" (1 Cor. x. 11) of a method of procedure which is for ever the same, and recorded "for our admonition," in order to shew that it will be put in execution whenever men commit similar deeds. Types did not cease when Christ appeared; there are types in the New Testament dispensation (Phil. iii. 17; 1 Thess. i. 7; Rom. vi. 17) as well as in the Old Testament dispensation. The typical system of the kingdom of grace is meant fundamentally and primarily to shew that God proceeds according to one counsel and purpose from age to age. In this respect there is an exact correspondence between the typical systems of revelation and nature. But as in nature there are foreshadowings revealed by embryology and geology, so in revelation there is also a scheme, and this a very grand scheme, of prefiguration. In the natural kingdom all inferior organisms point onward and upward to man; in the spiritual kingdom all life points onward and upward to Christ. Theologians, in discussing types, have confined their attention exclusively to these prefigurations; but in neglecting the other and wider view, they have not only missed much instruction, but have not been able to estimate precisely the meaning of the important truths to which their attention has been called.

It strikes us that a typical system runs through the whole Divine economy revealed in the Word. *First*, Adam is the type of Man. He and his posterity are all of the same essential nature, possessing similar powers of intuition and understanding, of will and emotion, of conscience and free agency, and God acts towards them in the dispensations of grace as in the dispensations of nature, as being one. Then, from the time of the Fall, we have two different typical forms, the one after the seed of the serpent, the other after the seed of the woman. Henceforth there is a contest between the serpent and Him who is to destroy the power of the serpent, between the flesh and the Spirit, between the world and the Church. Two manner of people are now seen struggling in the womb of time—a Cain and an Abel, an Ishmael and an Isaac, an Esau and a Jacob, an Absalom and a Solomon, the elder born after the flesh, and the younger born after the Spirit. It is this unity of figure fully as much as the "type" of sound doctrine which gives a consistency, in the minds of believers, to our religion in all ages; which enables the Christian to profit, to this day, by the teaching of the Old Testament; to sing, to this day, the song of Moses and the Psalms of David; and to perceive and feel that there are the same contests now as then, the same contests in the heart, the same contests in the world, between the evil and the good principle, between the first, or nature-born, and the second, or grace-born. In short, there are now, as there have ever been, but two men on our earth typical or representative; the first man, which is Adam, the second, which is Christ. "And so it is written, The first man Adam was made a living soul; the last Adam was made a quickening spirit. Howbeit that was not first which is spiritual, but that which is natural; and afterward that which is spiritual. The first man is of the earth earthy; the second man is the Lord from heaven."

There appear from age to age certain great leading powers of the first or earthy form, distinguished by their audacity and the oppression which they exercise over the Church, such as Cain and Lamech, Ham and Nimrod, Egypt and Babylon. "They have consulted together with one consent; they are confederates against thee; the tabernacles of Edom and the Ishmaelites, of Moab and the Hagarenes, Gebal and Ammon and Amelek, with the inhabitants of Tyre: Assur also is joined with them, they have holpen the children of Lot." These are represented in Christian times by Gog and Magog and Babylon. But we must confine our attention here to the examples of the better type, which appear and reappear throughout successive ages, and chiefly, in this section, to what is, after all, the most important, to the prefigurations of Christ.

It had been determined, in eternity, that, "He whose delights were with the children of men," should come to our earth in the fulness of time. He is called "the Lamb slain from the foundation of the world;" and as soon as man falls, there are symbols of Him: "Lo, I come, in the volume of the book it is written of me." The prefigurations of Christ may be divided into three classes:—typical ordinances, personages, and events. *First*, There is a number of ordinances, more or less of the same general mould, all imparting substantially the same instruction, all pointing to guilt contracted, to God offended, to a propitiation provided, and to acceptance secured through this propitiation;—the four great cardinal truths of revealed religion, as addressed to fallen man. There were sacrifices, in which the offerer, placing his hand on the head of the animal, and devoting it to destruction in his room and stead, expressed symbolically his belief in those great saving truths. There was the tabernacle, with the people worshipping outside, and the Shechinah, which had to be sprinkled with blood, in its innermost recesses, pointing to an offended God, but a God who was to be propitiated through the shedding of blood. There was the ark of the covenant, with the tables of the law inside, and the pot of manna, and the rod that budded, and, over all, the cherubim shadowing the mercy-seat—fit symbol of an arrangement by which the law is fulfilled, and provision made for a revival of life, and a supply of spiritual food by a God ready to meet with, and to commune with us on the mercy-seat. There is the scape-goat, with the sins of the people laid upon it, pointing, as clearly as the Baptist did, to "the Lamb of God, which taketh away the sins of the world."

Secondly, There are typical persons, such as Abel and Enoch, Noah and Abraham, Moses and Aaron, Samuel and David, Elijah and Elisha, shadowing the prophetical, priestly, and kingly offices of Christ. From the fall downwards there is a succession of such personages, with their individual differences, but all after a pre-determined model, exhibiting certain features of character in as marked a manner as the Jewish race show certain features of countenance. As the clouds reflect the rays of the sun before he appears above the horizon, so each of these, though dark in himself—alas! at times, shewing his native darkness, reflects certain of the beams—most commonly coloured, of the Sun of Righteousness, and shows that he is about to shine upon our world.

Thirdly, There are typical events, exhibiting the same truths in a still more impressive form. There is the flood, in which many perish, but a few, that is, eight souls, are saved by an ark symbolical of the Saviour. There is the destruction of Sodom, in which the inhabitants perish, while Lot and his family are rescued by heavenly interposition. Most instructive of all, and, therefore, occupying the most important place, there is the deliverance from Egypt. The state of the Hebrews as bondsmen, the deliverer prepared for his work by suffering, the method of the deliverence in the midst of contests and judgments, the wonderfully instructive journey through the wilderness, with the provision made for the sustenance of the people, and the statutes delivered are as certainly anticipations of a higher redemption to follow, as the fish and reptiles' digits are anticipations of the fingers of men. It is all true history, and yet it looks as if it were a parable written by some man of God for our instruction. We are trained in this training of the children of Israel; and by means of the discipline through which they were put, our imagining faculty has acquired some of our clearest and liveliest, some of our most profound and comforting representations of the method of redemption.

But we cannot understand the meaning of these ordinances, personages, and events, unless we take along with us both of the two grand principles which we have been unfolding in this volume. We must not confine our attention to their general homology, we must take into account also their special adaptations. We must not look upon them merely as prefigurations, we must look upon them as also "a figure for the time then present." (Heb. ix. 9.) These typical ordinances, persons, and events, are all after the same general plan, and exhibit in shadow the truths which the sinner most requires to know, and especially the person and work of the expected ONE under interesting and instructive aspects. But they were all at the same time adapted with exquisite skill to their own particular age, and the circumstances of which they formed a part. The ordinances, for instance, were appropriate worship on the part of those who were required to observe them, and, in some cases, they subserved important national and civil purposes. The persons who figure as types were all the while doing a work for their own day, and were, in most cases, we believe, unconscious that they bore a representative character—they were conscious only of looking onward to the light, and they wist not that their face was shining with the reflection of that light. The events, too, did, in most cases, impart a special lesson of their own, and, in all cases, were most important links in the chain of Providence. But just as the paddle of the whale serves a special purpose, but contains divisions not needful to its special purpose; just as the chick's head contains typical bones not required in order to its extrusion from the egg;—so the Old Testament types, while each accomplishes an end of its own, have all, at the same time, certain common features of a prefigurative character. Like the different species in the vegetable and animal kingdoms, like the answerable organs in different species, they diverge on either side in order to suit a purpose; but, meanwhile, they are all after one pattern. In human architecture, we are pleased to see that the portico and the passage leading from it have often a homology to the temple itself. It is the same in the temple of God. The gateway, and the pillars and avenues of approach, present the same general outline as the temple to which they form an entrance.

The whole of this method of procedure is in beautiful adaptation to the native tendencies and acquired habits of the mind of man. The skilful teacher is accustomed to instruct his younger pupils by means of signs, and pictures, and comparisons; it is thus that he conveys the ideas of remote objects and abstract truths. In the simpler stages of society, mankind can be taught general truths only by symbols and parables. Hence we find most heathen religions becoming mythic, or explaining their mysteries by allegories or national incidents. The great exemplar of the ancient philosophy, and the grand archetype of modern science, were alike distinguished by their possessing the power of comparison in a high degree, and both have told us that man is best instructed by similitudes. "It is difficult," says the Guest in the Statesman of Plato, "fully to exhibit greater things without the use of patterns," (παραδείγματα.) Lord Bacon, in more than one place, has declared, "As hieroglyphics preceded letters, so parables are older than arguments. And, even now, if any one wishes to pour new light into any human intellect, and to do so expediently and pleasantly, he must proceed in the same way, and call in the assistance of parables." It appears, then, that God was acting in accordance with the nature which He had given us, in His method of instructing the early Church. In Bible history there are no myths, but real events are made as lively as myths, and convey far more important instruction. And, even in Christian times, this representative system has been felt by all, but especially by the simple and unlettered, to be a powerful means of imparting great vividness and picturesqueness to the inspired teaching. The truth is exhibited ; not, as in systems of divinity, as a bare abstraction ; not, as in the words of Scripture, by a phrase expressive enough, but still a mere counter, bearing no resemblance to that which it represents ; but by a picture which the mind, as it were, sees before it. With such lively images before us, we feel as if we were walking amid living realities. We find, in particular, that the types of the Bible have ever been especial favourites with the "common people," who experience a difficulty in seizing an abstraction, or in grasping a generalization, but feel none in comprehending truths which are embodied in an incident, a person, or an ordinance. Take away the typical representations of the deeper doctrines of the Word of God, take away such figures as sacrifices, as the brazen serpent, as the scape-goat, the city of refuge, the sprinklings and ablutions under the law—abstract these from the apprehensions of the Christian who moves in the lower walks of life, and there would remain, we suspect, scarcely any idea—there would certainly be nothing remaining to enliven and engage the mind. It was in gracious accommodation to the same peculiarities of our nature, that the greatest of all teachers, " He who knew what was in man," taught the people by parables.

The right conclusion has been drawn by one in whose history difficulties have merely been " Schools and Schoolmasters" to strengthen his native genius. " As the veil slowly rises," says Dr. Hugh Miller, " a new significancy seems to attach to all creation. The Creator, in the first ages of his workings, appears to have been associated with what he wrought simply as the producer or author of all things ; but even in these ages, as scene rose after scene, and one dynasty of the inferior animals succeeded another, there was strange typical indications, which pre-Adamic students of prophecy, among the spiritual existences of the universe, might possibly have aspired to read—symbolical indications to the effect that the Creator was, in the future, to be more intimately connected with his material works than in these ages, through a glorious creature made in his own image and likeness. And to this semblance and portraiture of the Deity—the first Adam—all the merely *natural* symbols seem to refer. But in the eternal decrees, it had been for ever determined that the union of the Creator with creation was not to be a mere union by proxy or semblance ; and no sooner had the first Adam appeared and fallen, than a new school of prophecy began, in which type and symbol were mingled with what had now its first existence on earth ; and all pointed to the second Adam, 'the Lord from Heaven.'* In Him creation and the Creator

* This extract is from a notice by Dr. Miller of the Article in the North British Review previously referred to. In the same article he shews wherein Oken had erred. " Hence the remark of Oken, that 'man is the sum total of all the animals.' Hence, too, but with a still broader appreciation of the homologies which bear upon the lord of creation

met in reality, and not in semblance; on the very apex of the finished pyramid of being sits the adorable Monarch of all;—as the son of Mary, of David, of the first Adam, the created of God—as God and the Son of God, the eternal Creator of the universe. And these—the two Adams—form the main theme of all prophecy, natural and revealed. And that type and symbol should refer not only to the second, but, as held by such men as Agassiz and Owen, to the first Adam also, exemplifies, we are disposed to hold, the unity of the style of Deity, and serves to shew that it was He who created the worlds, that dictated the Scriptures."

SECT. II.—TYPICAL NUMBERS.

There is no object on which a greater amount of extravagant statement has been made, both in ancient and modern times, than the significance of numbers. The Pythagoreans, and later Platonists, evidently sought for some inherent power in numbers to account for the numeral relations that appear in nature. In the pages of Philo-Judæus and Josephus, numbers have a theosophic signification. In more than one country, certain

as their central type, his essentially profane and erroneous remark, that 'man is God manifest in flesh.' Let the reader, however, observe in what the error and profantity consists. There is a loose sense in which man *is* God manifest in the flesh;—he is God's image manifested in the flesh; and an image or likeness is a manifestation, or making evident, of that which it represents, whether it be an image or likeness of body or mind. Originally, at least in moral character, man was a manifestation of his Maker, and in intellect he is a manifestation of his Maker still. But the error and profanity of Oken consists in applying that to man, the *image*—man, the being in whom merely the homologues or *natural* prophecies converge—which is exclusively applied, in revelation, to a higher and more real manifestation of God in the flesh—that manifestation of very God himself which has formed the subject, not of natural, but of the revealed prophecies. The transcendentalist has gone, in his irreverent ignorance, a step too far; and yet his meaning seems real, though he himself mistook its nature, and employed improper language to convey it."—*Witness*, Aug. 1851. We may here be permitted to express a wish that the author will some time or other republish a selection from the articles in the *Witness* newspaper; they would be acknowledged not to be inferior to the republications from any of the periodicals of our age.

numbers have been supposed to have a magical power. Commentators have discovered a mystical meaning in the special numbers which appear and reappear so constantly in the Word of God. Others have not known what to make of Scripture numbers, while not a few have looked with suspicion upon the passages which contain them, or the Bible, because it is so full of them.

The train of observation and reflection followed in this treatise, may help us to discover what is the true significancy of such numbers.

In comprehending and recollecting the isolated and scattered phenomena of nature, and in the scientific construction of them, in order to these ends, man's intellect needs such recurring numbers, and when he does not find them in nature, he places them there. Man seeks them, too, in chronology, as an aid at once to the memory, which calls up events by the law of correlation, and the contemplative intellect, which loves to collect objects into groups. So strong is this tendency, that when such relations are not found among events, mankind will create them from the stores of their own ingenuity, and will lengthen or shorten periods to suit them to the measure of their Procrustes' bed. Hence it is, that in the speculations of early philosophers, in history handed down by popular tradition, and in all mythic systems of religion, we have recurrent numbers, such as three and five, seven and ten. The existence of this mystical tendency in premature scientific speculation, should not lead us, by an extreme reaction, to affirm that numbers have no significancy in nature; it should merely guard us from adopting them too readily—that is, it should prevent us from receiving them without inductive evidence, which is now, however, superabundant. On a like principle, the numeral relations of mythic religions should not be held as proving that biblical institutions and narratives are fabulous, simply because they contain recurrent numbers. It has been far too readily assumed, by certain neological critics in Germany and their followers in this country, we have shewn their dissecting acuteness by pruning away—on the pretence of improving it—the tree of life, till they have destroyed not only its lovely form, but its very vital principle, that every portion of the Old and New Testament is to be regarded as fabulous which contains a repetition of numbers.

Physical science shews that numbers have a significancy in every department of nature. Two appears as the typical number in the lowest class of plants, and regulates that pairing or marriage of plants and animals which is one of the fundamental laws of the organic kingdoms. Three is the characteristic number of that class of plants which have parallel veined leaves, and is the number of joints in the typical digit. Four is a significent number in those beautiful crystals which show that minerals (as well as stars) have their geometry. Five is the model number of the highest class of plants—those with reticulated veins and branches, is the typical number of the fingers and toes of vertebrate animals, and is of frequent occurrence among star-fishes. Six is the proportional number of carbon in chemistry, and 3×2 is a common number in the floral organs of monoctyledonous plants, such as the lilies of the field, which we are exhorted to consider. Seven appears as significant only in a single order of plants, (Heptandria,) but has an importance in the animal kingdom, where it is the number of vertebræ in the neck of mammalia, and according to M. Edwards, the typical number of rings in the head, in the thorax, and in the abdomen of crustacea. Eight is the definite number in chemical composition for oxygen, the most useful element in nature, and is very common in the organs of sea-jellies. Nine seems to be rare in the organic kingdoms. Ten or 5×2 is found in star-fishes, and is the number of digits on the fore and hind limbs of animals. Without going over any more individual numbers, we find multiple numbers acting an important part in chemical compositions, and in the organs of flowers; for the elements unite in multiple relations, and the stamens are often the multiples of the petals. In the arrangement of the appendages of the plant we have a strange series, 1, 2, 3, 5, 8, 13, 21, 34, which was supposed to possess virtues of an old date, and before it was discovered in the plant. In natural philosophy the highest law, that of forces acting from a centre, proceeds according to the square of numbers. In the curves and relative lengths of branches of plants, there are evidently quantitative relations which mathematics have not been able to seize and express.

He must be a bold man who will insist, that should the God who fashioned nature be pleased to give to man a revelation of His will, in order to solve certain great problems started by the existence of sin in the world, He shall not be at liberty to make His dispensations of providence, and His institutions for instruction and worship, bear a certain relation to each other. It is presumptuous, above all things, in any one to condemn as mythic every part of the Bible narrative which contains a recurrent number. This principle would turn the discoveries of the most eminent scientific men in modern times—the discoveries of Kepler, of Newton, of Decandolle, and Dalton into myths. The constant recurrence of certain numbers in the self-devised history of tradition, and the self-formed religions embodied in myths, is an acknowledgment on the part of man, that he needs such relations to enable him to follow history and comprehend doctrine And may not He who knows what is the nature of man, suit Himself to the creatures fashioned by Him, by instituting, in the realities of His dispensations and His ordinances, those very numerical relations which man will feign by his imagination, where the actual state of things does not present them?

We certainly do meet in Bible narrative with a recurrence of certain numbers, and these not unlike the numbers which recent science has disclosed in nature. The beasts were gathered into the ark, even as they are assorted in nature, in pairs; and our Lord sent out His disciples, as the fowls of the air are sent out, two and two, to support and comfort each other. Three derives its significancy from the very nature of God, and appears in the triple sacerdotal blessing of Jacob, (Gen. xlviii. 16;) in the thrice holy of Isaiah, (vi. 3;) in the three great religious festivals; in Jonah being three days in the whale's belly; in our Lord being three days in the grave; and in the threefold judgments denounced in the Book of Revelation, where the tail of the great red dragon draws the third of the stars, and three unclean spirits issue from the mouth of the dragon, the beast, and the false prophet. Let us not forget that the triad is the representative of Deity in many religions, and appears in the three-forked lightning of Jupiter, the trident of Neptune, the three-headed dog of Pluto, the tripod of Apollo, the three Fates, three Furies, three Graces, and thrice three Muses.* Four appears in Scripture in the altars, and sanctuary, and holy of holies, which was a cube; and groups of four are found in Revelation, such as, heaven, earth, sea, and fountains of waters; kindred, and tongue,

* See Article in American Biblical Repertory, republished in British and Foreign Evangelical Review, June 1855.

and people, and nation. Five is found in the pillars of the courts of the temple, which were five cubits high, and five cubits apart; and in the ten virgins, five of whom were wise, and five foolish. Six is once or twice mentioned as a significant number in Ezekiel. Seven is the most frequently repeated number in the Bible. We have first the seven days of creation; then the seven days of the week; then a series of seasons regulated by seven; the seventh year was a Sabbatical year, and 7 × 7 gave a year of jubilee; and at the close of the canon there are the seven spirits before the throne, the seven churches of Asia, the seven branches of the candlestick, seven angels with seven trumpets, and seven vials with the seven last plagues. The number ten appears in the tithes devoted to God, in the plagues which devasted Egypt, and in the commandments delivered amidst the thunders of Sinai. Twelve was the number of the sons of Joseph, of the tribes of God's people, and of the Apostles; the holy city measured twelve thousand cubits in length, breadth, and height, and had twelve foundations, twelve gates, and a tree of life which bears twelve manner of fruits. Multiple numbers are very frequent. Forty days, or 4 × by 10, was the time of Moses' sojourn on the mount with God, of Elijah's journey to Horeb, and of our Lord's temptation in the wilderness. There were 7 × 7 days between the passover and pentecost, and 7 × 7 years between the times of jubilee. The Tabernacle measured ten cubits in breadth and length, and 3 × 10 cubits in length; there were 4 × 12 boards in its frame, and the court was 10 × 10 cubits long, and the sacrifices on certain occasions were multiples of seven. We read of 7 × 10 disciples; Peter was exhorted to forgive his brother not seven times, but seventy times seven, and the redeemed on Mount Zion are 12 × 12 thousand.

This method of instruction is in admirable adaptation to the constitution of man's mind. It lends distinctness to the incident, it helps the intellect to grasp the truth, and the memory to retain it. It is one of many circumstances which adapt the Word like the Works of God to every capacity, to persons of all ages and sexes, times and countries. By these and similar means, the greatest of all Teachers still encourages little children to come unto Him, when other teachers would forbid them. Its institutions and its incidents strike the fancy and are fixed in the memory of youth; they interest by their correspondences the understanding of the mature man, and are found wrapt round the decaying memory of old age, the burden of which they serve to lighten, and the gloom of which they irradiate.

And in all this, whether in nature or in the Word, we are not inclined to find anything mystical or even mysterious. We are not disposed to believe it to proceed from any inherent power of numbers, as certain mathematicians and philosophists have imagined. Nor does it imply that any one number has a special significance. We have quoted so many cases of numeral relation in order to show that all, or nearly all, the lower numbers, odd and even, appear as principles of co-ordination both in nature and in the Word. No doubt, there are circumstances which have determined the use of certain numbers. Thus, the nature of the plant, as having an axis, with symmetrical sides, may have determinted the selection of the odd numbers 3 and 5 in the organs of the vegetable kingdom. The recurrences of 5 and 10 in human enumeration probably originated in the number of the digits. The triune nature of God, and the divine institution of the Sabbath, must have given rise to the frequent use of the numbers 3 and 7; and the circumstance that the patriarchs were 12 in number must have brought series of twelves in its train. Still, in all this there is no evidence of there being any power, virtue, or significance in any one number considered in itself.

We are not even inclined to look upon these recurrent numbers as implying any mysterious connexion, as theosophists have supposed, between objects which have the same number attached to them. We do not conclude that there is a connexion between the typical organs of dicotyledonous plants and the digits of animals, because they both range round the number 5. Nor are we to look upon biblical events as related, solely because they appear under the same number. It is possible, indeed, that the events may have a connexion in themselves, and have both appeared under the same number because of this connexion; but the evidence of their relation must be sought otherwise than in their numerical correspondence. In vindicating the existence of these numerical relations, we are thus, at the same time, laying an effectual arrest on the abuse of them. We do not admit them in natural science, except on evidence which can stand the rules of inductive logic; and we should not allow them in theology, except on grounds which can stand the tests of sound biblical interpretation.

SECT. III.—TYPICAL SYSTEM OF THE NEW TESTAMENT.

In looking at any one epoch of our world's history, we find traces of contemporaneous order and fitness. In comparing any one epoch with the preceding one, we find traces of a progression. It should be admitted, however, that we are not altogether in circumstances to determine the character of that progression. In physical and organic nature, it seems, so far as we can discover, to be an advance from the simple to the manifold ; from the more general to the more special ; from the type to the archetype. It rises from the crystal to the plant and the animal. Its foundation shows right lines and regular figures, while the superstructure sweeps out into varied curves. There is first the simple capacity in the germ, the bud, and then the unfolding of all the capabilities in distinct members.

Is not this the very law of the advance of the human mind? It begins with the simple and goes on to the multiple. It craves first for mere milk, and then acquires a relish for strong meat and varied dainties. In their literary tastes, men like first very easy and transparent narrative in prose, and songs with the simplest cadences ; then more elaborate prose and more adorned poetry ; and finally, perhaps, a style, to use the language of Burke, between prose and poetry, and better than either. Is not the history of human civilisation an advance from a union of labour to a division of labour ; from few and simple to many and complicated relations? Is not the advance in physical science (as M. Comte has shown) from pure space to body, to bodies with chemical affinities, on to bodies organized?

It is evident that there is some kind of progress in the history of religion, though we are not in a position to apprehend it closely, or unfold it fully. All the essential and saving truths are embraced in the earliest revelation of God, but they are in the bud, they are hopeful and prophetic ; it is only as ages advance that they are expanded to the view. Under the Old Testament the shadow becomes more and more defined as the substance draws nigh ; but it is only in the later prophets that we discover distinct lineaments. The figure presented in the first prediction is as large as it ever is afterwards, but its lines come out more and more distintly as the light approaches nearer and nearer. The doctrine which we are expounding, be it observed, is not the vulgar one of type and antitype, but that of typical forms, serying immediate and important ends in the age in which they appeared, but, at the same time, epitomes of an archetype to appear. When the Archetype presents Himself, what had before been dim is now distinct. In the scene on Calvary, in particular, we have the truths which the sinner is most concerned to know, of sin and salvation, of God offended and God pacified, set forth in the most awfully, and yet most winningly, impressive manner.

There seems to be the very same order in the mode of communicating the truth. First, there are symbols of various kinds, then prose narrative and poetry with simple correlations, then richer and more varied poetry, and, when we come on to the New Testament, interesting narrative, with interspersed spoken discourses with numberless parallelisms and most graceful curvatures, leading on to more elaborate and logically constructed prose, and the whole closing with a book in which prose, poetry, and symbol are combined.

And we are not to understand that the scheme of types, as we have explained it, disappears on the appearance of Christ, or with the close of the inspired canon. The continued operations of Christ in the Church are typical. Let us compare what He did when He walked on the earth in His human person, with what He is still doing on our earth as He walks spiritually in the midst of the lamps which He has kindled. His miracles, which attested His divinity, did not consist in ostentatious displays of power; in meteors flashing across the sky; in rivers, running backward to their source; in mountains being shaken to their centre; or in the moon wandering from her orbit. The testimony was to His love and compassion as well as His power. "The blind receive their sight, and the lame walk; the lepers are cleansed, and the deaf hear; the dead are raised up, and the poor have the Gospel preached unto them." Of a like type are His operations still. They do not consist in displays of physical power;—but in opening the eyes of the spiritually blind; in putting activity into those in no way disposed to the service of godliness; in curing all manner of soul-maladies; in gaining access to the most obdurate hearts by the power of His Spirit. We do not affirm that the one set of acts predicted the other—we venture on no such statement; but we maintain that both are after the same figure, that both originate in the same peculiarities of character, and that both are addressed to us as homotypal correspondences.

We still live under a system of types. Just as all the figures in the Old Testament look forward to Him who is the principal figure, so do the figures in the New Testament look back to Him. But there is this difference between the former and the latter types, that the latter, as becometh the dispensation, are not so much outward and ceremonial as inward and spiritual. There is a close mystical union between Him and each of His people; He and they are said to be one. They are one in respect of their human nature; "It behoved Him to be made like unto His brethren, and, forasmuch as the children are partakers of flesh and blood, He also likewise took part of the same;"—"He took on Him, not the nature of angels, but the seed of Abraham," and "was made in the likeness of man." He has become, too, the "head of the body, the Church," "the beginning, the first-born from the dead," and is the "first-born among many brethren." They are priests under Him as Chief Priest, kings under Him as Sovereign. By his appointment they are "predestinated to be conformed to His image." The Godhead once more issues the decree in reference to this man and to that man, "Let us make man in our image, after our likeness,"—so "God creates man in His own image, in the likeness of God creates He him." In the performance of this decree, they "suffer with Him," are "crucified together with Him," are "dead with Him," "buried with Him," and as they die with Him, so they are "quickened with Him;" they "rise with Him," and "reign with Him." In this household there are many children, and there are differences between them of gift and taste to suit them to their different heaven-allotted employments; but still we may discern in them all a family likeness, and the image of Him who hath begotten them. In this perfect system of types, the whole has a representative in every part, and every part is a symbol of the whole. Each living stone in this temple is carved after the similitude of the whole temple. He is the body, and every member in particular is after the pattern of the whole body. Each branch, each leaf of this Tree of Life, is an image of the entire tree.

With such patterns in the past and in the present, the disciple may everywhere be instructed. But let him remember, meanwhile, what is the object to which he should chiefly look. It is pleasant to see the path in which we walk trodden by the footsteps of the flock, but we are to follow the flock only so far as they follow the shepherd. In Him we have the image of the invisible God set before us in such a way that we can rise to a somewhat clear, and an altogether satisfactory apprehension of His character. It is when the soul is spread out before Him, and directed towards Him, that His likeness is imprinted—as by a sunbeam process, upon the tablet of the heart. Looking to Him, as lifted up upon the cross, we learn of Him the lessons which we have most need to learn—we learn of Him to be meek and lowly. A similar change, but differently produced, shall take place in heaven. In the Old Testament Church they had the shadow; in the New Testament Church we have the image; in heaven we shall have the substance—which as we behold, we shall be brightened into a likeness to His glory—"we shall be like Him, for we shall see Him as He is."

It appears, then, that in the New Testament Church there are post-figurations; but there are also pre-figurations. In spite of many partial relapses, the Church, as a whole, is advancing, and its past progress is but an earnest of its future progress till it cover the earth. As it advances, if not so simple, or perhaps so pure, yet it is richer and fuller, and shall inspire and fashion a greater diversity of character and of phases of life, and, at the last, all the accumulated stores of wealth, civilisation, and intellect, shall be cast into the treasury of the Lord.

When objects lie far distant from us, we must be on our guard against taking brightened clouds for sunlit lands; but we think we see some real truths, lying, we grant, on the very horizon of our vision. All animal bodies point to man as the apex of the earthly hierarchy. Professor Owen tells us that "all the parts and organs of man had been sketched out, in anticipation, so to speak, in the inferior animals." But may not this highest form on earth point to a still higher form? Man's body on earth may be but a prefiguration of his body in heaven. "But some will say, How are the dead raised up, and with what body do they come? The Apostle does not give a direct answer to this question, but he points to certain analogies, or rather homœophytes, which shew that while the body preserves its identity, it will be changed into a nobler form, as the seed is changed when it springs up as a plant. "It is sown a natural body, it is raised a spiritual body; for there is a natural body and a spiritual body," and we read of bodies "terrestrial," and of bodies "celestial." In heaven, then, our bodies are to be after a higher model, "spiritual" and "celestial." It doth not yet appear what we shall be, but being planted in the likeness of His death, we shall also be planted in the likeness of His resurrection, and when He appears we shall be like Him. Our bodies shall then be fashioned like unto His glorious body, which we may conceive to be the most sublimated and obedient form and modification of material agency;—and modern science, while it cannot efface the indelible distinction between mind and matter, is every day enlarging our conceptions of the capacities of matter. Thus, the simplest organism points by its structure upward to man, and man's earthly frame points to his heavenly frame, and his heavenly frame to Christ's spiritual body—and we see that all animated things on earth point onward to His Glorified Humanity as the grand Archetype of all that has life.

Professor Owen has another idea. He supposes that in other worlds, as there are the same laws of light and gravitation as on our earth, there may also be like organic structures: "And the inference as the possibility of this vertebrate type being the basis of the organization of some of the inhabitants of other planets, will not appear so hazardous when it is remembered that the orbits or protective cavities of the eyes of the vertebrata of this planet are constructed of modified vertebræ. Our thoughts are free to soar as far as any legitimate analogy may seem to guide them rightly in the boundless ocean of unknown truth. But if censure be merited for here indulging, even for a moment, in pure speculation, it may, perhaps, be disarmed by the reflection that the discovery of the vertebrate archetype could not fail to suggest to the anatomist many possible modifications of it beyond those we know to have been realized in this little orb of ours."

If there be any truth in this idea, then the animated matter of other worlds may point to the same Archetype as the animated matter of this world. And on the supposition, what a significancy would be given to the humanity of our Lord! When the Word became flesh, the Divinity was in a sense humbled; and when the Incarnate Word ascended into heaven, flesh or matter was exalted, and made to serve the most glorious ends. We thus obtain a glimpse of a way in which matter, throughout all its domains, may be exalted by its association with the Son of God taking our likeness; and of a way, too, in which other worlds, or all worlds, and other creatures, even principalities and powers in heavenly places, may be instructed by this "manifold wisdom," and by which God may "by Him reconcile all things unto Himself—by Him, I say, whether they be things in earth, or things in heaven."

But as we stand gazing on our ascending Lord, a cloud wraps Him from our view, and we hear, as it were, a voice saying, "Why stand ye here gazing?" and bidding us return to the observation of things clearly within the range of our vision.

APPENDIX.

SELECTED LIST OF PLANTS,

ILLUSTRATING ASSOCIATIONS OF COLOURS, AND RELATIONS OF FORM AND COLOUR.—(P. 166.)

DICOTYLEDONS.

Ranunculus repens, .	Corolla yellow; purple on calyx, on leaf-stalks, and on leaf-sheaths.
R. bulbosus, . . .	
R. nemorosus, . .	Corolla yellow; tips of young sepals purple.
Nasturtium Indicum, .	Corolla yellow; tips of sepals purple.
Cheiranthus alpinus, .	
Viola Curtisii, . .	Flowers yellow and purple.
V. lutea, ...	
Saxifraga ligulata, .	Corolla white, with purple spots; the yellow anthers lie on the purple spots.
S. sarmentosa, . .	Two petals white; three are spotted with purple, and are yellow at the base.
S. Aizoon, . .	Leaves yellow-green and red-purple; corolla yellow and purple; ovary first yellow-green, then red-purple.
Cytisus Laburnum, .	Four petals yellow; the fifth is yellow, with a purple spot,
Anthyllis vulneraria, .	Corolla yellow; tips of calyx purple.
Lathyrus pratensis, .	Corolla yellow; the odd lobe with purple veins.
Kennedya monophylla, .	Four petals purple; the odd petal has a yellow spot.
Cytisus scoparius, . .	Flower yellow; the odd piece has purple streaks on the inside.
Lotus corniculatus, .	Calyx yellow-green, and red-purple streaks; odd lobe of corolla yellow, with purple on the outside.

Swainsonia purpurea, .	Corolla red-purple; odd lobe with a white eye.
Hieracium Pilosella, .	Flower yellow, outer surface of ray purple.
Aster acris, A. spectabilis, A. cordifolius, A. Novæ Angliæ, ...	Centre yellow, circumference purple.
Rudbeckia fulgida, .	Centre purple, circumference yellow.
Corvisartia Helenium, .	Circumference and centre yellow; inner scales of involucre red-purple, outer scales yellow-green; stems red-purple, foliage yellow-green.
Gloxinia grandis, . .	Odd lobe of corolla red-purple inside; calyx yellow-green; stalks red-purple.
Ajuga Chamæpitys, .	Flower yellow, with purple on odd lobe.
A. pyramidalis, . .	Flower purple, yellow spot on odd lobe.
Galeopsis Tetrahit, .	Odd lobe yellow and purple.
G. versicolor, . .	Odd lobe yellow and purple.
Melittis grandiflora, .	Flower yellow, purple on the odd lobe.
Antirrhinum Orontium,	Flower purple, yellow on the odd lobe.
Euphrasia officinalis, .	Corolla purple streaked, yellow on the odd lobe.
Linaria Cymbalaria, .	Corolla purple, odd lobe with yellow spots and yellow hairs.
Schizanthus purpureus,	Odd lobe of corolla yellow and purple.
Sarracenia purpurea, .	Pitcher red-purple and yellow-green.
Rumex pulcher, . .	Anthers purple below, yellow above.
R. Acetosa, . . .	Perianth red-purple and yellow-green.
R. aquaticus, . .	Stem red-purple; dense masses of yellow-green flowers; the latter have sometimes red-purple streaks.
Pinus sylvestris, and other Coniferæ, . . .	Young cones purple and citrine.
Ficus elastica, . .	Buds red-purple, leaves yellow-green.
Drimys Winteri, . .	Young shoot red-purple, young leaf yellow-green.
Taxodium sempervirens,	Young shoot yellow-green; more advanced, red-purple; when older, it is citrine.

MONOCOTYLEDONS.

Lycaste Skinneri, . .	Sepals, outside yellow-green, inside red-purple; two upper petals white, or yellow with purple spots; third petal yellow and purple spots.

Brassia verrucosa, .	Sepals and two upper petals yellow-green and red-purple; third petal white, with green warts and yellowish eye; flower-stalks purple.
Oncidium Cavendishii, .	Third petal yellow and purple.
Epidendrum cochleatum,	Third petal yellow and purple.
Lycaste aromatica, .	Third petal yellow and purple.
Cattleya Loddigesii, .	Third petal yellow and purple.
Oncidium Papilio, .	Leaves red-purple and yellow-green.
Cypripedium venustum,	Petals yellow-green and red-purple; bract yellow-green, with red-purple line on the midrib, and one near each margin; ovary yellow-green, with red-purple lines corresponding to the adherent edges of the pieces of which it consists.
Listera cordata, . .	Flowers red-purple and yellow-green.
Iris pseudacorus, . .	Flower yellow, with purple streaks; stamens variegated with purple.
I. Germanica, . .	Calyx yellow and purple; corolla purple; pollen yellow.
I. Tricolor, . . .	Petals yellow; sepals yellow and purple.
Pandanus odoratissimus,	Teeth and edge of leaf red-purple, centre yellow-green.
Caladium pictum, . .	Centre of leef red-purple, edge of leaf yellow-green.
Strelitzia, several species,	Leaf yellow-green, leaf-stalk red-purple; sepals orange; petals blue.
Curcuma cordata, and C. ovata, . . .	Tip of bracts red-purple, base of bracts yellow-green; flower yellow.
Juncus compressus, .	Flower russet and green.
Avena pratensis, . .	Glumes citrine, with purple streaks and purple awn; anthers yellow and purple.
Papyrus antiquorum, .	Sheaths red-purple; stalks yellow-green.