THE PHILOSOPHY OF EVOLUTION.

In 1837, Hannah Acton of Euston Square, in memory of her late husband Samuel Acton, invested one thousand pounds in order to carry out her husband's wish, that "The Royal Institution of Great Britain should be enabled to extend and diffuse useful knowledge," with the condition that a prize of one hundred guineas should be given every seven years for the best essay "illustrative of the Wisdom and Beneficence of the Almighty, in such department of science as the Committee of the Royal Institution should select," leaving it in the discretion of the same Committee to withhold the prize if no essay be presented entitling its author, in their opinion, to such a reward.

At the last septennial period the prize was withheld; and hence two prizes were offered for the two best essays presented in 1872. The present essay was one of those selected by the Committee at that time. The other successful essay was written by the Rev. George Henslow.

THE

PHILOSOPHY OF EVOLUTION.

(AN ACTONIAN PRIZE ESSAY.)

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PREFACE.

In presenting the following pages to the public, the author wishes it to be understood that he does not expect to convert any to a belief in evolution. He addresses those who accept the doctrine in some form or other as established, although he has endeavoured, as concisely as possible, to present the reader with the reasons for accepting it. Those who remain unconvinced by the elaborate works of Darwin, Spencer, and others will probably not accept the views enunciated in these pages, which, however, it is hoped, will not be unacceptable to many who wish to reconcile the theory of evolution with the highest aims of human thought.

Neither does the writer of the present essay claim a place for it with the more solid works of original research quoted by him. The facts are, with few exceptions, widely known, and will be found in the works referred to. Many of the views are perhaps original, or have not, at least, been published to the author's knowledge; and for these he alone is responsible. To some, the chapters on the mode of evolution of the higher forms will appear too hypothetical; but they are presented only as hypotheses, and the reader will be enabled to judge how far the facts referred to in corroboration of the views expressed justify them.

The author has endeavoured to give the theory of evolution from the point of view of a physiologist as well as of a naturalist. He has attempted (it is to be feared insufficiently) to acknowledge his obligations in a list of works referred to as well as in footnotes, but would not omit on the present occasion to thank those numerous friends who have for years aided him in the prosecution of his favourite studies. Acknowledgments are especially due to Sir James Paget, Mr. Savory, Dr. Hooker, and Professor Flower, for their past teaching and ever ready advice.

Colville Gardens, W.
May 12, 1873.

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PART I.

CHAPTER I.

EVOLUTION AND CREATION.

Two hypotheses are current concerning the origin of living beings:—one that each species has been separately created for the fulfilment of special adaptations to surrounding circumstances; the other that each species has been gradually evolved or produced by the action of surrounding circumstances from an anterior and simpler form, that all animals and plants have arisen from one or more prototypes, and that their origin was in common with all the other various kinds of matter out of which our globe is formed.

Each of these hypotheses has its own supporters; each has from time to time been attacked, by those who believe in the other, as absurd and untenable. The first theory (that of special creations) is more largely received, from a general impression that the "Doctrine of Evolution," as the second hypothesis is called, is atheistic in its tendency, and because it is supposed to be in direct antagonism to Revelation.

With regard to the first objection, that the doctrine of evolution is atheistic in its tendency, it is easily shown that such is not the case.

The ultimate scientific ideas which we are able to grasp are those of *Energy* and *Matter*. That the absolute nature of these is incomprehensible, is of little moment; we recognize their existence. From the action of energy on matter and of matter on energy, Evolution results—a marvellous and complex NATURE arises. Matter in all its phases, which are innumerable, is correlated with energy, and energy in all its relations is correlated with matter; and the result of these correlations is an harmonious and beautiful universe, capable of having its laws and relations comprehended, to some degree at least, by intelligent Man. The teleological school have always held that the adaptations of special means to special ends is in itself evidence of an intelligent Creator; but surely the adaptation of energy to matter to the end that a universe shall arise is infinitely higher evidence! The adaptation of one great means to one great end is undoubtedly a grander and vaster conception; for as in the former we conceive the great Creator acting in a manner peculiarly human, in the latter conception we realize with Malbranche "that God desires that his conduct as well as his work should bear the character of his attributes: not content that the universe honours him by its excellence and beauty, he even desires that the means he uses should glorify him by their simplicity, their fertility, their universality, and their uniformity"*. How much more consistent is the belief that creation was complete at its birth and possessed within itself at the first moment all that the past has developed and all that future ages will bring in their progressive course, than that it is capable of improvement at intervals by new creations.

An objection will be urged by some against these views that if the universe has been so created, the Creator has ceased to act and influence creation. Such an objection is unscientific; for as time is only relative and only affects creation, it can in no wise be conceived to influence an eternal Creator †.

The hypothesis of evolution establishes in our minds the ultimate scientific ideas of *Energy* and *Matter*, with their relations of sequence or *time* and of distance or *space*, as the only ultimate scientific

* Malbranche, 'Ninth Conversation on Metaphysics,' sect. x.

† This view is given by Jules Simon, in his 'Natural Religion,' p. 160.

ideas. We learn that all changes of condition are due to a cause; and thus we are compelled to believe that a first cause exists: this is the ultimate religious idea. We may hold this belief without inconsistency; for as we know of but two ultimate modes of existence (Energy and Matter), we cannot know that the law of Causation exists beyond them.

Hence, whether organisms were evolved or whether they were created in the form in which we now see them, it is equally absurd to disbelieve in the existence of an adequate cause; and although we cannot know the nature of the first cause, we learn that its effects are intelligibly correlated. Again, though the theory of evolution explains to us how organisms have arisen, it can teach us nothing of the why. The purpose of creation remains as inscrutable as ever

With regard to the second objection (the supposed antagonism of Evolution to Revelation), it has long been conceded that it is impossible to test Science by Revelation; indeed it would be as reasonable to object to established astronomical facts on this ground as to the doctrine of evolution.

The hypothesis of evolution is supported by facts, analogy, and reason; whilst that of special creations is unsupported, and would have few adherents if the facts were calmly and dispassionately viewed. It would then appear, most undoubtedly, that the theory of evolution, although at first apparently antagonistic, on a limited view, to the doctrines of religion, when viewed by an unbiased mind in its largest relations affords the firmest basis on which religion can possibly rest. Those who object on the ground of religion should remember that the theory explains the purpose of the constant struggle for life, with all its concomitant pain, which we continually see around us; it shows how good arises from all the so-called evils of existence, as these are the means by which perfection is attained*.

* This subject is treated of at great length by Mr. Spencer, in his 'Principles of Biology,' part iii. cap. ii.

CHAPTER II.

THE NATURE OF THE EVIDENCE WHICH CAN BE ADDUCED IN SUPPORT OF EVOLUTION.

Before passing to the consideration of the evidence of Evolution, it will be well to consider the nature of the evidence which can be adduced. When the details of the hypothesis are under consideration, it will be found that evidence of modification under existing influences is abundant, and that the inference that such changes have a wider scope of action is the only inference which is not supported by direct observation. The inference that such changes have taken place in the cases to which they have been extended by the hypothesis is borne out by its explaining a vast number of complicated phenomena. These phenomena are inexplicable on the other received theory (that of special creations); or they are thought to be explained by the addition of hypotheses which are not the result of inference from known facts, but which are merely known facts stated in other words, or generalizations of the facts themselves. For instance, it is said that rudimentary organs exist in conformity to a type;

and this is only a generalization and not an explanation of the facts. It is merely the restatement of the existence of rudimentary organs in other words.

It is often said that we are not justified in receiving an inference as true because it explains a large number of facts. Let us examine how far this is the case. Suppose an inscription were found in an unknown language, and that a single sentence occurred repeatedly in the inscription, together with numerous subordinate sentences or clauses which were different in each case, but nevertheless always predicated something of the main subject. Let us conceive that some of the subordinate sentences were made out by a knowledge of a language similar to that in which the inscription is written. Let us then suppose that an hypothesis is framed as to the meaning of the main sentence; it is quite possible that this hypothesis may be entirely erroneous, and yet the relation of the subordinate sentences which occur in conjunction with it may become apparent by virtue of the hypothesis. Imagine, for instance, that the inscription refers to an Ibis embalmed by the ancient Egyptians; and that the main sentence describes the existence of this Ibis, whilst the subordinate sentences describe its attributes and the process of embalming. Let the hypothesis be that the main sentence relates to a king, and it is quite possible that the whole might appear perfectly congruous when read. Here we have a clear case in which the hypothesis would not be justified by its explanation of the inscription: numerous facts, the nature and relations of the words in the inscription, would be explained by an untrue hypothesis.

Exactly such a case occurs in the hypothesis that explains the nature of light by the supposed existence of an æther. A large number of observed facts are united and explained; but we do not know that they could not be otherwise explained. If the æther be proved to exist by the accelerated periods* of Encke's comet, as Mill † has already stated, the induction is greatly strengthened; but it is not rendered certain, because it is possible that the æther is not the cause retarding the motion and so accelerating the periods of the comet. The analogies between light and sound, and the impossibility for sound to pass through a vacuum, still further substantiate the theory; but it cannot be considered proven until the existence of the æther be demonstrated.

Let us revert to our illustration, and suppose that the inscription has been interpreted by the similarity

* Encke's comet passes through its orbit in less time in each succeeding revolution, owing to its continually diminishing tangential force and consequent gravitation towards the sun. Its retarded motion produces contraction of its orbit; and its periods are thus shortened.

† Logic, vol. ii. p. 19.

of most of the words in it to those of an existing language. Imagine the inscription to have been quite incomprehensible until an hypothesis was framed that it was written in an ancient language differing from some known language in certain letters. Let us assume by hypothesis that certain letters have been replaced by others, and suppose an intelligible reading results from the application of this hypothesis. Will any man doubt its truth if the inscription is at all complicated? Is it possible that coincidences should permit an inscription to be read in this manner? And is not the reading of the inscription sufficient proof that the real clue has been found? The answer to these questions is obvious; and a very little consideration will show that the chances against any such coincidences, even in a single sentence, are almost infinite.

Yet the only evidence of the truth of the hypothesis is its explanation of the facts of the inscription by the application of known laws. Languages are known to change in the manner supposed, although the particular language may not have been known to have changed. In this case the hypothesis is proved, because it is inconceivable that the inscription could have been read if it had not been written in the manner asserted.

Let us now compare this case with the one before us. Organic nature is a complex inscription; we know that certain animals and plants undergo modification under changed conditions; we frame an hypothesis that other animals and plants have been similarly changed. We find that we can read the inscription by this hypothesis; that is, numerous and complex facts are explained by it. We make no inferences, except by extending known laws and known changes to cases in which they are not known to have occurred. We know that by selecting certain horses we have bred the race-horse and the cart-horse from a common stock. We know that for every hundred or every thousand creatures born, but few survive. We see that the strongest and best-adapted creatures survive in some cases. We infer that the stock from which we modified our race-horse and our cart-horse was modified by nature, in the struggle for life and by the "survival of the fittest," from some other less specialized form. We then discover a complete series of transitional forms in the tertiary formation, evidencing the modification of the horse by successive stages from a creature nearly allied to the tapir. An hypothesis framed in consonance with these facts explains a vast number of complex phenomena most satisfactorily. Some phenomena undoubtedly remain unexplained; but so many are explained that we are surely justified, as in the case of the inscription, in believing that the hypothesis is proven.

J. S. Mill apparently admits this when he says of the proof of hypotheses:—"In order that this may be the case" (that the hypothesis be proven), "I conceive it to be necessary, when the hypothesis relates to causation, that the supposed cause should not only be a real phenomenon, something actually existing in Nature" (i. e. *known to exist*), "but should be already known to exercise, or at least be capable of exercising, an influence of some sort over the effect. In any other case it is no evidence of the truth of the hypothesis that we are able to deduce the real phenomena from it"*.

The sweeping assertion is frequently made that the explanation of numerous facts (*i. e.* of their causation) is no proof of the truth of an hypothesis. This, however, as we have already seen, entirely depends upon its nature.

When Mill states that an hypothesis cannot be received because it accounts for all the known phenomena, he refers solely to an hypothesis of the first kind, such as the undulatory theory of light. Even in this case it is extremely doubtful whether a false hypothesis could explain numerous and complex phenomena. It is true Mill asserts † that such are often explained equally well by two rival hypotheses. Dr. Whewell stated ‡ that he knew

* Logic, vol. ii. p. 20. † Ibid. p. 22.

‡ Phil. of Discovery, p. 271.

no such case in the history of science, where the facts are at all numerous and complicated; and there certainly is none. Such hypotheses must be looked upon, however, as extremely probable, although insusceptible of proof with our present knowledge.

Mr. Darwin, the great discoverer of some of the most important phenomena of evolution, has done his theory an injustice by comparing it with the undulatory theory of light*, seeing that he has never assumed the existence of an unknown cause or agent; he has only extended the effect of known causes to cases in which they have not hitherto been suspected of acting. The hypothesis belongs to those of the second kind, which are proved by their explanation of the phenomena to which they refer.

The cases are analogous to those of two sets of equations. One contains only as many unknown quantities as are capable of elimination, and each can therefore be solved; the other contains an unknown factor in all its terms, which can only be guessed at but not known.

Another form of argument leads us to the same conclusion; for just as every individual is gradually developed from a mere speck of organic matter, we may infer by analogy that the race has been simi-

* Origin of Species, 6th edit. p. 421.

larly developed. There are some who will object to this proposition on the ground that it is illogical. It will probably be stated by them that no analogy holds between the race and the individual; or it will be stated that this is a fallacy of generalization arising from the comparison of cases which have no parallel.

It is, however, easy for the naturalist to see that the argument is extremely strong. The analogy consists in the fact that the relation of the individual to its ancestors is similar to that of the family, race, or larger group to its; and this can be shown to be the material relation in this case.

It will be readily conceded that each individual is gradually developed from a mere speck of protoplasm called an ovum: this is an established fact; for it is true in every known case, and thousands of cases are known. A dozen, a thousand, or ten thousand individuals are descended from a single ancestor; and the ovum from which this ancestor was developed was similar to that from which the last individual is developed. Each ovum was produced by a parent nearly like its descendants, but not exactly like any, since individual differences occur throughout nature. There is no limit to this argument; for as every ovum has descended from a parent resembling its offspring in nearly every character, but not in all, it follows that the continuity of the law is inferred with a certainty which is great according to our belief in the uniformity of natural laws. If the race has not been developed, it must have arisen suddenly or have existed from all time. The last hypothesis is negatived by the strongest evidence; and the sudden origin of the race is in direct opposition to the belief that the laws of nature are uniform. This belief becomes strong in proportion to our knowledge of nature; indeed Mill affirms it to be the major premise of all induction*. Hence our belief in the development of the race becomes stronger as our knowledge of the laws of nature increases.

Again, there is abundant direct evidence of evolution. Considering the extreme imperfection of our knowledge, we can hardly expect to trace the descent of any one animal through many transitional forms; yet in one case at least there is most convincing and direct evidence of such descent—the case already referred to, the evolution of the horse from an anterior less specialized type.

The evidence is so complete that this can no longer be looked upon as hypothetical. The chain of connecting-links between the *Palæotherium* of the older tertiary rocks, through the *Anchitherium* and *Hipparion*, and the horse is too well marked to

* Logic, ii. p. 343.

admit of the existence of a doubt—not in one series of characters alone, but in the whole of those portions of the organisms that are known. As examples of this, the skeletons of the feet and the skulls of the *Palæotherium*, *Hipparion*, and horse have been selected; and figures are given (Plates VI., VII., & VIII.) which will enable the reader to form an idea of the nature of the transition between the ancient less and the modern more highly specialized forms.

Lastly, the geographical distribution of organic forms affords evidence which is but little less convincing than that of palæontology. In proof of this, nothing perhaps is more conclusive than the fact that those who are most conversant with the geographical distribution of plants are convinced of the truth of evolution. M. Alph. De Candolle, in his splendid work on the geographical distribution of the vegetable kingdom, sums up his conclusions in the following words :—

"The facts of geographical botany are, indeed, in general, clear and concordant, if we suppose, amongst flowering plants, that the most ancient of all are the majority of aquatic species and those inhabiting humid places, next many of the northern and alpine forms and most of the trees of our temperate regions, and if we suppose at the same time that the most recent species are principally found amongst the plants of tropical regions, especially amongst Dicotyledons with a gamopetalous corolla and inferior ovary, such as the Compositæ, Dipsaceæ, Campanulaceæ, &c., and, amongst other flowering plants, those with a specially complicated organization, such as Orchids, Palms, Apocineæ, Asclepiads, Cucurbitaceæ, Passion-flowers, Begonias, &c.,"—in fact, if we suppose the most ancient to be those with the least, and the most recent those with the most highly specialized parts. Mr. Bentham, one of the most learned and cautious naturalists, holds precisely similar views; and no one is more eminently fitted to form a conclusion.

The facts themselves on which these great naturalists have founded their opinions are too numerous and complicated to be given here; this is sufficiently proved by the size of M. De Candolle's work on the geographical distribution of plants, which consists of 1350 closely printed pages.

CHAPTER III.

THE RELATIONS OF ORGANIC AND INORGANIC MATTER.

Our present knowledge only permits us to speak with great caution with regard to the evolution of organic from inorganic matter. There is, however, much indirect evidence to justify a belief that it had such an origin; and this is important, since if it could be proved that organic matter had a separate origin from inorganic, it would be reasonable to believe in the separate origin of its various modifications.

Many experiments have been made with a view to prove that living things may originate *de novo* in various organic and inorganic solutions; and the hypothesis of spontaneous generation has been advocated by some, although it is indubitable that the weight of evidence has hitherto been in favour of the doctrine that no living thing can originate without the admission of living germs or seeds*.

* A careful perusal of Dr. C. Bastian's work 'On the Beginnings of Life' has failed to change the author's opinion on this point.

It is by no means, however, to be concluded on this account that living matter will never be artificially produced; for it will be seen in the sequel that the development of organisms and structure is probably a far more complex phenomenon than the production of mere structureless material capable of undergoing organization. Indeed we may confidently anticipate that such material will eventually be formed, just as sugar, alcohol, valerianic acid, and a multitude of similar organic bodies have been formed by the chemist, which were formerly believed never to originate except by the action of vitality.

Such structureless organic matter is called Protoplasm. It may fairly be looked upon as the basis from which all living creatures have arisen. Each individual is at first a mere speck of protoplasm; and the simplest forms of life retain that form throughout their whole term of existence. The most complex animal or plant consists of a mere aggregation of such minute particles variously bound together: of these some retain their primitive structureless condition, as "wander-cells" and white blood-corpuscles; and others undergo changes which alter their appearance, so that they are only recognized when their development has been carefully studied.

Protoplasm is a viscid structureless colloid, permeated by crystalloid atoms. It is very unstable in its composition, and contains the element nitrogen. It is capable of transforming energy, derived either directly or indirectly from the rays of the sun, into molecular forces, thus delaying its dissipation as radiant heat. The forces which originate in this manner, either produce movements of the mass or determine the formation of structure; they also enable it to assimilate suitable material to itself, so that its mass increases or grows. So long as these phenomena continue, it is said to live. Unless it is continually supplied with both energy and material, it soon undergoes such chemical changes that it becomes incapable of transforming energy: it is then said to die. It may, however, retain its properties indefinitely under certain conditions, when neither energy or material are supplied, if all chemical change be arrested, as by desiccation or freezing; its life is then said to be dormant.

There can be no question that protoplasm differs from all other kinds of material in the possession of certain well-marked properties, which have been enumerated above; but the same may be said of every substance in nature which has striking peculiarities. Ammonia, chloride of silver, or iron may each be said to differ as strikingly from all other kinds of matter, or at least from each other.

Although no other substance possesses all the properties of protoplasm, yet it may be confidently affirmed that none are entirely peculiar to it.

Its heterogeneous nature, partly colloid and partly crystalloid, as well as its unstable composition, may be passed over without comment; but its influence on energy requires careful consideration.

When light falls upon a surface it is either reflected, transmitted, or absorbed. In the latter case it disappears as light, its vibrations being transformed into heat. Whether this heat arises from work done in the body by the light-vibrations, or whether it is the direct result of the impact of the vibrations of light, has not been determined; but in the majority of inorganic bodies no apparent change results, even when the action of light is prolonged for a considerable time. In some cases, however, we have abundant evidence of molecular work being performed by the impact of light-vibrations. This is well seen in the processes of photography and bleaching. Light acts as a powerful deoxidizer, and is extremely energetic in its effects on certain salts. It is also capable of giving rise to rapid chemical combination, as, for instance, when it falls upon a mixture of chlorine and hydrogen gas. When light falls upon vegetable protoplasm, its energy is applied to the deoxidization of carbon and hydrogen, and the formation of such new compounds as starch, cellulose, and sugar.

Its energy is moreover applied to the rearrangement of particles and the formation of structure. Plants grow most rapidly when the sun is shining; when they grow during the night they derive the forces required for molecular rearrangements from the potential energy stored up in their hydrocarbonaceous material by its reoxidization. Neither carbon nor hydrogen can be separated from oxygen without energy being expended or rendered potential or imperceptible; and such energy is always again rendered sensible by the reoxidization of carbon-compounds.

Certain silver salts are readily decomposed by the action of light; but the process requires, or is at least much accelerated by, the presence of colloids, such as collodion or albumen. This is especially seen in photography. The deoxidization of carbon by light in the presence of protoplasm is probably a closely similar phenomenon.

Although comparatively few bodies have their molecules sensibly affected by light-vibrations, or undergo change of structure under the action of this form of energy, all substances are more or less influenced by the less rapid vibrations of heat; and just as protoplasm undergoes change, or dies, when deprived of the peculiar forms of energy to which its atoms are susceptible, so all substances would become entirely changed if they were deprived of the vibrations of heat which they continually receive from without.

No line can be drawn between heat- and light-vibrations, except by the peculiar physiological action of the latter upon the human retina: the one passes insensibly into the other. A continuous gradation of similar vibrations exists in the spectrum of an incandescent body, beginning with the most rapid beyond the extreme violet, and ending with the slowest and most intense far beyond the extreme red. Certain substances, as silver and gold salts, are most affected by the most rapid vibrations (the so-called actinic or chemical rays); vegetable protoplasm is chiefly sensitive to the intermediate vibrations of the visible spectrum, whilst most bodies are maintained in their present physical condition by the vibrations of heat beyond the extreme red. The action of energy on protoplasm is therefore peculiar in degree rather than in kind.

It has already been observed that the sun's energy may be stored up by becoming potential or latent in solid carbon and its compounds with hydrogen, and that it may be set free again by their recombination with oxygen. As Meyer, long ago, and Tyndall, more recently, have shown*, the combustion of coal gives back the energy rendered latent or potential by the plants of the coal era. Protoplasm has the power of converting potential energy derived originally from the sun's light, and freed by the oxidization of carbon-compounds, into molecular forces, which give rise to changes in its form and condition. The changes, however, which take place in a bar of iron during its oxidization, or rusting, are of a precisely similar nature: force is evolved or set free by the rusting of the iron; this force warms the metal and gives rise to molecular movements of the bar.

The capacity of assimilating suitable material to itself has long been considered a peculiarity of living matter. Its increase of mass, however, is entirely analogous to that which a piece of brass undergoes when immersed in a suitable solution (an alkaline solution of zinc and copper) and supplied with energy by means of a voltaic current. The alkaline salts of the two metals are decomposed, and the metals themselves are united into an alloy. Protoplasm, under the influence of energy, gives rise to similar decompositions and recompositions of certain suitable kinds of matter.

The fact that the nutrition of protoplasm is interstitial, whilst the accretion of new matter to in-

* Tyndall, 'Heat a mode of Motion.'

organic masses takes place on the surface alone, is often spoken of as a distinction of fundamental importance. In both cases, however, the accretion of new material takes place at the point of contact between the increasing mass and the food-material. In the case of protoplasm the food-matter is disseminated throughout the mass, whilst in the case of the brass medal the two are in contact at the surface only. The cases are quite analogous to the phenomena of combustion. In the ordinary flame this takes place on the surface only, at the points of contact between the supporter of combustion and the combustible gas; in the oxyhydrogen flame of the lime light it is interstitial, because the supporter of combustion and the combustible gases are intimately mixed.

The fact that protoplasm undergoes change, or dies, when it is either deprived of food-material or energy, cannot be used as a means of distinguishing it from other kinds of matter, since this alteration is clearly due to its chemical instability; and numerous inorganic bodies are prone to undergo similar change.

It is now well established that fish and amphibians may be frozen and kept in this condition for long periods, perhaps indefinitely; and yet, when thawed with sufficient care, they are found to be alive and to have suffered in no way by the process.

The ova of salmon have been transported in this way to the antipodes, and have retained their vitality perfectly.

To all appearance, the albumen of an egg solidified by boiling and that of one consolidated by freezing are identical; yet the two differ in this, that the former cannot be restored to fluidity without undergoing chemical change, whilst the latter readily returns to the fluid state without its composition being altered. No less an authority than Dr. Richardson* has proposed the terms "Pectous and Glacial Death" to designate these two conditions, thus recognizing their close affinity.

These and similar facts go far to show that the difference between dead and living organic matter is a chemical difference, or a difference of molecular arrangement giving rise to a change in the action of energy upon it. Exact parallels are found in the magnectic properties of iron and some of its compounds, as an alteration of chemical constitution renders these insusceptible of the influence of the magnetic force—and in the electric conductivity of copper wire, which is materially affected by its hardness and ductility.

Hence it appears that, although living matter or protoplasm is an extremely remarkable body, it is

* "A Lecture on Experimental Medicine," published in the 'Medical Times and Gazette,' Feb. 1871, p. 181.

separated by no wide impassable barrier from other kinds of matter. It is acted upon by, and reacts on energy ; but this will only distinguish it from other substances in degree, as they also are so acted upon. It increases by assimilation of suitable material ; but such increase is not entirely peculiar to it. Lastly, the difference between dead and living organic matter is probably chemical, or due to a new arrangement of atoms. Hence there is no reason to believe that protoplasm cannot have been evolved from inorganic material ; and, as we have already seen, analogy and the belief in the uniformity of Nature's laws lead us to the conclusion that it probably has been so evolved.

PART II.

CHAPTER IV.

THE NATURE AND ORIGIN OF STRUCTURE.

The tendency of protoplasm to acquire structure has already been referred to; but the acquirement of structure is not necessary for the manifestation of vitality. The simplest living forms exhibit no structure; and cells possessing the highest physiological endowments scarcely differ in this respect from those which perform no active function; indeed the latter class are often far more complex than the former. On the other hand, structure may be acquired by inorganic bodies under the influence of energy. The beautiful structure of melting ice, the crystallization of the axles of railway-engine-wheels under repeated mechanical shocks, and that of selenium under the influence of light, the fibrillation of certain minerals (as amianthus and asbestos) as well as of the blood-clot, are examples of structure arising in dead material.

Herbert Spencer * insists strongly that the tendency of all homogeneous substances to become heterogeneous, from the unequal action of various forces upon them, is a powerful cause of the origin of structure; and there can be no doubt that the various modifications of this law, which he calls "the instability of the homogeneous," are extremely potent in their action. Just as a portion of wax cools unequally, so that its periphery becomes solid before its centre, a mass of protoplasm may acquire an external envelope harder and more dense than its central portion. This is exactly the condition of the little Amœba of our ditches; and thus we have the first indication of the manner in which a cell-wall may originate.

As we have already seen, protoplasm has the power of oxidizing its food-material, and of setting free potential energy from carbon compounds. The Amœba or Proteus feeds upon such material by imbedding it in its interior; and during its oxidation potential energy is rendered sensible. This energy, by acting on the particles of protoplasm, gives rise to molecular movements. No structure is originated by the internal forces thus set free; but

* First Principles, 2nd edit. p. 401.

movements of the mass result. The external denser body-wall, which may fairly be looked upon as the result of external influences acting upon the mass, is sufficiently soft to move with the interior; and pseudopodia are pushed out and drawn in again around its periphery. If a viscid drop of caramel or burnt sugar be allowed to fall into water, the action of the water upon it forms an external envelope. Finger-like processes will then be protruded, probably from the imbibition of water by the mass; these bear a striking resemblance to the pseudopodia of an Amœba; and although their origin is undoubtedly due to a totally distinct cause, they serve to show that a force acting throughout the mass, as one may readily conceive the forces of an Amœba act, may give rise to extremely unsymmetrical processes, quite like pseudopodia.

It appears probable (although at present we have not sufficient evidence on this subject) that, if the energy which gives rise to slow irregular movements in the Amœba were pent up by the more complete hardening of the body-wall, it would either give rise to molecular rearrangements within (as it actually does in the encysted Amœba), or it would be collected in one point, thus giving rise to more energetic movements of one part of the surface. It appears probable that the production of flagella and cilia may be thus determined.

Numerous Foraminifera produce flask-like shells open at that part which corresponds to the mouth of the flask; the pseudopodia are then formed at one part of the surface of the animal only—that corresponding to the opening. This arrangement is probably not entirely due to the formation of a shell around the body of the animal, because a form of rhizopod, *Lieberkuhnia*, which has no shell, puts forth one large many-branched pseudopod, the offshoots from which form a complex reticulation around its body *. In this case the material of the central nucleus and that of its reticulate pseudopodial system are constantly changing places, a regular circulation passing from one to the other. We may rest assured that the protrusion of a single branching stolon is the result of the influence of external or internal physical conditions. The influence of currents, temperature, and light may determine the point of the viscid nucleus which is prolonged, perhaps by a directive influence over the currents of the protoplasmic matter, or perhaps by determining a polarity of its atoms.

Such a creature as this, having once acquired a body-wall, would necessarily protrude its pseudopodia from a single point; and these, it may be readily conceived, would also become altered by

* Carpenter, 'Foraminifera' (Ray Society).

the acquirement of an external hardened covering. Their reticulation could no longer take place, and the appendage would either become simple or permanently branched. Its power of movement would probably become concentrated and definite; and either a cilium or flagellum would result when the protruded portion became simple, or such an organ as the lophophore of a polyzoan with its ciliated appendages when it remained compound.

Such changes as these would certainly account for the formation of the flagellate type of infusorian from the reticulose rhizopod; and these considerations, as we have seen, afford indications of the mode in which far more complex structures have originated.

Another similar series of changes resulting from the gradual hardening of the body-wall of the Rhizopoda would lead to the formation of many points of motion on the surface. We see the steps of such a process in the perforate Foraminifera, where numerous pseudopodia are protruded from various parts of the body-mass, in the sun-animalcule, *Actinophrys*, where the pseudopodia are stiff and circumscribed by the hard external body-substance, and in many other Radiolarians (Plate III. figs. 1, 2, and 3). We are thus led to the ciliated Infusoria by an easy transition.

Future observations directed to these points will probably throw light upon this important subject; at present, however, it may be safely held that the energy set free in living matter may either produce general movements of the mass or special movements of portions of it; and as the movements become more circumscribed, they become more manifest and more rapid.

The gradual acquirement of such organs as cilia, and of other forms of structure, the nature of which will be considered in another chapter, is clearly guided and regulated; otherwise it could not have progressed in the definite and regular manner in which it has in nature, and organisms could not have attained the perfect adaptation to surrounding circumstances which they exhibit.

The laws which have so guided and regulated the evolution of the animal and vegetable kingdoms are doubtless extremely complex; but one of the most powerful, perhaps the most powerful, agent of evolution is the principle of Natural Selection, which may be fitly named, after its great discoverer and expounder, Darwin's Law.

CHAPTER V.

NATURAL SELECTION (DARWIN'S LAW).

Natural Selection "signifies the preservation of such variations* as arise and are beneficial to the being under its conditions of life"†. Mr. Darwin shows that variation exists in nature: every animal and plant undoubtedly presents individual differences. These variations are larger in some species than in others, and frequently merge so gradually and imperceptibly into the characters of a so-called variety that it is sometimes impossible to determine to which stock an individual belongs. This is well seen in polymorphic genera, such as brambles, *Rubus* (Plates I. & II.), and gum-trees, *Eucalyptus*, amongst plants, and certain beetles, *Harpalus*, and some genera of mollusks, *Brachiopods*, amongst animals. Polymorphism occurs more rarely, perhaps, amongst the more highly differentiated forms of life; but certain genera of monkeys are undoubtedly

* The term variation is used in this essay to express the deviation of an individual from its parent form; the term variety to express a greater deviation, believed by the author to be the result of accumulated variations.

† Darwin, 'Origin of Species,' p. 63.

polymorphic. In the American genus *Cebus* the various forms are ranked by some naturalists as species, by others as mere geographical races*.

Individual differences have undoubtedly a certain influence on the life of the animal or plant; this is shown by Mr. Darwin in numerous examples. The poisonous action of the paint-root (*Lachnanthes*) on white pigs, and its innocuous influence on black pigs, in Virginia, is a striking instance of this kind. It is impossible to say how slight a variation may determine the life or death of an individual in the struggle for existence and constant competition to obtain food. A slight difference of shade in the colour of a creature may render it inconspicuous, and enable it to evade its enemies; and, as we have seen, this may also correspond to altered constitution, so that it is enabled to feed on material which would otherwise have a more or less baneful influence upon it. A slight increase of strength or rapidity of growth may be of immense importance in its competition with allied forms; increased fleetness, or the special development of some organ to a slightly greater degree than in kindred species, may be of paramount importance. Such and similar advantages would certainly in many cases enable a possessor to survive in the struggle for life.

Mr. Darwin shows how man has been able to

* Darwin, 'Descent of Man,' vol. i. p. 227.

modify the horse, the dog, and the pigeon by selecting certain individuals to breed from, and justly infers that, since man has been able in a short time to produce very marked varieties by the gradual accumulation of selected variations, the much more accurate action of natural selection, which results from the agency of external conditions acting through immense periods of time has produced far greater results. The gradual accumulation of variations, whether under natural or artificial selection, is the result of inheritance or transmission to the offspring.

In order to understand fully the effect of Darwin's Law on evolution, it will be necessary to consider the laws of variation and inheritance as far as possible with our present knowledge. Variation and inheritance are undoubtedly complemental to each other, just as resistance and conductivity are in an electrical conductor: to use a mathematical expression, they are inversely proportional to each other.

As we have already seen, extreme susceptibility to undergo change (or, in other words, to vary) is the principal characteristic by which protoplasm is distinguished from inorganic matter. The power of transmitting characters truly, or without variation, is so diametrically opposed to this property, that, although hereditary transmission is so universal and powerful in its action, it must, if evolution be admitted, be looked upon in great part as a subsequently acquired character. The laws of variation are therefore those which should naturally be considered first; and from a consideration of these it is thought a clue at least to the nature of hereditary transmission may be obtained.

CHAPTER VI.

VARIATION.

Mr. Darwin has carefully pointed out that variation may be either definite or indefinite: that is, it may result directly from the definite action of some one or more conditions; or it may be the result of a slight change in numerous complex relations, so that it is apparently irregular or indefinite.

Variations in living beings may be fitly compared with variations in the weather. Thus when the temperature falls below a certain point a fall of snow may be confidently predicted instead of a fall of rain. The snow is known to result from a low temperature. It cannot, however, be predicted that a shower of rain will occur at a certain time and place in cloudy weather, because, although no one doubts that the occurrence of a shower is the result of certain physical conditions, these are so numerous and complex that rain cannot be predicted from several of them having been observed; hence showers are commonly looked upon as the result of accident or chance.

Thus definite variations occur constantly in some animals and plants under the influence of certain conditions. For instance, Mr. Gould believes that birds of the same species are more brightly coloured when living under a clear atmosphere than when living near the coast or on islands. Wollaston is convinced that residence near the sea affects the colours of insects. Many maritime plants belonging to very different families are glaucous; and others are succulent. A dry locality undoubtedly produces a thorny condition in some shrubs; and pubescence is a common result under similar conditions. The same species are often perfectly smooth in wet meadows, and covered with down in dry places.

A question of great importance arises with regard to definite variations, Are they in themselves adaptive? Is the bright colour of birds living under a bright atmosphere at the same time the result of the strong light and beneficial to the creatures which live under it? Is the hairiness of plants in dry places the result of the dryness and beneficial to plants as a means enabling them to withstand drought?

This question must be answered with great caution, since it is one of extreme difficulty. We do not know why hairiness appears in a plant in a dry place; yet it is doubtless connected with the nutritive function. But whether the hairs become of use to the plant in connexion with its growth in a dry place, or not, is probably determined by natural selection: even if the hairs are needful to the plant to enable it to withstand drought, we cannot tell that they have not gradually arisen by the survival during many thousand generations of those plants only which tend to become hairy in dry places, at least amongst those species which are frequently subjected to conditions of drought. The same may be said of most definite variations arising from external causes. For instance, certain birds and mammals become white in winter, perhaps from the direct effect of cold on certain peculiar constitutions; yet if this be so, natural selection is probably the main instrument by which the effect has been produced, those animals surviving continually which tend to become white in winter and to resume their coloured coats in the ensuing summer; for it will be readily conceded that assimilation to the colour of surrounding objects is an important means of concealment.

There are, however, another set of changes which arise from the direct effect of internal conditions connected with certain laws of nutrition, which are undoubtedly adaptive in their nature. These formed the basis of Lamarck's hypothesis, and have probably been great factors in the origin of the forms we see around us, although of late their importance has been, to a great extent, lost sight of. Such are :—the tendency of tissues to become developed by use; the increase in the size of bones, and of inter-muscular septa and ridges of bone, with increased development of muscle; the hardening of the skin from the action of external agencies, by hypertrophy, to enable it to resist external influences. Such are the induration of the blacksmith's hand by labour, and the broadening of the palm to produce a more effective grasp.

Indefinite variation chiefly differs from that which is definite in not affecting numerous individuals in the same locality, and in its much slighter degree. Individual differences are of this kind. It is indubitable that the occurrence of grey, blue, or dark eyes, or dark or light hair in an individual depends on conditions; yet no one can say on what special conditions. As we have already seen, individual differences are sometimes as considerable as definite variations; this is especially seen in polymorphic genera.

With regard to the question, are indefinite variations adaptive? the same answer must be given as in the case of definite variations, as one merges into the other by numerous transitions: it is probable that many individual differences connected with the nutritive function are the result of use and disuse, and are therefore adaptive. This materially lessens the difficulty of understanding the evolution of many complex organs, and abridges the time which must have elapsed during their formation. The relation, however, of nutrition to evolution will be subsequently considered*.

Organisms vary greatly in their susceptibility to undergo variation; some vary so slightly, and others so considerably under the same conditions, that one is constrained to believe that the amount of variability exhibited by any species is due to constitutional influences. Hence organisms may be spoken of as exhibiting various degrees of plasticity † or rigidity.

Mr. Darwin very justly attributes the greater part of the modification of species by natural selection to the gradual accumulation of slight, usually indefinite, variations. He does not, however, appear to recognize that plasticity, or the power to vary, may be increased as well as diminished by natural selection, although this latter fact is undoubtedly admitted by him; for he says, when speaking of highly modified organs occurring in species the allies of which have the same organs considerably less developed, "such organs must have gone through an extraordinary amount of

* Chapter X.

† Capable of being moulded, modelled, or fashioned to a purpose.

modification since the genus arose; and thus we can understand why they should often still be variable in a much higher degree than other parts; for variation is a long-continued and slow process, and natural selection will in such cases not as yet have had time to overcome the tendency to further variability and to reversion to a less modified state"*.

In the opinion of the author there is abundant evidence that plasticity, or the power to vary, is transmitted from generation to generation like any other hereditary character. The most variable individuals, if paired, probably produce the most variable offspring, just as the long slender individuals, when paired, produce long slender offspring. Every constitutional tendency is known to be hereditary to a greater or less degree. The greater variability of domesticated animals and cultivated plants, as compared with wild forms, is probably due to the unconscious selection of the most plastic individuals. Those which vary most either definitely or indefinitely (that is, those which are most readily influenced by external or internal conditions) are the most plastic. The variation of such is most distinctly marked; and they are therefore selected for breeding; hence the most plastic are unconsciously selected.

* Origin of Species, p. 132.

It may be that the extreme increase of plasticity which would originate in this manner from the continual pairing of the most variable individuals (that is, those presenting extreme variations) causes the great delicacy of constitution so apparent in highly modified forms produced artificially. These are especially liable to give birth to malformed young; and it requires great care and attention to rear their offspring. Slight causes acting on an abnormally plastic organism produce changes which are incompatible with life or health; and the embryo is often so irregularly developed that it is incapable of living after separation from its parent. A single cross, probably by diminishing the plasticity of the organism, often improves the stamina of such breeds materially.

In nature such excessive plasticity is rarely, if ever, acquired; and this is probably due to constant crossing of the more by the less variable individuals, as well as to the fact, strongly insisted on by Mr. Darwin, that great deviations from the normal type could probably scarcely ever be useful in a complex animal, all the parts of which are, so to speak, nicely balanced against each other.

Just as selection of the most variable forms would apparently lead to increased plasticity, so the selection of the least variable would probably lead to rigidity of the organism. This would occur whenever rigorous selection has perfected any part, and the conditions of life become fixed and constant. In this case the species would flourish as long as its surroundings remained unchanged; but extinction would probably follow any rapid or considerable change in its conditions of life, since, from the gradual elimination of plasticity, it would be little adapted to withstand even slight changes which require modification of structure.

Individuals belonging to any species which has not been subjected to changed conditions for long periods of time would tend to become rarer as soon as any change occurred, from loss of plasticity. Frequent crosses with other slightly different individuals, by introducing slightly different conditions, would, on the other hand, favour the occurrence of plasticity. This view accounts for the great benefit resulting from crossings with other individuals, and the greater variability of mongrel races. The vast number of peculiarities of organization which exist in nature to ensure cross fertilization in plants and hermaphrodite animals shows the high importance of its influence on the race.

Widely spread and common species are the most variable *; variability, as we have seen, is the direct result of changing conditions acting upon a plastic organization. Species are probably common

* Darwin's 'Origin of Species,' p. 42.

and widely spread from their plasticity; and this plasticity would be the result of frequent crossings between individuals slightly different from each other, and of continually changing conditions which have followed continuously upon those by which the species was first determined in its descent from a primitive type.

The species of large genera are more variable than those of small genera*; and this is probably to be accounted for in the same manner: the genera are large and wide-spread because they are plastic.

In complex organisms the different organs of the body present very various conditions of plasticity; those which have been most rigorously selected under unchanged conditions vary least. As Mr. Darwin has pointed out, rudimentary organs, secondary sexual characters, as sexual ornaments and organs of offence and defence, present only in one sex, are extremely variable; such parts have not, at least in many cases, been subjected to the searching influence of natural selection.

Organs which are highly developed in one species, but less developed in all the allied species, as we have already seen, tend to become highly variable; such organs bear indications of having been recently developed by the natural selection of those

* Darwin's 'Origin of Species,' p. 44.

individuals which presented them largely developed, or possessed a higher degree of plasticity in those parts. Lowly organized structures retain much plasticity from their tendency to vary never having been checked by selection. Such forms are probably never as variable as those which are undergoing rapid modification; but it is extremely difficult to judge of the amount of variability in very different forms of life. Where few characters exist, the variability of one is liable to be regarded as of undue importance, when compared with the variation of a single character in organisms presenting a great number of special organs and highly differentiated parts.

Of all organized beings, man is probably the most easily influenced and modified by the action of external and internal causes. The human species, and especially the higher races of man, are the most plastic of all animals. No creature probably presents such strongly marked individual differences. The races of mankind are most distinct; and man is able not only to accommodate his organism to a great range of conditions, but is likewise endowed with extreme delicacy of constitution, at least in his most highly developed or civilized form; and diseases of far more manifold types are the result, as well as far more frequent and serious deviations of development, even when compared with the more plastic domestic races of animals.

This great plasticity is probably due to the rapid stages by which his organization has progressed, especially amongst civilized races, where those individuals whose intellectual faculties vary most in the direction of acuteness and quickness of action are greatly favoured in the struggle for life: hence, probably, that undue plasticity of the brain by which insanity is ever on the increase amongst highly intellectual races. No man versed in history and mental disease can for a moment doubt the insanity of such men as Caligula, Nero, Domitian, and Commodus, or the fact that they were the descendants of the greatest families of a race which had culminated with excessive rapidity.

It would therefore appear that rapid modification, by the selection of the most variable and therefore the most plastic forms, increases plasticity, and that want of variation in the conditions of life tends towards the establishment of rigidity as soon as the organism becomes adapted to the conditions around it. Hence *changed conditions are of the highest importance in causing variability.*

Two other conditions are believed to affect variability to a great degree, excess of food and long-continued transmission. Andrew Knight believes that variability is in some way connected with excess of food; and the opinion is held pertinaciously by most breeders, that a character becomes fixed by long transmission: both these opinions, however, will be more conveniently discussed in the next chapter.

CHAPTER VII.

INHERITANCE.

It is no part of the present plan to prove the great generality of the transmission of characters from the parent to its offspring. In all ordinary cases it is a matter of common observation that each kind produces young like itself; amongst breeders it is a deep ingrained belief that all characters, both normal and abnormal, are inherited; and Mr. Darwin, whose minute acquaintance with the subject entitles him more fully than any other to express an opinion, says :—" Perhaps the correct way of viewing the whole subject would be to look at the inheritance of every character as the rule, and its non-inheritance as the anomaly " *.

Inheritance is apparently such a mysterious power, that it requires no slight mental effort to view it as a mere expression of the fact *that all variation is limited.*

Before entering upon the consideration of inheritance viewed in this light, it will be necessary to attain some definite ideas of the relation subsisting

* Origin of Species, p. 10.

between the parent and its offspring. As this subject is one of great complexity, and as it will be considered at some length in another chapter, it will be sufficient for the present to regard the offspring as a portion separated or broken off from the parent. In the simplest forms of life, as in the Amœba and Rhizopoda generally, this is strictly true, the parent mass merely divides into separate portions as it increases in size; and in cases of reproduction by gemmation or budding the same relation subsists. In sexual reproduction the case is far more complex; but there is abundant evidence * that the transition from buds to ova is very gradual; and that from agamo- to gamogenesis is far from abrupt. The great difficulty lies in the comprehension of the process of development, rather than in that of hereditary transmission; and the consideration of this subject will be entered into in the next chapter.

We have already seen that the plasticity, and therefore the variability, of an organism may be greatly modified by natural selection. It must not be supposed, however, that all inheritance is ascribed here to such loss of plasticity; great deviations from any acquired form and structure are probably prevented by far more definite causes;

* Darwin's 'Animals and Plants under Domestication,' vol. ii. p. 358.

and the consideration of these must now engage our attention.

It has already been shown that structure probably originates from the definite action of forces upon structureless living matter (Chapter IV.); and a simple illustration will show us how the acquirement of structure may influence the variability of the organism.

Let us suppose a body composed of numerous extremely mobile spherical particles; let us conceive that the definite action of energy sets all these particles vibrating in one direction, and that the spheres adhere to each other, and are ultimately converted into cylindrical rods, and these again, by mutual pressure, become hexagonal prisms. The extremely mobile body would be converted into one possessing increased mobility in the direction of the axes of the prisms; these would still be capable of free movement in the direction in which they were originally acted upon, but would not readily be altered by the impact of new forces acting in other planes. The prismatic structure of our hypothetical body might remain susceptible of great modification, but would surely exercise the strongest influence on all the subsequent changes which the body might undergo.

New structures might be added under the influence of new or modified forces; and these would act chiefly on particles the mobility of which remained free in the direction in which they acted. Such particles might arise from the accretion of new material; for new forces would act only slightly on the already acquired prismatic structure.

We may thus see how the acquirement of structure may render organisms less susceptible to the action of new forces; and if this has been rendered more easy of conception by the above hypothetical illustration, it will have served its purpose; for the author disclaims all idea of pointing out the exact process by which rigidity has really been acquired; the principle is all that need be insisted on. It will probably be objected that the structure of organic beings is so complex that it is inconceivable that it can have originated and become fixed in this manner; but such an objection is not a weighty one, since it is impossible to conceive the extreme degree of susceptibility to the action of energy possessed by living matter. We know that light-rays of different colours affect the retina of the eye differently; that is, the susceptibility of its structure is such that it is affected by shocks of energy which are so minute and transient that six hundred and ninety-nine million millions occur in one second of time and the impression of violet is transmitted to the brain, whilst the impact of about five hundred million million * vibrations gives the sensation of red; the other colours of the spectrum rise gradually in pitch from red to violet.

Every new structure acquired by an organism may be looked upon as a new means of narrowing the variability of the organism, and probably of increasing its susceptibility to the action of those forces by means of which such a structure is acquired, since so long as the increase of this susceptibility is useful to the organism, those forms which are most susceptible to such influences will survive.

If this view of the influence of structure on inheritance be correct, it is not difficult to see that variability may be connected with excess of food, as Andrew Knight supposes it to be: excess of food over that which is required to nourish already acquired structure would probably produce a fresh supply of undifferentiated structureless material; and this, on our hypothesis, would be susceptible to the action of new or modified forces.

Variation, however, is not only limited by structure, but also by the limitation of conditions. Thus the pebbles upon the beach vary considerably in size; but this variation is limited by the

* More exactly 474,439,680,000,000. Tyndall, 'Heat a Mode of Motion,' p. 243.

conditions under which they are formed: none are so large that they cannot be rolled by the action of the waves; and none are so small that they are lifted and dashed against each other by each successive breaker. In the first case the stones may be rounded and worn, but they do not assume the form of pebbles; and in the latter case the fragments are fractured into minute angular particles of sand.

We may fairly infer that the variability of structureless living protoplasm is limited by the conditions under which it is placed, and that it is further limited by the fact that protoplasm is extremely liable to undergo chemical change under altered conditions rendering it incapable of transforming energy; in other words, any considerable change produces death. It is probably only under gradually changing conditions that evolution progresses; and hence it is not difficult to understand why the lower forms of life remain constant, and transmit their characters truly through innumerable generations.

The accurate manner in which the form and markings of the beautiful geometrical flint shields of the Radiolaria and Diatomaceæ (Plate III.) are inherited is not difficult to explain on this view, although at first sight it appears incredible that it should depend on so simple a law.

It is well known that if sand or fine dust be scattered upon a metal plate, and the plate be made to vibrate by means of a bow or a string drawn rapidly across one of its edges, the sand leaves certain portions of the plate and arranges itself in a beautiful geometrical figure. This is caused by the formation of centres of vibration in the plate, with lines, called nodal lines, between them, where the vibrations destroy each other and the particles of the plate are at rest. Nothing appears more probable than that similar points of vibration and rest exist upon the surface of these shield-forming organisms, and that the excreted silica which forms their shells comes to rest at the nodal points.

Just as the particles of various gases are supposed to be continually vibrating, according to the kinetic theory, in waves of a definite length, which varies in different gases, so one can readily conceive the particles of extremely mobile protoplasm may vibrate regularly, and the nature of the vibrations may differ in the various species; this would determine the beautiful geometrical form of the flint shields diagnostic of each, by permitting the siliceous exudation to solidify only on the nodal lines.

It is a point worthy of careful consideration that the lowest forms of life only produce geometrical forms, which often present angles and angular figures; as soon as structure is acquired, it appears as if the free mobility of the particles of living matter were interfered with, so that no similar phenomena occur amongst the higher forms of life.

The forms of the shells of the Foraminifera chiefly depend upon the manner in which the protoplasmic masses which they contain undergo multiplication; and this is probably determined by their molecular condition. The ridges on the surface of the shells, however, may result from the formation of nodal lines upon the moving mass of living matter which they contain: these are apparently always parallel to the axis of growth, even in the most distinct forms in which they occur; so that they are probably determined, like it, by the molecular condition of the protoplasm.

The forms of the shells of the Foraminifera vary within certain limits, so that many of the genera are highly polymorphic; this is probably due to the variability of their conditions of life, chiefly to rapidity of growth and the amount of food which each individual obtains. Although many existing forms are apparently identical with those of the chalk era, they still vary in the same manner: this is a strong argument against the view that mere repetition of a character through many successive generations serves to render it more fixed. On the view of inheritance advocated in these pages, it is easy to see that mere repetition would in itself have no power to prevent subsequent deviation. Mr. Darwin has sought carefully for evidence in favour of the opinion that characters become more fixed by long inheritance; but the conclusion he arrives at is against this view.

The persistence of rudiments after they have ceased to be of functional importance has been used as an argument both in favour of and against the hypothesis of evolution. It is evidence in favour so far as it shows the extreme probability of a genetic relation between living organisms. It has been advanced as an argument on the other side, because it is said that rudiments ought to disappear under the same influences which caused the reduction or rudimentary condition of the original organs. Under the view of inheritance here advocated, however, it is easy to see that such would not necessarily be the case. Variation is limited in every case; and, as Mr. Galton has shown, great deviations from the average are less common than slight deviations, and occur equally on either side of the mean or normal condition. Under these circumstances the development of a part must be not only useless but absolutely prejudicial before its disappearance can be determined. It is true that atrophy follows disuse; but there is no evidence to show that a part ever undergoes total absorption from this cause; and therefore we should not expect the disappearance of a rudimentary part to be determined in this manner. The nutrition of rudiments is scarcely likely to affect the nutrition of the whole organism appreciably; and all the more highly organized forms of life, even when growing rapidly, hold a large reserve of nutrient material in the circulating fluid.

We may conclude, therefore, that variation is limited by the limitation of conditions; it is further limited by the acquirement of structure; and, lastly, the action of natural selection under unchanged conditions tends to produce rigidity. Even rudimentary organs remain unless there is a direct influence at work to produce their destruction: it is not sufficient that they are useless; they must be positively harmful.

The offspring, therefore, remains like its parent, and is said to inherit the characters of its parent. It inherits these characters more closely as the complexity of the organism increases, except when conditions occur which are favourable to the development of plasticity. The more complex laws of inheritance in its connexion with development and the phenomena of reversion remain for our consideration; these may be most readily conceived by the study of Mr. Darwin's hypothesis of Pangenesis.

CHAPTER VIII.

PANGENESIS.

Mr. Darwin's hypothesis of Pangenesis*, like the undulatory theory of light, is one that is rendered extremely probable, although it is not proved to be true, because we are able to account for the phenomena by its application. It belongs to that class of hypotheses which contain an assumption, at present at least, incapable of proof. Dr. Hooker said of this hypothesis in 1868 †, "there is no question but that to Mr. Darwin's enunciation of the doctrine of Pangenesis we owe it that we have the clearest and most systematic *résumé* of the many wonderful phenomena of reproduction and inheritance that has yet appeared; and against the guarded entertainment of the hypothesis, or speculation if you will, as a means of correlating these phenomena, nothing can be urged in the present state of science."

Mr. Darwin supposes that every cell or minute fragment of an organism consists of myriads of

* Animals and Plants under Domestication, chap. xxvii.

† Dr. Hooker's presidential address to the British Association at Norwich, 1868.

atoms (or, as he calls them, for the sake of distinction, *gemmules*), each of which is capable of being nourished into a cell like its parent cell, and is further capable of being transported to distant parts of the organism, and of being bound up, so to speak, with myriads of other gemmules from every other part of the organism to form a reproductive body,—in other words, that the simple, apparently structureless, reproductive cells, be they ova or sperm-cells, ovules, pollen-grains, buds, or sporules, consist of myriads of gemmules each of which has been thrown off from some distinct part of the parent, which it is in itself capable of reproducing. Under this hypothesis the reproductive element consists of minute fragments of every part of the parent, and bears the same relation to all its parts that the fragment of the structureless Amœba does to the whole. The conception of this must be perfectly clear; for "the intellect knows no difference between the great and small;" it is just as easy to picture a gemmule as it is to picture an ovum or a minute fragment of a structureless Amœba.

We can of course have no direct demonstration of the existence of such minute particles; but the relation of the reproductive elements to the parent affords extraordinary confirmation of the probability of the truth of the hypothesis of Pangenesis.

The ovum of the most highly organized animal is a minute cell, a little mass of protoplasm, which becomes separated from the parent when the parent has arrived at maturity; but it is a fact of great significance that it is probably never formed at that time, but has invariably lain in the ovary from a very early period in the developmental history of the parent; and then it did not originate as a new structure; its first origin was from the primitive ovarian mass. The primitive ovarian mass was in all probability a portion of the blastoderm from which the parent was developed, whilst the blastoderm itself was merely a segmentation from the grandparent. This relation of the ovum to its progenitors is apparently universal.

The evidence on which this important statement rests would occupy much space; but some of the most remarkable facts in support of it will now be adduced.

The ovaria of the chick first become apparent as early as the fourth day of incubation*, and are apparently formed from a portion of the blastoderm itself; in insects these organs are developed in the egg, and persist in a rudimentary condition throughout the whole life of the larva†. In birds

* Carpenter, Phys. p. 888.

† Weismann, "Nachembryologie der Dipteren," Zeitsch. für wissen. Zool. Band xv.; Bessel, "Studien über die Entwicklung

and mammals the ovaria are always formed at a very early stage, and the ova* themselves are completely differentiated from the substance of the ovarium at the time of birth†. This extremely early development of these organs is apparently of the highest importance. It seems that there are always hundreds of ova separated from the ovarian tissue even at the time of birth. According to the researches of E. van Beneden, these, in some animals at least, undergo multiplication by division at a subsequent period; but it is highly improbable that any new ova originate in any other manner after birth, or, indeed, after the ovarian tissue becomes differentiated from the primitive protoplasm of the ova: in other words, the secondary formation of ova seems to depend on nutritive reproduction, and not on nutritive repetition, any newly developed ova being merely portions of the first set, and never new formations; and the same is probably true of the sperm-cells of the male‡.

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der Sexual-Drüsen bei den Lepidopteren," ib. Band xvii.; also 'The Anatomy of the Fly,' by the author.

* That is, the protoplasm, as distinguished from the deutoplasm of the yelk, is in existence.

† E. van Beneden, 'Recherches sur la composition et la signification de l'œuf,' p. 169.

‡ The evidence of this rests upon certain pathological conditions.

It is true that Pflüger * thinks that new ova are formed periodically in adult animals, just as plants produce new flowers and fruit at distinct periods; but this is clearly an unjust comparison, and the statement would require very strong evidence to substantiate it, as it is exceedingly improbable that the ova of Mammalia should be developed so many years before maturity if they were capable of being developed at a later period. As the ova are only minute nuclei up to the time when they begin to undergo the changes immediately preceeding their maturation, it is almost impossible, if not impossible, to substantiate Pflüger's opinion by direct observation.

In plants the case is very different; as each bud is undoubtedly the recommencement of the cycle of vital changes which characterize the life of the plant, the existence of the protoplasm of the ovules from the first appearance of the flower-bud would be equivalent to the existence of the protoplasm of the ova from the commencement of the process of development in any animal, except some of the compound polypes, which are quite analogous to plants as far as the production of buds and the regular recurrence of the vital cycle iu each bud is concerned. Under such circumstances it may be regarded as almost certain

* E. van Beneden, *l. c.* p. 171.

that each ovum would receive a series of gemmules from every part of the parent from its earliest stage of development, and that each successive stage up to the period of maturity would be similarly represented in the ovum.

If the view here adopted be true with regard to ova and ovules, it is also probably true of all the other forms which the reproductive elements assume, as sperm-cells, pollen-grains, buds, and sporules, or of all those parts which are believed by those who hold the theory of pangenesis to be composed of myriads of gemmules which in their aggregate represent the life-cycle of the parent. Under this view, therefore, it is easy to see why the reproductive elements appear in a rudimentary condition at so early a period in the life-history of the parent; and this, although no proof of the theory of pangenesis, is, to say the least, a most remarkable justification to those who entertain the hypothesis.

On this view it is not difficult to conceive the nature of the more complex phenomena of development and inheritance: every gemmule is limited in its variability by its conditions of existence, by all its relations and correlations, as well as by its physical composition and nature; and if each gemmule became developed in the same sequence with all the other gemmules in which it was formed, the life-history of the offspring would be a repetition of the life-history of the parent. Mr. Darwin thinks this sequence is ensured by the "affinity of these gemmules for other partially developed cells in due order of succession;" and this appears to be an exceedingly probable explanation of many of the more complex phenomena of inheritance.

Gemmules which do not become developed may nevertheless multiply according to Mr. Darwin's hypothesis, and may be transmitted through many succeeding generations, thus enabling us to understand many remarkable cases of reversion or atavism, cases in which the lost or rather dormant characters of a more or less distant progenitor reappear in the progeny; and the improbability, as Mr. Darwin has pointed out*, is not greater, that such rudimentary gemmules should be transmitted, than that useless rudimentary organs should be truly inherited through millions of generations.

* Origin of Species, p. 126.

CHAPTER IX.

NUTRITION.

Nutrition is only a name for that peculiar series of chemical changes by means of which organic matter increases in bulk by the assimilation of new material. As we have already seen*, it is separated by no definite line from chemical change amongst inorganic bodies. Without change it is manifest that there could be no evolution; so there could be no progressive evolution without continuous change; and this condition is fulfilled by the nutritive process. Without it there could be neither growth nor reproduction; and, as we have seen, reproduction is the great means by which the animal and vegetable kingdoms have been evolved. It is therefore necessary that we should attain clear ideas concerning the relation of the function of nutrition and evolution.

The food-material of all organic matter is obviously unlike the matter nourished to a greater or less degree; even when, as in the case of flesh-feeding animals, it is very nearly like the organism which it nourishes, it undergoes changes in the

* Page 23.

stomach which render it more or less unlike before it comes into contact with the tissues to be nourished. Again, material is required for the production of energy; and this is derived from food which is often of the same nature as that by which the organism itself is nourished; hence there is frequently, perhaps always, a balance of material which is excreted or thrown out from the part or organism. The food may therefore be divided into three parts, according to its ultimate destination—that which nourishes the organism, that which is used for the production of energy, and that which is excreted or again turned out by the growing tissue.

In simple cellular organisms this excreted material often forms a shell around the growing tissue; and the same occurs almost universally in the vegetable kingdom. Plants, which expend but little energy, also secrete a large quantity of energy-producing material in the form of wood, cellulose, and sugar—the two former building the hard framework or skeleton which supports the delicate protoplasmic centres of nutrition by means of which the vital processes of the plant are carried on, and the latter being poured out as manna upon the leaves and branches or into the nectar-bearing organs of their flowers.

In the more complex forms of life, in which the food-material is distributed to various parts of the organism by means of the circulatory fluid, each cell assimilates to itself from this fluid certain definite constituents for its own nutrition; and hence it is advantageous to every organism that its several organs and structures should vary in their demands for nourishment from the general store. In this way the various parts fit in with each other, so that the material which is unsuited for one is used by another, and the greatest economy results.

Sir James Paget, years ago, enunciated this view in his surgical pathology, and showed that every part may be looked upon as an excretion to every other in highly complex organisms. Some organs perform this function to a very great extent. An example will render this phenomenon clear. A stag feeds upon grass, a large portion of which is dissolved by the process of digestion and passes into the circulating store of nutritive matter, the blood. Some of its constituents are oxidized for the production of energy; others repair the waste of the body in the adult animal, and build new tissues in the young one. Some of the remaining elements of the food are excreted from the body. But a large quantity of calcareous salts have been derived from the herbage on which the animal lives. This is drawn from the circulating fluid for the production of horns. The same salts that nourish the horns of the male form the bones of the young in the female when this sex is hornless. All animals which feed on large quantities of comparatively slightly nutritious matter, with few exceptions, have a complicated digestive apparatus; and a large quantity of innutritious material is consequently dissolved and absorbed into the blood. In such animals there is a strong tendency to the production of largely developed skeletons or cutaneous organs. It is not difficult to see that the formation of such structures would probably be of great advantage to the individual, by relieving the special excretory organs by which they would otherwise be removed from the blood. Most insects which feed on material containing but little nutriment in comparison to its bulk produce cutaneous horns, knobs, and enormously developed mandibles. The thoracic appendages of the Lamellicorn beetles and the great jaws of the stag beetle may serve as examples, whilst the grotesque beaks of the Toucans and Hornbills may have had a similar origin.

The Ruminantia amongst the Mammalia are especially characterized by their strong tendency to produce horns, and by their extremely complex digestive apparatus, which enables them to dissolve an exceedingly large percentage of the saline constituents of their food. This is probably a necessary consequence of their peculiar mode of digestion, as a very large proportion of the absorbed salines are immediately excreted by the kidneys. A horse does not take more than a third of the earthy and alkaline salts contained in its food into its blood; whilst a milch cow absorbs more than 95 per cent., of which nearly eight ninths are excreted by the kidneys and one ninth appears in the milk. When fed on cultivated grass and potatoes (which are comparatively nutritious food for a ruminant compared with the wiry herbage which often forms their sole diet), a cow excretes by its kidneys no less than twelve ounces of earthy and alkaline salts per diem; whilst a horse fed on hay and oats does not average one fourth of this quantity. It is easily seen, therefore, that the kidneys are very largely taxed in the ruminant, even when fed on highly nutritious material. A much larger quantity of water is therefore required; and this seems directly proportional to the quantity of salines excreted*. Any excess of salines or diminution of water would most undoubtedly seriously affect the health of the animal, unless some provision existed for freeing the blood of earthy salts; hence the horns are clearly of the highest importance.

This principle has probably had a very ex-

* These calculations are made from analyses by Boussingault, Ann. de Chim. et de Phys. tome lxx. p. 136.

tended influence on the evolution of all the more complex forms of animals and plants, and has perhaps, in many cases, produced the first rudiments of parts which have afterwards become extremely important organs under the influence of natural selection.

This view is not so hypothetical as it may appear at first sight; for it must be remembered that the nutrient fluid (the blood in animals and the sap in plants) retains a very constant composition in each species under all circumstances: for just as the primitive Amœba assimilates suitable material only, so the terminal cells of the rootlets of plants and the epithelium of the alimentary canal in animals have the power of selecting certain elements of food; and this power is transmitted by inheritance with great constancy. Hence the composition of the nutritive fluid is to a great extent invariable in any form of animal or plant, and depends apparently upon the nature of the food which has been usefully assimiated throughout many generations. Any change of structure or unusual development of a part would undoubtedly alter the balance existing between the composition of the sum of the tissues and that of the blood or sap; so that it would be useful to the animal that other structures should likewise undergo modification; and in all cases where an important organ became gradually modified by natural selection the nutrition of other organs would necessarily change with lapse of time. It is indubitable, if evolution be admitted, that the nature of the food has had immense influence in altering the nature of the digestive organs; so one can readily understand that changes in the nature of the blood would modify the internal structures of the body.

No doubt some of the modifications which arise in a tissue or organism with any modification of the pabulum on which it feeds, are the direct result of the action of the modified food; others are the result of minute variations selected by the survival of the fittest. As we have already seen, there are probably millions of gemmules which remain undeveloped in every organism: slight variations must exist amongst these gemmules; and those which find nutriment most suited to their constitution will be those most easily and most advantageously developed. Hence in a complex organism we need not wonder that many parts should be undergoing modification at the same time; the wonder would be if they did not.

It may be asked by some how it is known that the absorbent cells which feed the blood do not regulate its composition by taking in exactly as much of each kind of material as is required from time to time. The answer is that an excess of nitrogen in the food is absorbed and at once excreted from the blood, whilst hydrocarbons derived from the same source are deposited as fat, showing that the amount of material of each kind absorbed depends rather upon the amount presented to the absorbent surfaces, and that the tissues, as well as, perhaps, the blood-cells themselves, and the excretory glands keep the character of the blood constant. The kind of food presented depends most undoubtedly in animals upon the appetite; and in plants it is nearly constant: some kinds are absorbed, others are continually rejected by the absorbent surfaces. We see no difficulty in believing that the quantity of fat deposited by an animal is correlated with the other processes of nutrition, and should not refuse to extend the same principle to all the other tissues. It will be readily conceded that it is in the highest degree improbable that the nutrition of the epithelial absorbent cells alone should be affected by an alteration in the composition of the blood, more especially as they have themselves become independent of it for their own nutrition; yet such a supposition is inevitable if it is argued that change of nutrition in any part is not balanced in another. It must in such a case be compensated for either by a change in the proportion of the nutrient materials absorbed, or by excretion by means of special organs; and this would in many cases originate waste, a condition which, we may rest assured, would be speedily checked by natural selection.

The formation of pigment by both animals and plants is probably the result of this law of correlated nutrition. This seems especially likely in plants, where the bright colouring-matter of the flowers is commonly a substitution-product of ammonia. The various vegetable aromatics and alkaloids, which have a similar composition, may clearly be attributed to the working of the same great law. Certain equivalents of carbon and hydrogen may fairly be supposed to remain as a balance in the sap after the nutrition of various organs; and these, in contact with ammonia, would give rise to the various colours and properties observed in plants. As the quantity of carbonic acid absorbed by the leaves of any species is probably in direct proportion to the amount of ammonia and water taken up by the roots, the nutritive process remaining the same, the residual products would be tolerably constant, as they are really found to be, in different plants of the same species.

The dermal appendages of reptiles and the feathers of birds, rich in pigment and nitrogen, are probably entirely excrementitious to the other tissues, and, without doubt, depend in great part for their origin on the solid nature of the excretion of the kidneys. Birds especially, leading a very active life, excrete material rich in nitrogen; and the feathers, which are shed periodically, enable them to throw off that element without overtaxing their renal organs.

In man the loss of a furry covering to the skin may be accounted for by the same hypothesis. In this case it is scarcely possible to doubt that we see the effect of correlated nutrition. As vast stores of material are needed for the nourishment of the nervous system (so far more highly developed in man than in any other animal), it follows that some other albuminous tissue must have suffered, or the balance of the economy would have failed. As the brain gradually enlarged, the hairy covering of the skin was most easily dispensed with. Phosphorus was likewise required in larger quantities for the nervous system; and the osseous became reduced in size.

The above argument may be briefly summarized as economy of nutrition; and it will become apparent that economy of nutrition is of all conditions that which conduces most surely to the survival of the race.

A given pabulum being supplied, certain essential structures are nourished, and the residue is economized in the production or modification of other parts, often giving rise to ornamental appendages or bright colours; whilst the action of the same principle correlates the modifications of different organs or parts with each other.

CHAPTER X.

THE RELATION OF NUTRITION TO FUNCTION.

LAMARCK attributed much to the effect of use and disuse; and his views do not appear to have received the attention of late which they deserve. Great as the effects of natural selection, or Darwin's Law, undoubtedly are, there are many facts to show that Lamarck's Law of variation from use is probably only second to it in its influence on the evolution of complex forms. No doubt many of Lamarck's illustrations are fanciful and unwarranted; but wherever nutrition is affected by activity of function, it is impossible to disbelieve in its wide and extended action.

It is an established physiological fact that the nutrition of an organ is much influenced by its activity. The beautiful researches of Dr. Parkes on the excretion of nitrogen throw much light upon this subject by the manner in which they elucidate the law of nutrition in muscular tissue. It has long been known that use tends to increase the nutrition of an organ, and that disuse determines its waste, or at least materially interferes with its nutrition. The arm of a blacksmith, with its marvellous muscular development, is a familiar example of the effect of use; whilst the emaciation of the limbs of a patient confined to a bed from an accident is no less familiar as an example of the effect of disuse. It was not, however, until Dr. Parkes showed that the quantity of nitrogen excreted from the body is increased by rest and diminished by muscular exercise, that the truth became known that the growth of muscle is most active during the active performance of function. As nitrogen is only required in the economy for the repair and production of tissue, it follows that, if the nitrogenized tissues retain the same weight, the same quantity of nitrogen that is taken in as food will be again excreted, whether derived directly from the food or from tissue which has been replaced by new material; if more tissue is developed or built, less nitrogen will be excreted than is taken in; if less tissue is formed than degenerates, then more nitrogen will be excreted than the food supplies. During exercise, less nitrogen is excreted than is derived from the food; hence more is converted into tissue than degenerating tissue gives back. When, however, rest follows exertion, the over-nourished muscles give back some of this extra nitrogen, and hence more is excreted than is afforded by the aliment. The same law probably appertains to every organ—the greater its activity, the greater its tendency to grow. In this way we may account, to some extent at least, for the proportions of the body. The shape of the bones may, and probably does, become modified in a similar manner: the tendinous insertions of muscles, being subjected to a greater strain, become hypertrophied; bone-cells or osteoblasts originate in the subjacent periosteum under the new stimulus, and a crest of bone is produced. The strong tendency for cartilage and bone to be developed in the large tendons of some animals favours this view; and the following remarkable passage in the writings of Mr. Wallace is evidence of high value upon this point. Writing of the Orang-outang, he says:—"When we examine the crania, we find remarkable differences of form, proportion, and dimensions, no two being exactly alike. . . . . This variation enables us to explain satisfactorily the marked difference presented by the single-crested and double-crested skulls, which have been thought to prove the existence of two large species of Orang. The external surface of the skull varies considerably in size, as do also the zygomatic aperture and the temporal muscle; but they bear no necessary relation to each other, a small muscle often existing with a large cranial surface, and *vice versâ*. Now those skulls which have the largest and strongest jaws and the widest zygomatic aperture have the muscles so large that they meet on the crown of the skull, and deposit the bony ridge which separates them, and which is the highest in that which has the smallest cranial surface. In those which combine a large surface with comparatively weak jaws and small zygomatic aperture, the muscles on each side do not extend to the crown, a space of from one to two inches remaining between them; and along their margins small ridges are formed. Intermediate forms are found; and the size and form of the ridges are independent of age"*.

Checked and guided by natural selection, the hypertrophy of tissue, directly due to its activity, undoubtedly leads to the most important modifications, especially as the additional supply of nutriment would probably lead to additional variability, a probability already mentioned as Andrew Knight's view.

Mr. Darwin, in his 'Origin of Species,' has given a long series of facts relating to the loss of organs from disuse. The rudimentary condition of the eyes of creatures living in darkness, as in caves and subterranean burrows, is one of the most important, as we may infer safely that the defective condition in this case is due to want of use, since the eyes are well developed in the embryo and

* Quoted from Huxley's 'Man's Place in Nature,' p. 40.

larger in the young than in the adults, in some species at least*.

With regard to the heredity of such changes, the weight of evidence is certainly in its favour. Brown Séquard found that mutilations tended to be inherited; and there is little doubt that diseases due to malnutrition are transmitted to the offspring.

We may well believe, therefore, that altered conditions of nutrition are adapted to function, since the organ is nourished in a direct ratio to the work done—that such changes are hereditary to a high degree, and would tend to produce adapted varieties, or varieties suited to meet the contingencies of their mode of life—that increased functional activity would induce variability by increasing the amount of nutriment afforded to the active part; and hence both adaptive variation and minute indefinite variations would be occurring at the same time, thus, guided by the powerful agency of natural selection, hastening the perfection of a functionally active part or organ.

* Packard, 'Nature,' vol. v. pp. 484, 485.

CHAPTER XI.

THE RELATION OF NUTRITION TO REPRODUCTION.

THE different opinions which have been held by thinkers concerning the relation of the functions of nutrition and reproduction are not a little remarkable. From the most elementary consideration of reproduction in its simplest form, it is apparent that its relation to nutrition is direct and unequivocal (p. 50). The protoplasmic substance in the lowest forms of life divides when it increases beyond a certain size; and this process is repeated whenever sufficient nutriment has been assimilated.

It is true that when the supply of nourishment falls short, as at the approach of winter, such an organism frequently becomes encysted (that is to say, surrounded by an envelope of excreted material) and breaks up into a multitude of minute reproductive bodies; so that it may appear on a very superficial view as if starvation hastened the process of multiplication. It must be remembered, however, that this is only a temporary condition, as each of the reproductive bodies will require exactly as much nourishment before it is itself capable of reproduction as if it had been segregated from the parent mass in its more developed or larger condition; hence all that can be said upon this subject is that any temporary failing of food-material hastens the multiplication of the species only by accelerating the separation of the young from the parent. Such a separation amongst the lower forms of life is undoubtedly highly advantageous as a means of dispersion, by temporarily augmenting the number of organisms produced, although this temporary increase is undoubtedly in a direct ratio to the amount of nourishment afforded to the parent by surrounding conditions.

Similar arguments, however, have been illogically applied to the case of the higher animals by thinkers of very considerable pretensions; and thus the most serious misconceptions have originated. It has been supposed by Mr. Doubleday (and many have followed him) that the rapid increase of animals and plants is checked by abundant nutrition. The established fact is brought forward that the reproduction of some plants by seed is favoured by a sterile soil; and it is asserted further, by the advocates of these views, that the fattest and best-fed individuals amongst animals produce the fewest offspring.

A careful consideration of the facts, however, will at once dissipate this delusion.

There can be no doubt that the tendency of diminished nutrition is to separate the young from its parent in the earliest possible condition of development in which it is capable of survival. We have seen that the breaking up of the encysted Amœba favours greatly its dispersion and therefore its means of obtaining food; it is therefore of the highest advantage to the species, and will surely tend to occur even when food is more abundant, as those individuals which are most prolific will have the best chance of survival.

In plants two forms of reproduction exist, buds and seeds. The buds usually remain attached to the parent; and when the amount of nourishment is extreme the formation of buds and leaves continues with great rapidity. Any cause checking further increase in this direction, either by the proportion of the roots to the leaves and new growing buds becoming diminished or from deficiency of food-material in the soil, tends at once to induce the separation of seeds from the parent. These seeds are undoubtedly modified buds, and, like the minute reproductive particles of the Amœba, serve to disseminate the species at a less cost to the parent organism. As this means of increase, however, is highly advantageous, it tends to become developed independently of the amount of food supplied.

In the higher forms of animal life the case is very different. Each race has already in them acquired the tendency to separate young at as early a period of development as is consistent with their survival; and the young, or ova, are constantly separated in each kind at nearly the same stage of development; hence all the young, in any species, require an equal share of nutriment for their production. In this case the food-material is apparently shared between the offspring and the parent, and both are debilitated by any failing either in quantity or quality. It does not appear, from observation, that a slight diminution produces any difference in the number of the young which are born in the first generation; but as these are ill-nourished, fewer live to produce offspring; and the race degenerates and dies out if such conditions continue. On the other hand, a large supply of nourishment produces vigorous parents and vigorous offspring, which have a far better chance of reaching maturity.

The argument that fat animals produce few young is invalid—first, because fattening depends rather on the nature of the food than on its quantity, and, secondly, because such animals are always kept under unnatural conditions to favour the deposition of fat. Remembering how slight the unnatural conditions are which will produce sterility, it is not at all to be wondered at that such individuals become sterile. Most birds are rendered incapable of procreation by captivity; and a large number of animals are never known to breed when confined in dens or even in paddocks. Hence such facts cannot be admitted as evidence of a doctrine depending mainly on a false analogy between plants, which are capable of reproduction in two ways, and animals, which procreate in one manner only. No one thinks of denying that the size of a tree depends on the amount of nourishment afforded to it by surrounding circumstances; and this is a tacit admission that reproduction by buds takes place in a ratio directly as the amount of material assimilated. Nor is it believed by any gardener or naturalist that a starved flower produces more seeds than a well-nourished one; indeed the number of well-formed seeds, other things being equal, is in a direct ratio to the degree of nutrition afforded to the seed-capsule or ovary.

The increase of all living beings proceeds in a geometrical ratio; and this follows as a direct result of the fact that each parent, or pair of parents, produces several young, each of which, or each pair of which, become mature and multiply in the same manner. This method of increase is checked by the fact that only a limited number of individuals can live in a given area; so that in an already stocked country only two offspring can survive for each pair of parents. The struggle for existence between the offspring is the result of their early separation from the parent, which enables that organism to reproduce economically to itself; but, as we have already seen, when once the period of separation has become fixed, the number of young produced will be directly as the amount of nourishment obtained by the progenitor.

It is possible that amongst human beings scarcity of nourishment in a community, by favouring the early separation of the offspring, may give rise to a slightly greater number of births in the first generation; but any such increase is abundantly compensated by the extra mortality of such descendants, probably in the first months of life, certainly within the first year; and it may be held with safety that the number of the offspring which reach maturity, if the scarcity of nutrition continues, is only a fraction of the number that would become capable of multiplying under more favourable conditions. The idea that the birth-rate and, therefore, the mortality of the human race would decrease if food were abundant is a visionary hypothesis incapable of being held by any who have taken an enlarged view of the subject.

The law of reproduction is :—that, as dispersion is beneficial to an organism, every form tends to produce young in far greater numbers than can possibly survive; these, by competition with each other and with surrounding circumstances, are improved by the survival of the fittest, whilst the number that survive is directly determined by the amount of food; that although the principle of economy of nutrition causes the young to be separated from the parent at as early a period as is consistent with their chance of survival, when that period of separation becomes fixed the number of young produced in the first generation is in a direct ratio to the food supplied—although, when the period of separation varies, a larger number are sometimes produced by a temporary period of arrested nutrition, giving rise to an earlier separation of the young.

CHAPTER XII.

VARIATIONS OF DEVELOPMENT.

CERTAIN complicated phenomena connected with the process of development may be conveniently considered in this connexion.

Like all the phenomena of vitality, the period at which any organism commences to reproduce its species is subject to some slight variation. It is well known that the age of maturity varies much in the human race and domesticated animals. Many birds commence to breed before they have acquired their adult plumage*; and although it is difficult to obtain evidence, it is almost certain that the period at which the first nest is formed varies considerably in the same species, especially amongst sea-birds. Several amphibians breed whilst still retaining their larval characters; and the evidence that insects vary in their period of maturity is very strong, especially amongst the Hemiptera†. *Myrmus miriformis*, Fall., and *Sphyracephalus ambulans*, two British species of bug, are, as a rule, apterous,

* Cope, "Origin of Genera," Proc. Ac. Nat. Sci. Phil. 1868.

† Ent. Soc. Trans. 1871, part ii. p. 195.

although winged females occasionally, but very rarely, occur; and the apterous condition is accompanied by other signs of imperfection, especially in *Myrmus,* where the ocelli are extremely rudimentary, whilst they are largely developed in the winged individuals. It may be objected that in these cases we see the process by which wings are acquired, and that the undeveloped species are ancestral forms; this seems extremely improbable, as the species which exhibit an apterous condition belong to very different families. The sudden appearance of wings in a few individuals is more like reversion than a tendency to develop a new organ, especially as such wings are always like those of the nearly allied and normally winged species. According to Mr. Cope * the males of several amphipod crustaceans become sexually mature whilst still retaining their larval characters.

A remarkable instance of this kind occurs amongst the Echinodermata, if, as Müller thought, *Echinocyamus,* a form usually admitted as a distinct genus, be really sexually mature; for Agassiz has almost proved that it is a young form of some Clypeastroid †. Another example of early maturity occurs perhaps in the case of *Echinus norvegicus,*

* "Origin of Genera," Proc. Ac. Nat. Sci. Phil. 1868.

† Bulletin Mus. Comp. Zoology, vol. i. p. 291.

which, although sexually mature, is evidently only a dwarf form of the deep-sea *E. Flemingii* *.

There are two ways in which variation in the period at which reproduction commences may, and probably has given rise to very considerable modifications—first, by the agency of natural selection, and, secondly, by direct variation produced by changed conditions.

It is perfectly clear that each species will derive advantage from commencing to multiply at as early a period as is consistent with the maintenance of characters adapted to the mode of life and the economy of the species. Hence the great majority of animals tend to produce young before they are perfectly mature. In the higher forms of life no considerable modification is likely to arise from this condition, as more individuals are always produced after maturity than before; so that even in cases in which any considerable advantage arose from such an early brood, it would not probably materially affect the species. In the lower forms, however, in which a large number of individuals are produced at one time, the case is very different. The early breeding of a species may be of very material advantage; the later broods being cut off, for instance, by the approach of winter or dearth of food, the earlier alone would survive; and thus in

* W. Thomson, 'The Depths of the Sea,' p. 117.

course of time the adult characters would be liable to be lost. In the species of Hemiptera already cited, the extremely rare occurrence of adult characters is thus accounted for.

Instances of the direct action of conditions are seen in highly fed domestic animals, which become mature at an early period of life. In the human race it is well known that girls arrive at womanhood at an earlier period in hot than in cold countries, perhaps from the custom of early marriages. Amongst the lower forms of life such changes in the period of maturity, although their effects are not very appreciable in the higher forms, give rise to great changes of form and structure.

Changes of period in the lower animals would, as Mr. Cope has suggested, produce very remarkable changes of form. The immature sexuality of the larvæ of insects, if the mature forms were lost, would, for instance, produce a new division of the Annulosa. Perhaps "we see the effect of accelerated development of the ovaries in the viviparous agamic generation of Cecidomyian larvæ. Dr. Leuckart's observations * leave little doubt that the germ-stocks are actually modified ovaries, and that the development of the new larvæ within the body of the mother is the result of the non-development of the rest of the sexual

* Ann. & Mag. Nat. Hist. 1866, 3rd series, vol. xvii.

apparatus. The agamic nature of the process is no objection to this view, as we know that parthenogenesis is by no means uncommon amongst perfect insects even when they are ready to produce young in the ordinary way." In the agamic reproduction of Aphides we observe the same tendency to the non-development of the accessory organs of generation. The pupa of *Chironomus* exhibits a similar phenomenon, as Grimm has shown, thus uniting the parthenogenesis of adult and larval forms *.

The developmental process is probably subject to variations from its very commencement. This is seen in some kinds of malformations; arrest of development, union of the fingers or toes, and supernumerary digits arise from slight deviations occurring at very early periods of life †. These may be extremely slight in their commencement, and yet their effects may be very considerable. As a rule it appears that the earlier any variation occurs, however slight at first, the graver its effects on the adult form. Those who have worked most carefully at the subject of teratology admit that no definite line can be drawn between ordinary varieties and the lesser forms of malformation. The

* Darwin, 'Origin of Species,' p. 387.

† 'Teratological Catalogue of Specimens in the Hunterian Museum,' by the Author.

aortic arches present considerable variation in their mode and order of obliteration; and this gives rise to extreme variety in the distribution of the vessels of the adult. Von Baer has shown that the disposition of the viscera is liable to be entirely reversed by a very slight variation early in the process of development; and it is exceedingly difficult to see the limit to the change which might occur in a very few generations by very slight deviations from the usual process of development in its earlier stages, if these became useful to the individual. In domesticated animals and in Man, all known deviations of development are so considerable that they could hardly be advantageous. This is probably owing to the great plasticity of the ovum and its susceptibility to disturbing causes.

On the other hand, a comparison of the rudimentary toes of some species of deer with digits undergoing abnormal atrophy in certain malformations will show at once the same process manifested in both. Fusion of bones is occasionally observed from arrest in the development of some of the histological tissues between them; and similar fusion occurs normally in nature. Webbing of the digits and the formation of a patagium or flying membrane occur both as normal and abnormal conditions. As such characters appear suddenly from early deviations of development in abnormal conditions, it is not difficult to believe that they arise suddenly and are selected when they are useful. Although it would be unwise with our present knowledge to assert positively that such changes have really given rise to new and permanent forms, nevertheless the hypothesis explains satisfactorily the occurrence of webbed toes and flying membranes in very different highly developed animals.

There can be no doubt that variations are most frequent during the later periods of development, and that those which occur in the earlier stages are usually disadvantageous, as they give rise to very considerable modification of structure; useful variations would undoubtedly usually be so slight in the young embryo that they would pass unperceived. The apparent invariability of embryos is probably due to this; and hence they afford the most important evidence of the line of descent by which any form has been perfected.

Another point of considerable interest in this connexion is that organs are developed at an earlier period in some types than in others. The common duck, for instance, is hatched with exceedingly rudimentary wings when compared with the chick; and this difference is even more marked about three or four weeks later, when the wings of the duck are still, like those of the penguin, mere flippers; whilst those of the chick are provided with well-marked quill-feathers, reaching nearly to the tail. Plate V. represents the half-fledged young of the wild duck and red-legged partridge, where the contrast is even more marked. This subject has yet to be worked out; but it is extremely probable that the period at which each set of organs become developed may also afford an important clue to the genetic relations of many organisms.

Metamorphosis is a form of development which has perplexed the student of evolution considerably, although Gerstäcker and Fritz Müller have done much of late to clear up the difficulties of this intricate subject. It is undoubtedly a mere modification of the ordinary process, but may be either direct or acquired.

Direct metamorphosis is analogous to ordinary development, in which each successive stage represents one period in the history of the species in the same order in which evolution itself progressed. The likeness of the embryos of mammalia, birds, lizards, and snakes is complete at an early period of development; so the young of most crustaceans resemble each other closely at corresponding stages of development.

When the embryonic stages of an animal are passed in an active state, as in the larval forms of

Crustacea and insects, considerable modification occurs, so that the primitive relation between the different stages often becomes so obscure that it is often impossible to trace it. The changes are then said to be acquired; and when these are more or less sudden they are spoken of as acquired metamorphosis.

Thus we observe every degree of variation between a perfectly active and a perfectly passive pupa. At each moult insects remain passive for a longer or shorter period. It is easy to see the advantages gained by cutting short the period of development and the number of moults—which reaches the number of twenty or more in *Chloëon**, and possibly does not exceed two in the blowfly †, although two or three partial moults probably occur about the spiracles at an early period. Weismann thinks these moults are entire, but has never observed a skin cast or a maggot in the process of moulting. At each ecdysis or moult a certain amount of change takes place; variations in the amount undoubtedly occur, and would be seized upon by natural selection whenever they tended to be useful to the organism. A larger and larger store of nourishment would be provided

* Sir J. Lubbock, "Development of *Chloëon*," Trans. Linn. Soc. vol. xxiv. p. 61.

† 'Anatomy of the Blowfly,' by the author.

for each change, if such a variation were useful; and the period of change would become longer, the metamorphosis more considerable, and the number of moults reduced; or the changes at each previous moult might become less. It is thus probably that the undeveloped forms of insects have come to differ from each other more than the perfect insects in numerous species.

Sometimes the embryo in the egg becomes invested in a maggot-like skin, as in the Isopoda, and in the Diptera with a complete metamorphosis; in these the embryo and pupa are more like each other than the intervening larva stage, a condition which probably originates in a kind of intussusception or involution of the anterior extremity of the embryo. Such conditions may fairly be considered acquired metamorphoses, and may have arisen from variation in the developmental process *. The phenomenon is not unlike that observed in *Sitaris*, a beetle which, when it is first hatched, is far more like the perfect insect than in the intermediate maggot-like condition which it afterwards assumes.

Lastly the period at which a creature leaves the egg or the matrix of its mother is prone to vary; and this probably gives rise to some forms

* This subject has been discussed by the author in the Trans. Ent. Soc. 1871, p. 200.

of metamorphosis. Fritz Müller believes that all the higher Crustacea pass through an entomostracous (*Nauplius*) condition either within or without the egg. In the majority this condition is passed through before birth, although in some prawns it forms a distinct larval stage, owing to the premature escape of the embryo from the egg.

The most remarkable instance of premature escape from the egg occurs, however, according to the observations of M. Ganin *, in the Hymenopterous genus *Polynema*. In the species which M. Ganin made the subject of his investigations, the eggs are deposited in those of a dragonfly (*Agrion virgo*), and produce a cellular body simple in form and without a trace of further organization. This remarkable embryo escapes from its egg and is developed at the expense of that of its host, which serves it as a great food yelk.

* "Beiträge zur Entwickel. bei den Insecten," Köll. Zeitschr. für wissensch. Zool. Band xix. p. 417.

PART III.

CHAPTER XIII.

THE ORIGIN OF TYPES.

The unity of form and structure observed in the members of any class or group of animals or plants is spoken of as conformity to a type. Types, under the theory of descent, are ancestral forms; but conformity to type apparently proves too much, since all the Vertebrata, with the exception of some of the lower forms of fish, must have descended from three or four highly specialized types. The common ancestors of fish and amphibians, of birds and reptiles, and of mammals must in each case have exhibited all that is common to the members of the great divisions of vertebrated animals descended from them. How can we account for the existence of three or four complicated typical ancestors and no more? How can we account for the absence, not only of transitional forms in great numbers between them, but also of all modified descendants from those transitional forms? Admitting that the ancestral line uniting a reptile and a mammal may have been lost, how is it that the reptilian ancestor and the mammalian ancestor only have left descendants, so that a wide gap exists between mammals and reptiles? This difficulty appears formidable at first sight; but it vanishes if we consider the probabilities of the case.

All the more simple forms of life are aquatic or oceanic; the world of waters teems everywhere with lowly differentiated and lowly specialized organisms.

We may picture to ourselves the earliest representative of the Vertebrata as a fish-like creature, such as the *Amphioxus* or Lancelet, without limbs, but with a segmented cartilage-like rod representing its backbone, with ciliated respiratory clefts resembling the pharynx of an ascidian, and with numerous delicate tentacles around the margin of the mouth—fish-like in its outward form (a circumstance clearly correlated with its mode of life), but otherwise almost as unlike any division of specialized fish as it is unlike an amphibian. Such a creature may have existed in countless millions, just as the Pteropods of the Arctic seas now exist, except that it could, in the early period of the history of evolution, which we are endeavouring to realize, have had no great whale-like enemies to keep down its numbers as those of the existing Pteropods are kept down. At such a period it is even improbable that any invertebrate would have been much, if any, more highly specialized, since there can be no reason why one mode of specialization should have been in advance of any other. If time had then sufficed for the formation of a cuttlefish, there is no reason why it should not have sufficed for the development of a highly organized vertebrate fish.

Amongst these millions of lancelet-like creatures some would vary; some may have lost their incipient segmentation and may have become invertebrates again; others may have perfected it, and have become evolved, by the action of the laws that have hitherto been discussed, into vertebrate forms. All these would exhibit a notochord inherited from their ancestors; and all would have preserved more or less of their elliptical form, so advantageous to them in aiding their progress through the water. Before any very great divergence had occurred from the lancelet type, some of the forms, hitherto unchecked by competition, would come into competition with each other, and those which possessed any considerable advantages over others would eventually occupy their place by their extermination. Several forms would undoubtedly eventually survive; but many would not succeed in the struggle for life under any one set of conditions, and no great change of conditions would occur until the new-formed vertebrates became sufficiently specialized to migrate into new localities.

The first form of vertebrated animal may be supposed to have become widely distributed, as its gradual migration, or its independent origin under similar conditions from similar ancestors, would as yet be unchecked by enemies. Similar variations would undoubtedly occur in distant parts of the area stocked by our primitive form; and the same conditions which favoured one form in one region would favour a similar form in another.

The importance of a wide area and facility for dispersion in aiding evolution is probably very great: this is exemplified by one of the most remarkable floras in the world, that of New Zealand. The plants of this island are in marked contrast with those of Australia: more than a third are unisexual; and nearly all have inconspicuous, slightly differentiated flowers*. Although many are highly variable, little or no progress seems to have occurred towards improvement, and the more remarkable types are gradually becoming exterminated by the invasion of European weeds. It appears as if

* J. D. Hooker, 'Flora of New Zealand,' p. xxviii.

isolation alone had enabled them to maintain their ground.

As the power of migration increased and competition came again into play, the same process of extermination would weed out all the less specialized forms which were not protected by isolation or by some special conditions favourable to their peculiar natures. As each place in the polity of nature became stocked with already specialized forms, new forms would have no power to invade it, unless equally strong, equally adapted, and equally specialized. As some two or three forms descended from the *Amphioxus*-like ancestor would have the start of all others, and would become widely spread because no enemies existed, their descendants would always prevent any subsequent process of specialization amongst lower forms. The descendants of the more highly developed organisms would gradually become modified to occupy every space. It is the principle of priority: a stronger race, a more developed race, have already occupied every portion of an area; and hence no new forms rise to compete successfully from amongst lower or less-specialized creatures. All great improvement is checked in the less perfect forms by their soon coming into contact with the more perfect. It is the slowness and gradual nature of evolution which prevents the passage of lowly specialized types through any long series of changes, as such forms would always soon come into competition with species already more highly gifted to succeed than they could be. As soon as a vacancy occurs in the polity of nature for a new form, it becomes occupied by creatures of a type most nearly adapted for it, and no opportunity is left for the improvement of a lowly developed one. It will be perfectly clear to all that the apes of Western Africa would be quite unable to become improved in the direction of tameness and the development of a milder disposition and a less arboreal life as long as man occupies the country; so we have no reason to believe that the *Amphioxus* could leave its home burrowed in the sand, and develop fins for swimming in the water, as long as hundreds of highly specialized enemies exist.

It is easily seen that rudimentary fins, by enabling the primitive lancelet form to leave the bed of the sea, would have been advantageous whilst no fish provided with more perfect fins existed; on the other hand, such modifications occurring now, would only lead to the destruction of the fish with imperfect fins by those in which these organs have become perfected, the only safety for the little lancelet being its habit of remaining buried in the sand.

The existence of vast numbers of lowly organized and but little-specialized forms in the ocean is no argument against these views, since it is probable that, like the lancelet in the sand, they occupy places in the polity of nature in which they do not come into competition with more highly developed forms.

There are many reasons why a lowly organized form should not be exterminated; it may be too prolific and too small to come into competition with larger creatures. Lancelet may compete with lancelet, or minute crustaceans may war with each other or with equally minute forms; but, just as the huge whale is unable to exterminate the prolific Pteropod, highly organized forms rarely completely destroy minute and lowly developed animals.

An objection has been made by several authors that crossing and intercrossing would prevent improvement except under isolation; but it must be remembered that numerous individuals are continually varying in one direction. The circumstances which induce any particular form of variation in one individual, however complex, will tend to produce a similar variation in many; and if these are favoured in any way, they are sure to leave a majority of descendants. Again, one favourably varying individual, although crossed and intercrossed with many having a less favourable form, will undoubtedly tend to improve the whole of their descendants, unless another cross occurs from an individual which has varied in the opposite direction. If the first variation is favourable and the second unfavourable, it is clear that the race will be oftener crossed by individuals having the more favourable variation; and thus the species will eventually inherit the more favourable tendency, which will tend to become more and more marked.

Again, all tendencies towards specialization or the development of new parts will tend towards isolation. The little lancelet-like ancestor of the Vertebrata by the development of fins would become more extended in its distribution; the individuals which were best adapted for swimming would leave the bed of the ocean and occupy a higher level. Thus those capable of swimming would become separated from those incapable of swimming, and would become more or less isolated from their less-active ancestors: whilst the non-evolving race retreated into the sand to escape from enemies increasing on every side, the more highly developed forms would seek the surface of the waves, and thus come under totally new conditions of life. As evolution progressed, the conditions of life would become more and more unlike; certain forms would become isolated in rivers and pools; and these, like the aquatic plants amongst which they passed their lives, would gradually spread from the water to the damp places around it, and so eventually become habited to the dry land.

We might therefore expect that uniform improvement would go on over the most extended areas, by crossings with the best-adapted variations occurring more frequently from their surviving to the period of maturity more often, or from their obtaining more food and therefore leaving a larger number of vigorous descendants than the less-favoured varieties. Thus a type form originates, and members of it become isolated by spreading into areas where different conditions appertain, either becoming inhabitants of a different level in the ocean or spreading into colder or warmer latitudes, and becoming altered by the direct effect of conditions, so that they are no longer fertile when crossed with their ancestors. The type form diverges in different directions, and new types occur, each more specialized than the first. These come into competition by migrating beyond their original areas, and mutually react on each other. If they are mutually strong, each may become modified, and new forms may arise under these new conditions, so that each type becomes modified and innumerable forms arise from the highly specialized types; these continually prevent any considerable deviation, in the direction of specialization, amongst the older and simpler forms, which cannot compete with them.

Thus we should expect to find exactly what we do find—type forms with groups of allied forms around them. Transitional forms would occur rarely, as they do, but would not have innumerable forms descended from them, except in certain definite directions. The study of classification and the affinities of living beings is entirely confirmatory of the views which have been adopted here.

Mr. Darwin treats this subject briefly in his 'Origin of Species.' He says:—"As natural selection acts solely by the preservation of profitable modifications, each new form will tend, in a fully stocked country, to take the place of and finally to exterminate its own less-improved parent form and other less-favoured forms with which it comes into competition." The expansion of this pregnant sentence includes most of the views expressed in the foregoing chapter.

CHAPTER XIV.

ON THE ORIGIN OF THE HIGHER VERTEBRATES.

In order to bring the argument into a narrower compass, the application of the preceding views will be attempted to the case of certain special forms. The three great terrestrial types of vertebrates (reptiles, birds, and mammals) have been selected for this purpose. These have all attained a high degree of specialization; and they have been chosen because they present especial difficulties.

As we have already seen, the facts of geographic botany have led M. De Candolle to believe that aquatic plants are the most ancient; zoology and comparative anatomy tend to the same view amongst the higher vertebrates; and an endeavour will be made to show that the marine and aquatic forms of reptiles, birds, and mammals tend to unite those forms with each other and with the lower amphibian and fish or ichthyopsid types in a very remarkable manner.

It is universally admitted that the Amphibia form the connecting link between the fishes and the higher vertebrates; they are partly aquatic and partly, as their name indicates, amphibious. Several aquatic amphibians are closely related in structure to the Lepidosiren (or mudfish) of the Australian and African rivers, a type which has been lately shown by Dr. Günther to be nearly akin to Ganoids through the newly discovered genus *Ceratodus*—a fact foreseen by Professor Huxley, who had already pointed out its affinities with the most ancient Ganoids of the Palæozoic era. Again, some extinct labyrinthodonts, frog-like amphibians of large size with ventral armour-plates like alligators, have skulls approaching ganoid fish, whilst others are peculiarly reptilian in their characters.

Reptiles are the most diverse in form, and, in the majority of cases, the least-highly differentiated, of terrestrial vertebrates; they are probably the descendants of types strictly transitional between the mammal, bird, and amphibian; and they exhibit a vast number of marine aquatic and semiaquatic forms; the extinct Ichthyosauria and Plesiosauria, the existing tortoises, turtles, and Crocodilia, and the semiaquatic lizards and snakes are sufficiently well-known examples.

Amongst birds the penguins and auks are highly aquatic; and an endeavour will be made to show that they exhibit remarkable reptilian tendencies.

There are two great types of birds at present existing on our globe:—the Ratitæ, or Ostriches and Cassowaries (great land birds with rudimentary wings and enormously developed legs); and the Carinatæ, or keel-breasted birds, which include all the other bird forms. The latter are decidedly the most differentiated in a special direction, and as a subclass have the fewest reptilian characters. The penguins belong to the carinate subclass, and divide the claim to a transitional position between birds and reptiles with the Ratitæ, or ostrich form. There can be no doubt that the sternum and shoulder-girdle of the Ratitæ are remarkably like those of some Reptilia, whilst the rudimentary cervical ribs and prepubic bones of the ostrich are unmistakably crocodilian. It is, however, important to remember that the skull of the carinate tinamou is certainly more reptile-like than that of any other bird, although other parts of its organism are highly differentiated on the bird type.

The scarcely united tarso-metatarsal bones of the penguins and their near allies the frigate birds are strongly reptilian characters, as are also the large fibula and broad expanded scapula and solid bones of these birds. In one of the penguins (*Pygosceles*) the coracoid has a large fontanelle, as it has in the Ratitæ, a reptilian character, dividing the bone into a coracoid and precoracoid; this condition exists in a less degree in the king penguin. Again, the proximal tarsal bone is less intimately united with the tibia than it is either in the ostriches or in the aërial birds—another eminently reptilian character.

In the penguins the wings (which are perhaps the most characteristic organs of birds) are rudimentary, as they are in the ostrich form, and more especially in the Apteryx. There is this great difference, however, that in the penguins they are of high functional importance and are used in diving, just as the turtle uses its anterior paddles for progression through the water; whilst those of the ostrich family only preserve the rudiments of a function, and in the Apteryx at least are quite useless. They certainly have the appearance of aborted rather than newly acquired organs.

The view that the aquatic penguins belong to an early type of birds has been materially strengthened of late by Professor Marsh's remarkable discovery of an Ichthyornid type of birds in the Cretaceous shales of Kansas with amphicœlous vertebræ, a carinate sternum, and posterior extremities closely resembling those of swimming birds. Not only have the remarkable fossils on which his description is founded the amphicœlous vertebra of a fish or more properly of a Rhynchosaurian lizard, a type of reptile with characters tending to the bird type, but they have jaws furnished with numerous minute conical teeth *.

Passing from aquatic birds to the aquatic mammalia we find far more diverse forms; but, complex as the subject is, the inference that the earlier types were aquatic is well borne out.

Two remarkably reptilian types of mammals exist, the duck-billed Platypus and the Australian Anteater; one of these, and the more reptilian of the two, is entirely aquatic.

Amongst the higher Mammalia, the Cetacea or whales and the Sirenia or herbivorous whales are highly differentiated forms; and these at first sight appear to form an exception to the view that the aquatic are less highly developed and less differen-

* The following are the principal characters of this remarkable fossil type, according to Professor Marsh:—

Skull of moderate size; eyes placed well forward. Mandible long and slender; rami not united at the symphysis, abruptly truncated behind the articulation of the quadrate, not encased in a horny sheath. About twenty conical teeth implanted in sockets in each side of the mandible and maxillæ; scapular arch, wings, and legs those of a bird. Vertebræ amphicœlous. Sternum carinate. Bones of the posterior extremity resembling those of swimming birds. Last vertebra of the sacrum unusually large; tail unknown. Bones, except those of the skull, not pneumatic. *Ichthyornis dispar* of Marsh was about the size of a pigeon. Another form, *Aptornis celer*, has also been discovered. The skeletons are described in the 'American Journal of Science and Arts,' vol. v. 1873.

tiated than the terrestrial forms. That these vast animals have passed far from their primitive type form is indubitable; but they still exhibit resemblances to reptiles that are as puzzling as they are unmistakable—not to the reptile of to-day, but to the great extinct ichthyosaurian. Passing over the general resemblance of form, which is not in itself important, the non-union of the majority of the ribs and sternum, the peculiar articulation of the ribs with the vertebræ, the remarkable sternum itself, the chevron bones of the caudal region, the late union of the neural arches and bodies of the vertebræ, the long symphysis of the lower jaw, the remarkable teeth, and the absence or extremely rudimentary condition of the pelvis are either reptilian or ichthyosaurian tendencies.

Palæontology undoubtedly reveals several transitions between the ordinary Cetacea and Sirenia, as well as between these orders and terrestrial forms belonging to exceedingly highly differentiated and diverse orders. Nevertheless the foregoing considerations seem to indicate that the whales form no exception to the views advocated here, and that they are rather to be looked upon as the descendants of marine ancestors of existing terrestrial forms than as the descendants of a highly modified terrestrial type.

The seals may probably be safely viewed in the same light. Mr. Parker informs me that the face of a young embryo of the pig has the guise of the aquatic hippopotamus—a fact that points strongly to its origin. Lastly, the aquatic insectivora and the more highly differentiated and half aquatic rodents may in each case be looked upon as the descendants of more truly aquatic forms. The capybara is clearly a transitional animal; and the Insectivora are undoubtedly a little-differentiated and transitional group.

This glance at the aquatic forms of the higher vertebrates has brought before us a number of types exhibiting transitional conditions between the great vertebrate classes; we may add to these the remarkable extinct ornithocelid reptiles, which had many points of structure in common with birds:—the Pterosauria, with which one form is classed (*Ornithopteris*) which Professor Huxley is inclined to suspect is a true bird*; and the extinct Archæopteryx, a bird which had a long lizard-like tail, and which formed a well-marked transition between birds and reptiles. With such known transitional forms between the great types of vertebrates, rather than marvel that we do not find closer connecting links, the wonder appears to lie in the fact that we find so many, when we remember how many ages must have passed since

* Vertebrated Animals, p. 271.

such intermediate forms were the only representatives of the higher vertebrata; for on the theory of evolution it is almost certain that mammals resembling the Platypus and Echidna, and possibly birds not unlike our Penguins, existed when Crinoids, Brachiopods, Lamellibranchs, Cephalopods, and Cephalaspid Ganoids swarmed in a Silurian sea.

All the relics of exceedingly ancient forms which we see still living or find in a fossil state present some points in common which possess high interest. As we have seen, a very large proportion of them are highly aquatic; and if we except specially modified marine forms which bear evidence of having undergone very great changes (and all have undoubtedly changed materially since they branched from the main stock), the living species are confined to isolated areas or regions which contain no more recent types to compete with them; and many of these are verging towards extinction.

The above considerations and facts seem all to indicate to us that the terrestrial types originated from a highly developed marine type; and if we bring to our aid the light thrown upon the subject by embryology in the relations of the amphibia with fishes on the one hand, and reptiles on the other, we may now proceed to picture to ourselves the origin of the higher vertebrate types with a degree of precision that is marvellous when we consider the complexity of the subject and the vast lapse of time which must have passed since these types first breathed upon our globe.

Looking very far back into primæval time we must picture some oceanic fish allied to our present box-shaped chimeras, closely related to the ancient ganoids, and probably much like our existing mud-fish, swarming in myriads amongst the shallows around some gradually rising continent, or lurking in vast beds of sargasso-like weed in a young-world ocean, doubtless ages after the time when the sea swarmed with their lancelet-like ancestors; for a great gap exists in our knowledge. And now we must picture to ourselves the ocean teaming with highly developed invertebrates.

The paddle-like fins of this ancient type of Lepidosiren, or mudfish, served it as a means of progression; and we may well believe that it became transformed into some primæval amphibian. The use of the fins as prehensile organs is common amongst fishes; some forms now leave the water, and even climb trees by their fins; and the whole genus *Chironectes* is remarkable for the elongation of the proximal portion of the fins. In one species, *C. punctatus**, the pectorals closely resemble the limbs of an amphibian, in external appearance at

* Plate IV. represents three forms of *Chironectes*, with the pectoral limb in different stages of development.

least. Several species apparently build nests by means of these organs. Prof. Agassiz has recently described a nest from the gulf-weed which he ascribes to a *Chironectes*.

The close relation of the amphibian and fish types is seen in the development of the former as exemplified in the frogs and newts; and the skull of the highly specialized frog is undoubtedly fish-like in all its earlier stages of development.

We actually see a long range of transitional forms between the tufted gills of a young Elasmobranch fish and the air-breathing organs of a frog; and although we do not know what the precise nature of the changes was by means of which a fish's fin became converted into a webbed foot, it does not appear difficult to believe in the transformation of a prehensile fin, used at one time for climbing and at another for swimming, into such an organ. The further transition from the amphibian into an aquatic mammal on the one hand, and into a reptile on the other, is perfectly gradual. Mr. Parker, in his wonderful monograph on the frog's skull, says *, "I am bold to say that no Sauropsidan (the type of birds and reptiles) lies in the direct line which should connect together the nobler amphibian forms and the lowest mammal;" and, speaking of the structure of the ear, he con-

* Phil. Trans. 1871, p. 201.

tinues, "the elevation of the adult Anuran," or frog type, "in very important structures, attained by no bird or reptile, which brings it almost into contact at certain points with the mammalian margin, is very suggestive." The same author * believes that "an amphibian, full of latent power of change," a power which we may well believe had been developed by the gradual selection of changing forms to fill the new conditions of life which had been gradually laid open by the acquirement of the power to breathe air, "need not have taken in its metamorphosis merely the path that leads to the reptile and the bird; for the least deflection at first may have sufficed to bring about all the differences which we see between these types and the lowest mammals."

In his no less admirable researches on the development of the fowl, the same author almost completes this picture from an embryological point of view. He says, recapitulating the development of its skull, "Having erased, as it were, the characters of the culminating type (those of the gaudy Indian bird), I seemed to be amongst the sombre grouse; and then towards incubation the characters of the sand-grouse and hemipod stood out before me. Rubbing these away in my downward work the form of the tinamou looked me in the face; then

* Phil. Trans. 1869, p. 804.

the aberrant ostrich seemed to be described in large archaic characters; a little while and these faded into what could just be read off as pertaining to the sea-turtle, or most probably the rhynchosaurian lizard and not the sea-turtle, whilst underlying the whole the fish could be traced in morphological hieroglyphics."

With this picture before us let us inquire how the wings of birds may have been developed, as this has been considered one of the difficulties of the hypothesis of evolution. From the amphibian to the rhynchosaurian is no long stride. Extending into the cold arctic and antarctic regions, such creatures may have become clothed with downy feathers; and using their fore limbs as paddles, these may have become developed, by the formation of a short patagium, into something very like the wings of the penguins. Such birds, dwelling on the shores of a great southern continent, may have spread towards the tropic on to the land, and, losing their incipient power of flight, have acquired the type of the ostrich; whilst those of more southern or northern zones, gaining greater and greater strength and power in their paddle-like wings, first used for progression in the water only (as the short-winged auks and penguins and many of the diving ducks still use theirs), may ultimately have taken first short and then longer flights.

Indeed the steamer duck of the Straits of Magellan exhibits such a transitional condition at the present day, some of the individuals only using their wings for aërial progression.

Mr. Ray Lankester has suggested the term homoplastic for structures which are alike, but which have probably been independently evolved. Such structures undoubtedly exist in great numbers; and the acquirement of a patagium or flying-membrane appears to be such a phenomenon. Bats amongst the mammalia, pterodactyles amongst reptiles, and birds are all characterized by the presence of such a membrane. It is not a little remarkable that a patagium occasionally occurs, although very rarely, as an abnormal result of development, just as webbing of the digits does. When we remember that probably the limbs are formed at first as mere thickenings of the edges of the blastoderm*, from which they ultimately become freed, just as the fingers and toes are formed in the broad paddle-like extremity of the primitive limb, it is not a matter for surprise that the intermediate blastoderm should sometimes become converted into a patagium, just as that between the digits often persists as a web. Such a modification may readily be believed to have occurred at the same time that the outer layer of the blastoderm

* Catalogue of Malformations in Hunterian Museum, p. 79.

was undergoing modification to form the amniotic sac (which is characteristic of all these higher vertebrates), although now its occurrence is exceedingly rare. The existence of a patagium in the pterodactyles, in lizards, in some mammals, and, to a less degree, in birds may have been due to such a variation in development.

Modification of the sternum to form a keel is probably another example of homoplastic change, probably resulting from the action of muscles favouring, or perhaps even causing, the deposition of bone in their septa—a view borne out by the occurrence of a keeled sternum in such diverse forms as pterodactyles, ichthyornid and carinate birds, by its absence in the ostriches, as well as by its development in other birds being proportionate to their power of flight*. The modification of the rhomboidal sternum of lizards in the flying and diving birds may be the result of disuse, exosteal ossifications replacing the primitive cartilaginous basis of the sternum of the ancestral form in these.

The facts that the dragonflies amongst insects are aquatic, and that some Hymenoptera use their wings for diving, tend by analogy to confirm the hypothesis that wings for aërial flight were useful

* See a quotation from Mr. Wallace on the skulls of anthropoid apes, *supra*, page 79.

in their rudimentary state as paddles for progression in the water.

With all the complex laws of variation giving rise to adaptive, correlated, and indefinite modifications, checked and guided by natural selection, it is impossible, with our present knowledge at least, to account for all the varied modifications which have arisen; but enough has been done to show that even the highest types have been evolved. Without the hypothesis, how inexplicable are the facts! with it they conform to the great unity which all science seeks.

CHAPTER XV.

GEOLOGICAL RECORD.

The crust of the globe is a great fragmentary treatise on evolution, the imperfection of which, as a record, has been so ably treated by Mr. Darwin that little remains to be said; but the objections to the theory of evolution on geological grounds are of so serious a nature, if we believe that the fragmentary chapters which we see are a continuous history of the past ages of our globe, that it is most important to review this subject *in extenso.*

It is now very generally admitted by geologists that every stratum is formed from the detritus of an earlier bed of rock, and that every rock, whether it be hard or soft, is not only undergoing degradation by the action of the waves along the shore line, or by the torrents and currents of rivers, but also by the continuous action of air, of alternating frosts and suns, and of rain upon its surface. These agencies produce the phenomena known as subaërial denudation, the older rocks being frequently laid bare by the wearing away of all newer deposits. The vast effects of subaërial denudation are seen in long ranges of inland cliffs, which consist throughout their entire extent of one kind of rock, and differ in this from all those cliffs which are formed along coast-lines by the action of waves, as these constantly exhibit sections of various formations.

It is only the harder strata that can resist subaërial action for any considerable period of time; and the formation of such hard strata probably occurs only very rarely. It is a fact worthy of especial note in this connexion, that very few of the tertiary and post tertiary strata are of a nature to resist the prolonged action of subaërial agencies. Any one who has carefully watched the rapidity with which the exposed surfaces of the mammiferous and red crags are undergoing "weathering" and are being removed, will perceive how very improbable it is that any trace of that deposit will be left to tell its tale to a geologist of the remote future.

The cliffs of the coast of Suffolk are a very instructive instance; these are not only undergoing degradation under the influence of the weather, but are gradually being excavated and broken up by the waves. If subsidence of the land were to occur, successive portions of the deposit would be exposed to the same action; so that it is extremely improbable that any of its fossils would remain *in* *situ*; the whole stratum would probably be carried further south by the action of the tides.

It is certain, moreover, that a very large number of the tertiary deposits of England, with the exception perhaps of the clays of the London basin, would be entirely washed away if the level of the land were raised during any very long period of time and then subsequently depressed gradually, so that the uncovered edges of the strata were successively exposed to the influence of the air and sea.

A walk across the hills to the left of the road between Sunnindale Station and Farnborough will convince the observer at once of the fact that there is little probability that the denuded Bagshot sands, a marine tertiary formation of great thickness, would be fairly represented in future ages if the waves of an advancing ocean washed amongst these hills. Creeping up slowly by the now fertile alluvial valleys, the mind pictures such a sea washing down and levelling the upper layers of the ancient sea-bed, and depositing in it, perhaps, recent shells and then covering it over with chalk washed from the high lands surrounding the London basin. If previous elevation of our island were to occur, and the valley of the Thames and its tributaries were worn down some eight or ten hundred feet first, so that the now shallow valleys became greatly augmented, the secondary strata would be denuded in places, and the high sand and clay cliffs would be mingled and levelled by the advancing waves during subsequent depression.

On the other hand it is probable that some at least of the tertiary deposits of the Mediterranean region, which consist of limestone of considerable hardness, would remain even under the least-favourable circumstances; and it is indubitable that the softer clays, marls, and gypsums would be preserved under favourable conditions.

As both subsidence and elevation are always, in all probability at least, extremely gradual, and as very long periods of quiescence intervene, it is far more likely that any given formation, except those of stony hardness, will perish than that it will remain to record the age in which it was deposited. We know that a vast period must have elapsed since the London and plastic clays were deposited; and yet it is extremely improbable that one remnant of the Miocene and Pliocene crag of England which covers them will remain to bear witness of that almost immeasurable period of time. Even the harder rocks of the same era on the continent of Europe may be washed and pulverized until no trace remains; and, as we have seen, the great basins of Eocene deposit are by no means certain to stand the test of time.

With regard to the deposits which are at present in process of formation, a very large number will in all probability contain no fossils. The process of fossilization is a chemical one, and depends on a large number of conditions. The formation of any concrete, especially such as contains much calcareous matter, is favourable to the preservation of fossils; but the mud and silt at the bottom of our large rivers and estuaries, which is perhaps the most likely resting-place for organic remains, is in the majority of cases quite unfit for their preservation.

The deposition of concrete material is undoubtedly a chemical phenomenon. The recent deposits of the Mediterranean are apparently of this character, and the bed of the Atlantic is doubtless highly adapted in places for the preservation of organic remains. During the process of upheaval, however, a very large portion of these strata will be inevitably subjected to the action of the waves along the coast-line; and future ages will at least considerably reduce the thickness of these deposits long before they are again submerged and covered by another layer of thick rock. They cannot become safe records of the present period until all these conditions have been successfully fulfilled. The thin edges of the present Mediterranean deposit alone are likely to contain the remains of existing terrestrial vertebrates; and if the upheaval of the continent of Europe occur gradually in the remote future, they will undoubtedly be entirely removed by the action of the waves. The delta-mud of the great rivers is an extremely unfavourable deposit to stand the test of time, and, like our crag deposits, would probably crumble away under the influence of the air and coast-line action. If this be so, we may well believe that the record of the tertiary and recent periods on any future continent in the European region will be represented only by a few imperfect deposits at most. The surface of every stratum is liable, nay, almost certain, to be removed to a greater or less extent after or during upheaval; it will again undergo destruction during subsidence; and many will be entirely removed, as, for instance, the crag and recent deposits of England.

Lastly, long periods elapse in every region in which the deposits contain no fossils, from the mud being of a nature quite unfavourable for their preservation; so that we may rest assured that the record of the organic world which will remain to chronicle the recent and tertiary periods will be of the most meagre description.

If we once attain the true conception of the probabilities of the case, if we once bring our minds to remember that every thick deposit must have been laid down at the expense of one of equal thickness, of the same extent of surface, we shall perceive that we can only know the lowest layers of the very thickest deposits that have occurred during the history of our globe. No wonder need be expressed that we cannot trace the changes between two forms of life occurring in closely superimposed strata if a thousand feet of rock has been worn away by the action of rain and sun between their now contiguous surfaces.

The fact that superimposed strata conform in their stratification to the beds beneath them, is in itself very insufficient evidence that denudation has not occurred; many of the Silurian strata are perfectly horizontal in Sweden, Russia, and Canada, although the mountain-chains above them consist of rocks deposited long after them *. Gradual depression would be no more likely to alter their plane than the elevation to which they have evidently been subjected. Numerous changes of level must have occurred during the deposition of the conformable secondary strata of England, a fact evidenced by successive changes of climate, alternation of marine and freshwater beds, as well as by the presence of numerous layers of coal and trees fossilized in an upright position. The level Eocene strata have undoubtedly been upheaved, and

* Lyell, 'Principles,' i. p. 315.

may be again depressed, without undergoing any deviation from the horizontal plane.

M. Elie de Beaumont * has traced more or less fully and conclusively the evidence that at least sixty, and perhaps more than a hundred, oscillations of level have occurred during the deposition of the strata of Europe, on geological grounds alone; whilst palæontological research quite bears out the view that numerous changes between the relations of land and sea must have occurred, as it shows us numerous changes of climate took place, and alternations of deep sea and littoral forms are revealed; these are undoubted evidences of gradual upheaval and subsidence.

The change of a deposit from sand to calcareous rock or shale must have been accompanied by serious physical changes; and yet such beds continually conform in their stratification to each other. Such changes must also have given rise to considerable migrations of the species living in each region, so that a totally new form would appear from migration.

We must further remember that the ancient Lias and Trias, with all the older rocks, are still undergoing destruction; so that in considering the probabilities of any of the more ancient periods having representative strata, it is by no means fair to

* Notice sur les Systèmes des Montagnes. Paris, 1852.

compare them with the tertiary deposits: every stratum will evidently become more fragmentary in its record as time elapses, as every stratum is again liable to denudation and destruction, even after having remained covered for millions of years.

These considerations account in part for the fact that we never find a large series of transitional forms between two well-marked species or genera occurring in successive deposits, although we find the more ancient fossils less specialized than the more modern forms of life.

There is another reason why we should not find a vast number of graduated transitional forms; out of millions of existing individuals, only a few are preserved. If a dozen or a hundred are preserved in one place, it is because extremely favourable conditions existed there for preservation; so long as external conditions remained constant, fossilization would occasionally take place: if a modified form is deposited, it is only looked upon as another species. Much variation is not likely to occur without change of locality or condition; and both would materially interfere with the chance of preservation.

We have already seen that there is reason to believe that highly specialized groups, derived from a common ancestor, must have diverged contemporaneously and progressed *pari passu*; and therefore we should not wonder at the discovery of the traces of birds and the bones of marsupial mammals in the trias, since reptiles, fish, and invertebrates were highly developed at that period.

There are, however, some special difficulties. It may fairly be asked, if the origin of the mammalia and birds were aquatic or marine, how is it no remains occur amongst those of the various reptiles which existed at a period when the mammalia must have been considerably specialized? Why do we not find mammalian bones amongst those of the Pterodactyles and Iguanodons of the Wealden? But it may fairly be answered that it is extremely improbable that freshwater mammals existed in a region teaming with crocodiles; if there were any, they probably lived high up in the rivers of that ancient continent; and the probability that their bones would have reached the large lakes and estuaries of the Wealden is small. The Galapagos archipelago has been called the Land of Reptiles; and the only existing mammal on the islands is a small mouse*. How erroneous would be the conclusion of a future geologist who concluded, on the evidence of strata deposited around the Galapagos, that the present era was characterized by reptiles and the absence of mammalia upon our globe!

* Lyell, 'Principles,' vol. i. p. 221.

Indeed the character of the fauna of the Trias and Oolitic period itself was very different in other regions of our globe; for the bones of great fossil reptiles are unknown in these formations, except in Europe*.

Perhaps in the Mesozoic era the arctic and antarctic regions abounded in mammalia and aquatic birds awaiting the extinction of the great saurian races to invade the temperate and tropical regions of the earth. It was probably the huge size of these reptilian inhabitants of the Wealden country which enabled them to hold the position of the dominant race; whilst their huge size was probably the very condition which brought about their extinction, just as the *Mylodon*, *Megatherium*, and *Macrauchenia* died out in America in more recent times. The reptilia of the Wealden may have disappeared with slightly changing conditions, or may have become extinct with the subsidence of the land when the waves of the great chalk-ocean invaded the estuaries and covered the forests of the Weald.

We may therefore safely infer that but few strata from amongst those deposited have lasted through the immeasurable æons which have intervened between the primary and recent periods. We know that these have only been very partially

* Louis Agassiz, 'Essay on Classification,' p. 154.

examined, and that the remains they contain of extinct animals represent the fauna of a small territory only, and that these have been preserved only under very rare conditions; so that, as Sir Charles Lyell has well expressed it, we have "a history of the world imperfectly kept and written in a changing dialect; of this history we possess the last volume alone, relating only to two or three countries; of this volume, only here and there a short chapter has been preserved; and of each page, only here and there a few lines."

Imperfect as we have seen geological record to be, all its direct evidence is in favour of evolution. All the earlier types of living things present a less degree of specialization than the later ones. Thus the Palæozoic Crustacea, the Trilobites, are most nearly allied to the *Edriophthalmia*, and are comparatively little specialized; the Mesozoic era presents us with macrurous forms; and the Tertiary strata contain Brachyura *. The most ancient corals are of a far simpler type than those of more recent strata. Every one admits that the existing Cephalopoda are more highly developed than the ancient Tetrabranchiate Ammonites and Nautili; and the most ancient mammalian remains are much less specialized than those of the tertiary formations. Examples of this kind might be

* L. Agassiz on Classification.

greatly multiplied; whilst, on the other hand, no cases can be cited in which the more ancient forms have degenerated, although many highly specialized types have become extinct.

A vast number of extinct forms are intermediate between existing types. The chain connecting the horse with the less specialized palæotherial type has been already mentioned. The *Palæotheria* and *Hipparion* were clearly intermediate between the highly specialized horse and tapir of to-day (see Plates VI. & VII.). The *Halitherium* is a link, according to Prof. Flower, between the Sirenia and hoofed animals, whilst *Zeuglodon* and *Squalodon* are believed by Huxley to connect cetaceans with the aquatic carnivora. Barrande asserts (and a higher authority could not be given) of the Invertebrata that he is every day taught that, although Palæozoic animals can certainly be classed under existing groups, yet at that ancient period the groups were not so distinctly separated as they are now*.

The fossils of other continents than the Old World bear the same relation to their existing faunas that those of Europe do to its present inhabitants. The fossil marsupials of Australia and the Macrauchenia and Edentates of America are undoubtedly related to their present faunas.

* Darwin, 'Origin of Species,' p. 302.

Thus we see that the relations of existing and extinct animals are definite, and favourable to the view of evolution; whilst the extremely imperfect nature of geological record explains the paucity of the evidence it affords.

CHAPTER XVI.

THE EVOLUTION OF MAN.

As far as the physical nature of man is concerned, this subject has been so ably treated by Huxley in his 'Man's Place in Nature,' by Darwin in his 'Descent of Man,' and by Häckel in his 'General Morphology,' that nothing more than a slight *résumé* will be attempted here.

Embryology teaches us that the process of development is the same in man as in all the other higher vertebrates; it is only in the later stages of the life of the embryo that it comes to differ from that of any other mammal; for a long time it remains identical with that of the higher monkeys; even in the middle of gestation the arms are longer than either the spine or legs, as in the anthropomorphous apes *; and the curvature of the spine, so characteristic of man, is not acquired until long after birth.

All the most distinguished naturalists of the present day admit that man is so nearly related to the higher apes that the Linnæan order *Primates*

* Huxley, 'Vertebrated Animals,' p. 493.

has been revived in the place of Cuvier's Bimana and Quadrumana.

The different genera and families of the Primates differ more in anatomical characters from each other and from the highest apes than these differ from man*. It is true a great break exists in the organic chain between the highest apes and man; but, as Prof. Schaaffhausen has remarked, "at some future period, not very distant as measured by centuries, the civilized nations of man will almost certainly exterminate and replace throughout the world the savage races. At the same time, the anthropomorphous apes will no doubt be exterminated. The break will then be rendered wider; for it will intervene between man in a more civilized state than the Caucasian, as we may hope, and some ape as low as the baboon, instead of, as at present, between the negro or Australian and the gorilla"†.

The difference of conformation, especially of the skull, in the different races of man is really immense. The narrow skull of the African type, with its projecting jaws, is in marked contrast with the broad-headed European skull, characterized by a prominent forehead and retreating jaws; whilst the beetle-browed flattened calvarium of the

* Huxley, 'Man's Place in Nature.'

† Darwin's 'Descent of Man,' vol. i. p. 201.

Neanderthal skull of the Quaternian epoch is even more unlike the higher types than that of the lowest Australian savage.

Man, like the lower animals, possesses useless rudimentary parts; like them he is subject to deviations of development, giving rise to monstrous conditions; and reversions of structure to conditions observed amongst the other higher mammals are frequent: thus he not uncommonly possesses a supra- or intercondyloid foramen to the humerus; and muscular variations occur, not unfrequently, which present the normal condition in the higher apes. One case is recorded in which seven such variations occurred in a single subject*.

Language may be looked upon as a connecting link between the physical and mental organization of man; and there is apparently nothing in its gradual perfection at all at variance with the doctrine of evolution applied to man. Animals most undoubtedly communicate with each other by a few sounds; even some insects emit a hum of alarm and one of pleasure. "That flies do hear may be inferred from their possessing the power of emitting special sounds, and also by the manner in which they disappear when one is captured and allowed to make the peculiar plaintive note

* Darwin's 'Descent of Man,' vol. i. p. 128.

which they invariably emit when distressed"*. The higher animals, and especially birds, indubitably express pain and pleasure by sounds; young animals call their mothers by a sound; and the mothers call their young in a similar manner. Sir John Lubbock, in his 'Origin of Civilization,' has given a long list of the words signifying father and mother in different barbarous languages; and they are, in almost every case, similar simple monosyllabic utterances, like pa, ma, and da, sometimes reduplicated, but evidently the first scarcely articulate utterances of the young. But few words suffice for the vocabulary of the savage; and three hundred words are a large number to an uneducated man† in a highly civilized country. The reduplication of syllables, so common in all savage races, points to the origin of words as repeated cries.

We may safely believe that language has been gradually evolved with the progress of man's mental nature; and it cannot be held to afford any but a difference of degree between man and the lower animals when we remember the vast difference between a savage and a highly developed language.

Turning from the physical to the mental nature

* 'The Anatomy of the Fly,' p. 33.

† Max Müller on Language.

of man, the evidence of evolution rests upon the facts that man possesses instincts and feelings common to him and to the higher animals, that many mental characters similar to those of man, but in a lower degree, are exhibited by the higher animals, that some races of men are more highly developed in their mental nature than others, and that mental characters are almost certainly transmitted from generation to generation in the same manner as physical characters. This has been shown with great power by Galton, in his 'Hereditary Genius' *. He shows most clearly that genius is a rare variation, and that it certainly is transmitted. Perhaps this is the strongest evidence of mental evolution which can be adduced.

Admitting, however, the evolution of the mind to have been fully made out, it does not justify the materialistic estimate, which it often fosters, or is supposed to foster, of the religious, moral, and intellectual attributes of the human mind: nor does evolution throw any light upon the nature or origin of consciousness and volition. An endeavour will be made to show that there is evidence of the existence of a cause which can neither be correlated with force nor matter.

Physiologists recognize two forms of nervous acts—reflex acts and voluntary acts. It is true

* 'Hereditary Genius,' by F. Galton, 1869.

that certain intermediate nervous acts exist betweeu these well-marked extremes; but they are probably all compounded of the two.

Reflex acts are most easy to understand. A store, so to speak, of latent nerve-force exists in a nerve-centre; a stimulus is applied by means of an external impression; this impression gives rise to changes of nerve-tissue or of equilibrium traversing a certain nervous tract; the equilibrium of nerve-force in a given part of the nerve-centre is upset: a current of force, or a series of changes, is set up centrifugally in another set of nerve-fibres, and an act results. A given stimulus gives rise to a given result; and the effect is always the same; it is often incapable of being arrested by the strongest effort; and it is sometimes even unfelt.

A voluntary act, on the other hand, is quite independent of an external impulse or sensation; it seems as if the latent nerve-force of a nerve-centre were suddenly set free in a purposive manner from some cause or influence acting from within. Mr. Bain thinks that the germ, so to speak, of volition is the periodic overflowing of nerve-force from a centre; but the purposive direction of such force by an act of the living being originating independently, or at least not directly dependent upon a stimulus from without, is a definition which more completely expresses the apparent nature of volition.

Let us examine how far this is an apparent, and how far a real definition of a voluntary act.

If we suppose that every voluntary act is the resultant of numerous combined impressions, or of a single impression, setting up a long train of already acquired tendencies, rousing, so to speak, a number of sequences, which have already become gradually correlated with the received impressions, just as the first bar of a familiar melody rouses a reminiscence of the rest, we are driven to the belief that a given stimulus capable of arousing this train will invariably give rise to a fixed and definite result. Suppose this result is stayed or modified by a more powerful stimulus giving rise to another more powerful series of nerve-changes, we still have the same difficulty, the result will be determined by the more powerful stimulus. Such changes and acts are purely reflex in their nature, and are exemplified in all complex instinctive acts. We all recognize such acts as clearly separable from those of volition: when such trains of thought are set going in our minds we recognize them as involuntary; we say these thoughts or trains of thought occur to us, and we cannot help them. All the force of education and of volition are needed to prevent our acting upon such impulses.

Every man knows that volitions arise from within. Let us suppose they are the result of overflowings of nerve-force. How is that overflowing guided to a particular result? A man wills to say *a*, *be*, or *ce*, and the overflowing is set to work to contract certain muscles to an accurate degree of tension, and the sound *a*, *be*, or *ce* results. The determination of one sound or the other is clearly independent of any already acquired train of nerve-action, although the complicated train of nerve-action required for each of these acts has already been acquired. Volition, as we say, determines the sound produced, determines the first of a series of complex acquired movements. Whatever may be said of memory and consciousness, it must be admitted that voluntary and instinctive acts differ much as voluntary and reflex acts do; and the purposive nature of volition cannot be explained by any hypothesis of causation from without. The more complex the nervous system, the more combined impressions we conceive as originating a voluntary act, the more inexplicable becomes the fact that the result is attained, and that the nerve-currents originated or set free do not become lost in a maze of innumerable filaments and nerve-cells so that irregular instead of regular acts would result. If the unity of our consciousness is made up of millions of conscious nerve-cells, we must believe that each cell is capable of communicating with any of the others by the channel it sees fit in itself to act. Such an hypothesis is surely in the highest degree untenable. If the image of the letter *a* falls upon the retina, it may fall upon almost any part of it; and yet it produces nearly the same result in our consciousness. Suppose the nerve-cells which take cognizance of this impression in any one portion are organically connected with the organ of speech, and we produce the sound *a* by a kind of complex reflex act: any other set of retinal tissue-elements may receive the same image, and the same result may follow; but that complexity of a similar arrangement which could enable us to perform or not to perform tens of thousands of complex acts resulting from tens of thousands of different impressions is self-annihilating. To believe that each nerve-cell is gifted with the power to receive and send a definite impression in accordance with every other nerve-cell concerned, as it must if our consciousness resides in the cells, is an hypothesis of the wildest kind.

Mr. Darwin with his usual clearness, at the very outset of his chapter on Instinct*, has disclaimed all intention to attempt to account for the origin of mental powers, and has recognized distinctly the difference between instinctive and voluntary acts; and in his 'Descent of Man' he has the following important passage:—"Little is known about the

* Origin of Species, p. 205.

functions of the brain; but we can perceive that as the intellectual powers become highly developed the various parts of the brain must be connected by the most intricate channels of intercommunication, and as a consequence each separate part would perhaps become less well fitted to answer in a definite and uniform—that is, instinctive—manner to particular sensations or associations"*.

Perhaps Instincts may be regarded as reflex acts selected by natural selection and inherited with the structures on which they depend; whilst Reason appears to be the result of sensations or reminiscences compared by volition and approved or disapproved according to the memory of prior experiences either acquired by former observation or learned from others' experience.

Memory may perhaps be looked upon as the result of associated ideas, so that when once set in motion, either by volition or external influences, trains of images associated by experience pass before us. The consciousness of such past experiences is in itself most marvellous; but the power of comparing them is still more inexplicable. Reason is surely a far more complex act than simple memory; and to some minds, probably by far the larger number, the belief that reason is a property of matter will in no wise commend itself.

* Descent of Man, vol. i. p. 38.

The action of the nervous system has been well compared to that of a complex telegraphic system. Let us suppose the wires to represent nerves, the batteries nerve-cells, the instruments nerve-terminations. However complex the system, and however complex the messages, automata could be conceived capable of working it so long as a given stimulus produced a given effect; but if given stimuli produced messages requiring comparison and correlation, and the effects needed modification so that they were scarcely ever twice alike, a clerk would be needed for the apparatus. If the electric fluid became periodically liberated and affected all the instruments at once, or in a given succession, mechanism alone would account for the phenomena; but if the electric current were always utilized according to ever-varying conditions which do not bear any direct relation to the manner in which the effect is produced (that is, which are in themselves unable to alter the arrangement of the apparatus by which the effects are brought about), a guiding intelligence is needed. Such appears to be the condition of the nervous system in the higher forms of life; and we recognize such a guiding power, although we know of its existence only by its effects on the organic mechanism; and we speak of it as the mind or soul.

Some will object to the hypothesis of a soul, on the ground that it is not known to exist in nature, and cannot, therefore, be known to be capable of producing the effects ascribed to it; but to this it may be fairly answered that when the effects are such that they cannot be produced by any known cause, they must result from an unknown cause or causes capable of producing the effects ascribed to them.

No known force is capable of volition or consciousness, nor is any form of matter so endowed; for, as we have already seen, the hypothesis that the brain is so endowed is untenable. We are therefore compelled to accept the hypothesis, which is commonly received as a matter of faith, that the body is endowed by a soul. We can only perceive the existence of a soul by its action upon matter. Just as we are conscious of our body only by its relations to the external world, so we are conscious of our soul only by its relation to the body: beyond this relation it is at once incomprehensible and unknowable.

CHAPTER XVII.

DIVINE WISDOM AND BENEFICENCE.

INTELLECT has been shown by Mr. Bain* to be the result of our successive experiences of the outer world. No man is born with intellect, but only with the power of acquiring experiences. To some the acquirement of such experiences is very easy, probably from a very sensitive condition of the organism inherited from the parents, or the result of individual variation. To others the process is laborious and difficult; but as we cannot tell how slight a variation of the organism determines the facility or difficulty of acquirement, we may well pause before we accept any theory of intuition.

It is true that the doctrine of intuitive ideas still commends itself to some minds; for, although few would now, probably, maintain it in its entirety, as enunciated by Plato, men of the highest ability are not wanting who maintain, with the late Dr. Whewell, that our conceptions of abstractions are intuitive—that time, space, and number are subjective and not objective impressions—that the idea

* Bain on the Senses and Intellect. See also Mill's 'Logic.'

of extension, for instance, exists in the mind and constitutes a "law of thought," as Dr. Whewell has defined an *idea* in his 'Philosophy of the Inductive Sciences,' a marvellously clear exposition of the views of the idealists. It is admitted by all that such intuitive conceptions are not perceived until we acquire knowledge; but those who maintain the Platonic doctrine in its modern modified form think that it is an inherent law which enables us to judge of the truthfulness or falsity of conclusions. Thus it is supposed that our exact conceptions of mathematical truths are the result of intuitive ideas or of laws which exist in the mind and warn us when we draw incorrect conclusions, or, rather, prevent the possibility of incorrect conceptions on fundamental or axiomatic truths—that, in point of fact, our conceptions are limited not by experience alone, but by certain inherent tendencies of thought, which act upon the intellect much as conscience controls the will—only that we are not allowed the same freedom of action in the former case, because we are unable to conceive the opposite of axiomatic truths.

That such opinions do not help us to conceive the manner in which our intelligence works is clear; and even if they did, this would be no good ground for their acceptance. Mr. Bain has shown most lucidly that we attain all our ideas of abstractions from experience and from the power which we possess of analyzing the impressions we receive. It is indubitable that animals have as good and, in many cases, a far better conception of space than man; the horse that leaps a fence judges his distance; and we must accord intuitive ideas to them if they exist in us. If we accord such inherent conceptions of abstract entities to a horse, shall we also ascribe ideas to an ascidian?

It appears probable that inheritance of structure may influence the nature of the reasoning process; just as an instinct is transmitted from the parent to the offspring, either of building a nest or of shunning man, so certain lines of thought acquired by a progenitor may be easier than others, and may have thus given rise to the belief in intuitive ideas. But we only put back the origin of the idea, or rather of the conditions which favour it rather than another, a few generations, and must ascribe its origin to experience.

Again, if intuitive conceptions and not experience control our thoughts, how can we explain the great difficulty which untutored Man exhibits in acquiring even the simplest abstract conception? We may deceive ourselves, undoubtedly; but no man has any conception of space without boundaries, because it transcends his experience, or of a line absolutely without breadth or thickness, from the same cause. As Herbert Spencer has well pointed out*, instead of an intuitive conception of time and space as absolute abstractions, the idea is entirely beyond us, and the perception of their relative existence is due to the existence of extension and sequence in nature.

If, then, as appears probable (nay, to some at least, certain), all human intellect arises from the contemplation of the universe, it is, to use a metaphor, the wisdom in the universe reflected upon the mind of man.

But whence this wisdom? whence the marvellous correlation of all things, and the fitness of each for all the others? as the poet philosopher Goethe expressed it,

> "All things with each other blending,
> All on each in turn depending,
> All to each their being lending."—*Faust.*

The doctrine of evolution shows us that special adaptations are the result of general laws; but it does not unfold to us the nature of the adaptation of those laws to each other. It shows us how creation has progressed; but it cannot explain the origin of the universal wisdom and beauty which our minds seek to discover. Instead of being last, wisdom must have existed first; the fitness of

* First Principles, pp. 47 & 158.

energy to matter and of matter to energy must have been ordained and foreseen, not with such reflected intelligence as ours, which depends on experience, but by Divine and Absolute Wisdom, the forerunner of all intelligence. The universe is a book spread out before us, in which the almighty wisdom of God is written; our minds imbibe it by the contemplation of Nature, whether we acknowledge its great source or no. Just as the sun's rays are feebly reflected by the moon, our intellects shine with divine effulgence. Can we believe with any justification that we, who cannot create a grain of sand or move a particle of matter except by borrowed energy, can create a thought by our own property?

It is thus, truly, that man, developed and evolved, becomes stamped with God's image, inasmuch as he reflects upon the minds of his fellow mortals the light of divine intelligence, shedding a halo of reflected splendour upon the world.

Beauty and harmony are as absolute in their existence as the truths of geometry. The Alisonian theory of beauty is most unsatisfactory: however we may admire that which is useful to us, it accounts in no way for harmony, either of form, colour, or sound; nor does the theory of utility throw any light upon the melody of sound.

Mr. Darwin, in his great work the 'Descent of

Man,' has brought forward some evidence to show that the lower forms of life admire the same ideal of beauty, to some slight degree, that we appreciate. Under the theory of evolution, the brilliant plumage of birds, the bright colours of insects in their harmonious blendings, and the warbling melody of birds are pleasing to their respective possessors, whilst they conform with our ideal of beauty.

The manner in which all beautiful birds display their plumage to their mates is in itself sufficient evidence that beauty produces a feeling of pleasure in their minds; and the remarkable case recorded by Darwin, in which a common duck deserted her mate for a more graceful pintail, is peculiarly human.

The strength of our passion for beauty, either in its external material form or when idealized and rendered abstract by the action of the mind, is perhaps the most intense that exists in our nature.

It is this appreciation of the beautiful, whether in its material or abstract form, which constitutes the æsthetic faculty. Under the theory of evolution, the cultivation of the æsthetic instinct, as it exists in the lower forms of life, must have progressed in a parallel groove, so to speak, with the survival of the useful. It is begging the question to say that the useful and the beautiful are one; for it is perfectly clear that in many cases beauty and use are distinct attributes, and it is only additional evidence of Divine wisdom that we find them so continually together.

It will be said by some, Is not this love of beauty, this æsthetic faculty, an intuitive idea or conception? It is clear, however, that no ideal of beauty can be realized which has never been perceived or taught by another. Man's standard of beauty varies much, and depends much, as Mr. Buckle has shown, upon the aspect of Nature around him; so that it appears as if no idea or ideal standard exists in the mind except such as is gained from without. The mind, however, is so constituted that certain impressions give us pain, and others give us pleasure. Beauty gives us pleasure, and pleasure of the most intense kind, whenever we cultivate our perceptive faculties sufficiently. There need be no intuitive idea of beauty to account for this; it is another of the indirect harmonies of Nature, unexplained by evolution, but doubtless dependent upon laws of the utmost importance hitherto undiscovered.

Mr. Darwin has endeavoured to show how the moral faculties have been developed; and to a very great extent he has succeeded, at least in convincing many of the justice and truth of his belief that morality is an amplification of the social instinct. Suppose the æsthetic faculty could be similarly accounted for, and suppose both hypotheses to have been substantiated beyond a shadow of a doubt, it would not weaken the argument in favour of religion one iota. The exertion of Divine wisdom is no less certain because we succeed in tracing the manner of its operation; nor is Divine beneficence contracted because we perceive that it extends to all creation. If the love of goodness and beauty have gradually been developed from a germ perceived by the lower forms of life, this is only a proof that the bounty of God extends to the humbler members of the organic world.

"The whole aspect of Nature" doubtless "answers intelligently to our intelligence;" and that it does so is, on this view, due to the fact that our intelligence is the reflection of the wisdom in Nature; but that the laws of Nature could evolve a human being and endow a mind, is a proof of marvellous adaptation—adaptation which, like that of energy for matter, could only have resulted from the absolute wisdom and goodness of an Almighty Creator.

We are thus led to attribute that wisdom and goodness which we seek in Nature, and which endow our minds with relative intellect, truth, and beauty, to God. Why, therefore, should we hesitate to attribute to Him that other attribute of mind which we know as WILL, and to believe that all things and all laws and relations exist by the ALMIGHTY AND ETERNAL WILL OF GOD?

THE END.

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PLATE I.

The Flowers of fifteen forms of the polymorphic genus *Rubus*, taken from Smith's 'English Botany.'

These are united by some botanists into three species, and are considered by others to constitute fifteen. The first thirteen figures represent the flowers of *Rubus fruticosus* (Hooker's 'Student's Flora'), the common bramble; they are united by numerous transitional forms, but have received the following names:—

Fig. 1. *Rubus discolor.*
2. —— *suberectus.*
3. —— *plicatus.*
4. —— *corylifolius.*
5. —— *rhamnifolius.*
6. —— *macrophyllus.*
7. —— *leucostachys.*
8. —— *Grabowskii.*
9. —— *Köhleri.*
10. —— *mucronulatus.*
11. —— *radula.*
12. —— *glandosus.*
13. —— *Leesii.*

Of the remaining forms, fig. 14, *R. Idæus*, is admitted to be a distinct species; whilst Dr. Hooker considers fig. 15, *R. cæsius*, to be a form of *R. fruticosus.*

The Plate is intended to show that varieties may differ as much or more than species.

Plate

B.T.L. sc.

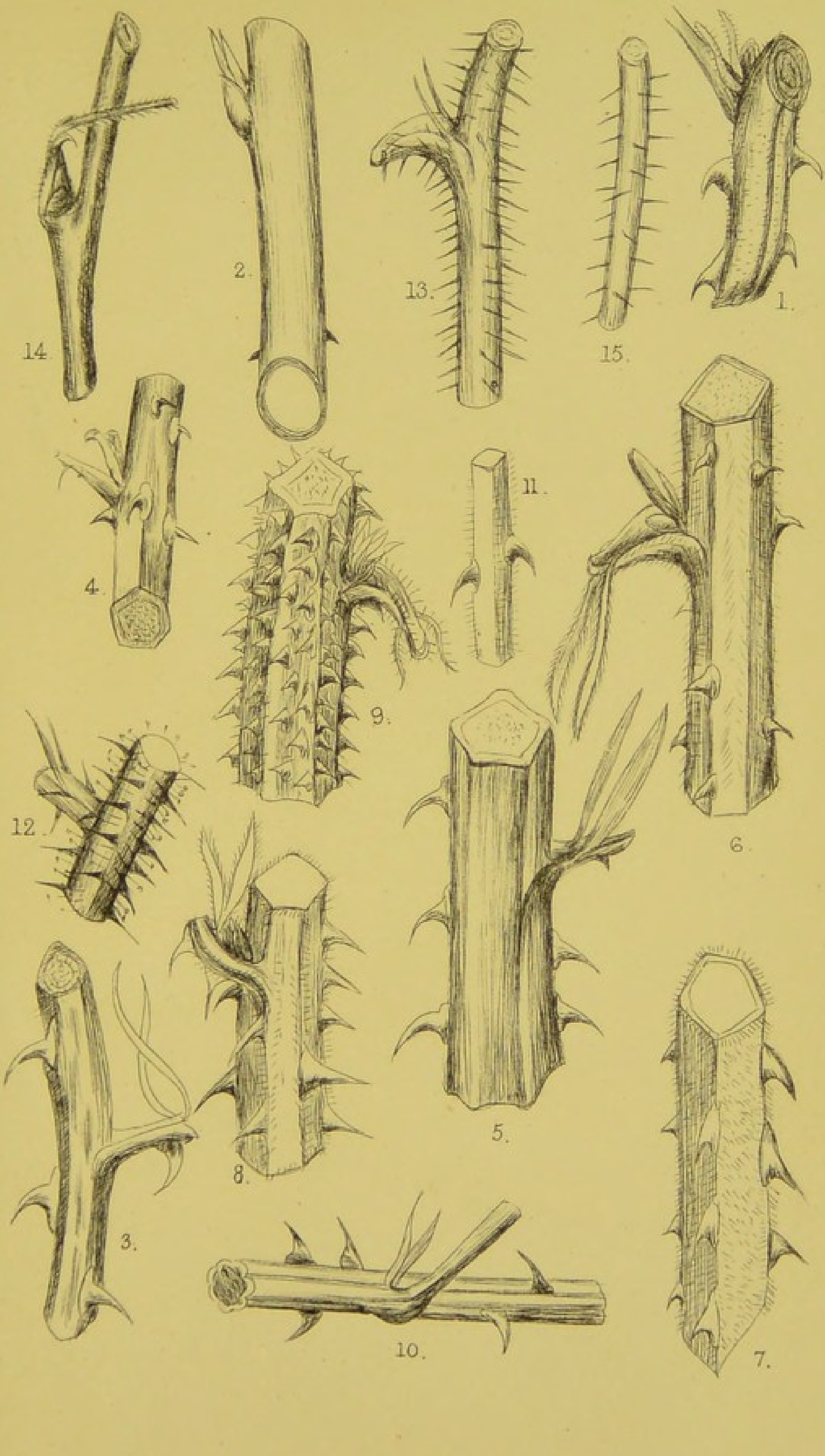
W. West & C° imp.

PLATE II.

The stems of the same plants, also from Smith's 'English Botany.' The numbers refer to the same forms as in Plate I.

Fig. 1. *Rubus discolor.*
2. —— *suberectus.*
3. —— *plicatus.*
4. —— *corylifolius.*
5. —— *rhamnifolius.*
6. —— *macrophyllus.*
7. —— *leucostachys.*
8. —— *Grabowskii.*
9. —— *Köhleri.*
10. —— *mucronulatus.*
11. —— *radula.*
12. —— *glandosus.*
13. —— *Leesii.*
14. —— *Idæus.*
15. —— *cæsius.*

The great variations exhibited in polymorphic genera are well seen in this Plate.



B.T.L. sc.

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PLATE III.

Represents the geometrical flint shields of certain of the lower forms of animals (*Radiolarians*) and plants (*Diatomaceæ*).

RADIOLARIA.

Fig. 1. *Heliosphæra actinota* (after Häckel).
2. —— *elegans* (idem).
3. *Eucecryphalus Schültzei* (idem).

DIATOMACEÆ.

Fig. 4. *Triceratium favus* (after Queket).
5. *Arachnoidiscus Ehrenbergii* (idem).

Plate III.

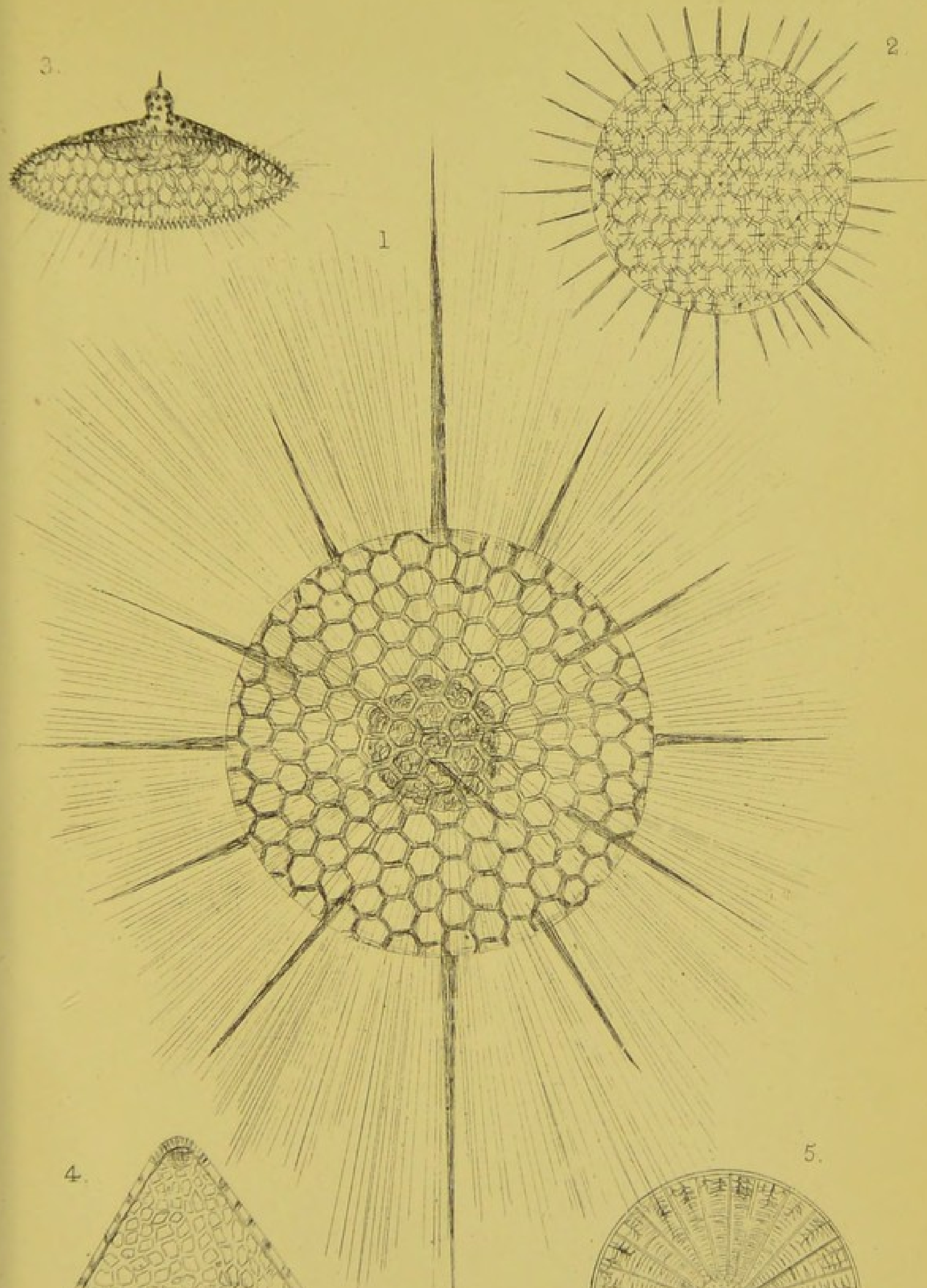

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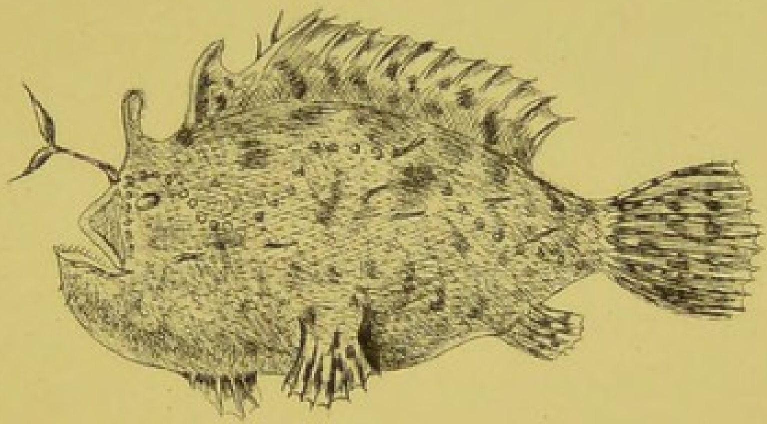
PLATE IV.

Three species of the genus *Cheironectes* (after G. Cuvier), showing the remarkable form of the pectoral fin exhibited in the genus.

Fig. 1. *Cheironectes scaber.*
2. —— *biocellatus.*
3. —— *punctatus.*

Plate IV.



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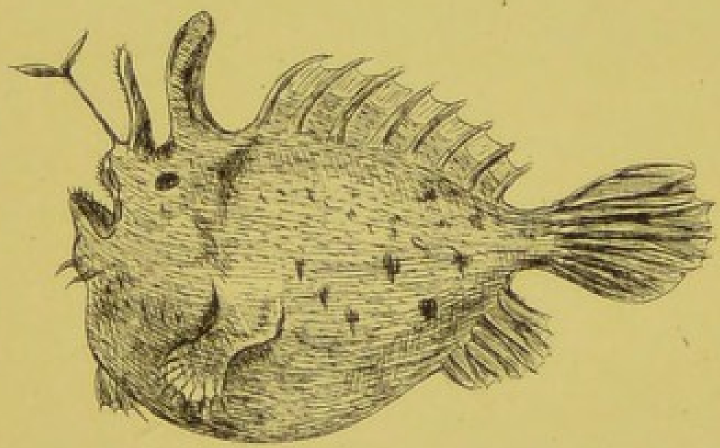

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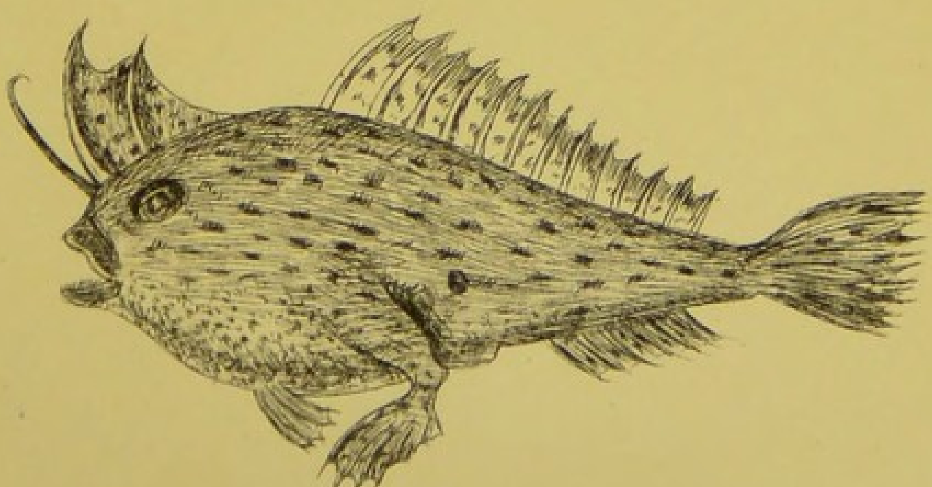

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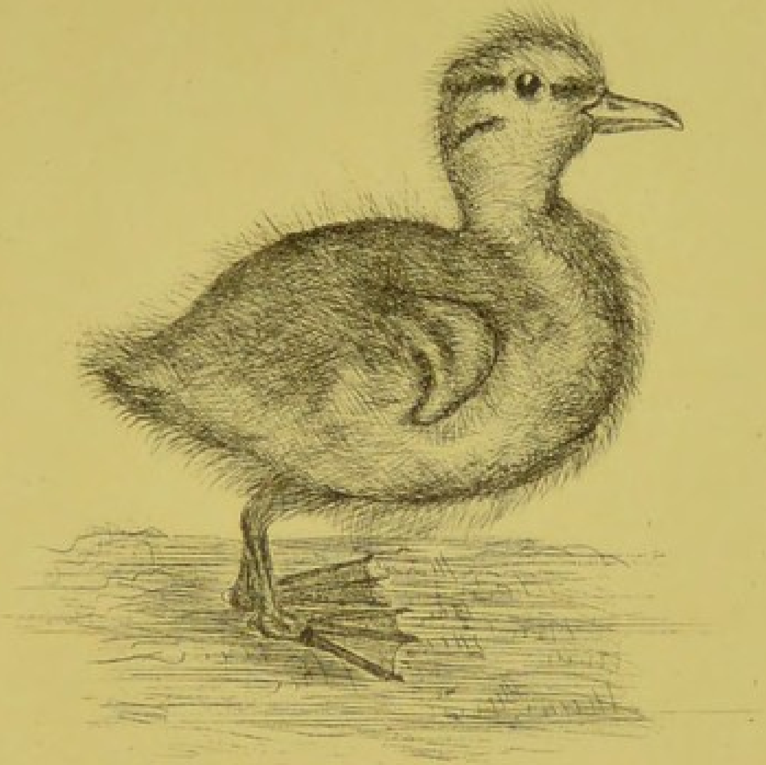
B.T.L. sc.

W. West & C° imp.

PLATE V.

Fig. 1. A young Mallard about a fortnight old, showing the extremely rudimentary condition of the feathers and wing.

Fig. 2. The young of a Red-legged Partridge of about the same age (for comparison with the last); both wings and feathers are highly developed.



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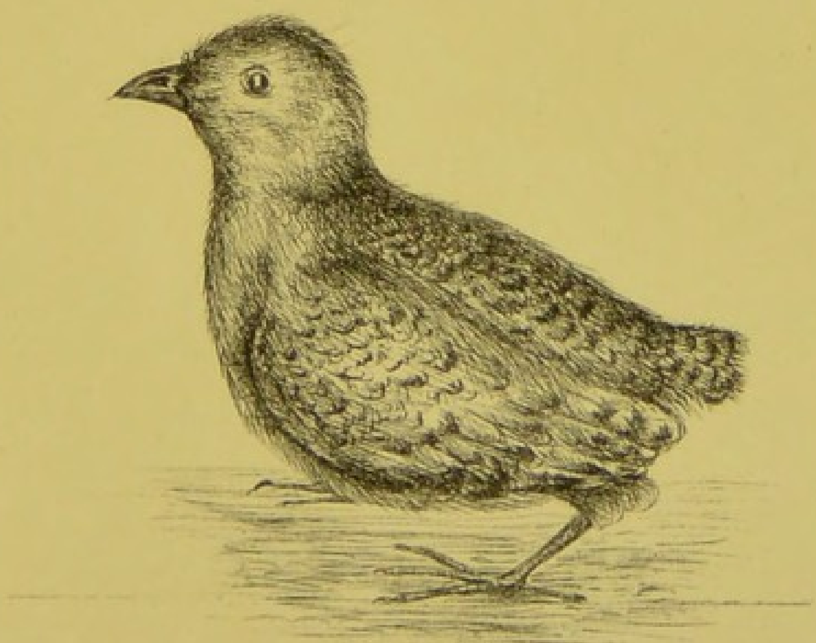

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S. T. L. sc.

W. West & C° imp.

PLATE VI.

Fig. 1. The skull of a recent Tapir (*Tapirus indicus*) (after Cuvier).

Fig. 2. The skull of *Palæotherium crassum* (after Cuvier).

Plate VI.

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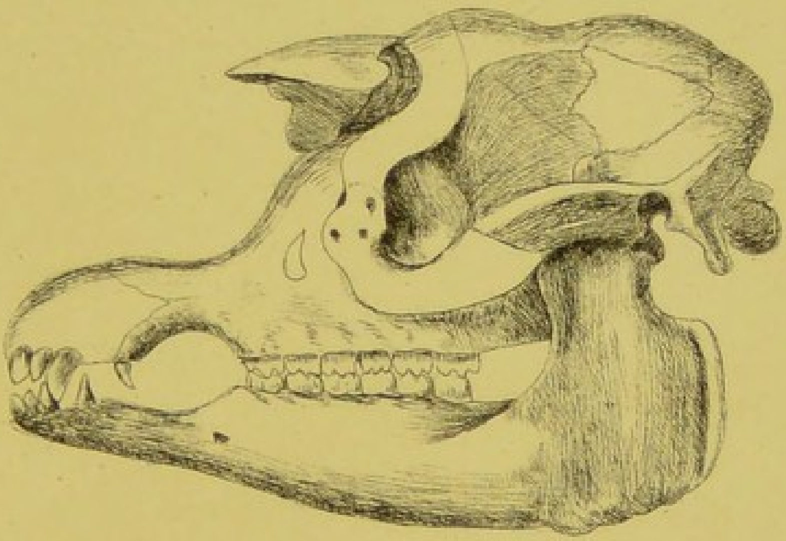

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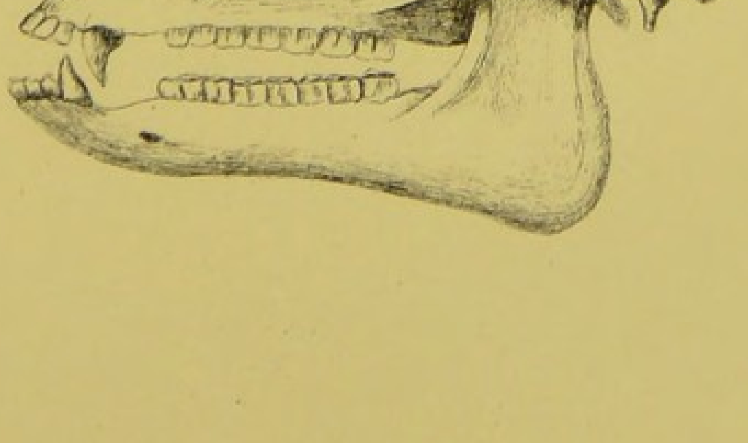


B.T.L. sc

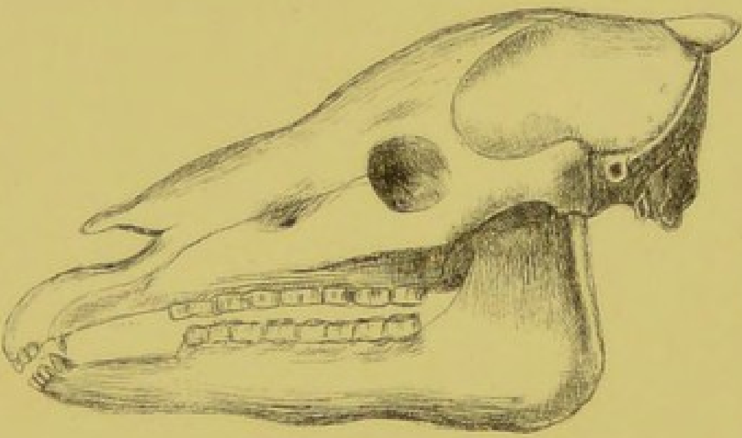
W. West & Co. imp.

PLATE VII.

Fig. 1. The skull of *Hipparion gracile* (after Gaudry).
2. The skull of the Horse.

These figures, with those in the last Plate, are intended to illustrate the intermediate and less-specialized condition of extinct when compared with recent forms.

The second figure of Plate VI. and the first figure of Plate VII. will be seen to be intermediate between the extreme forms represented in the other figures.



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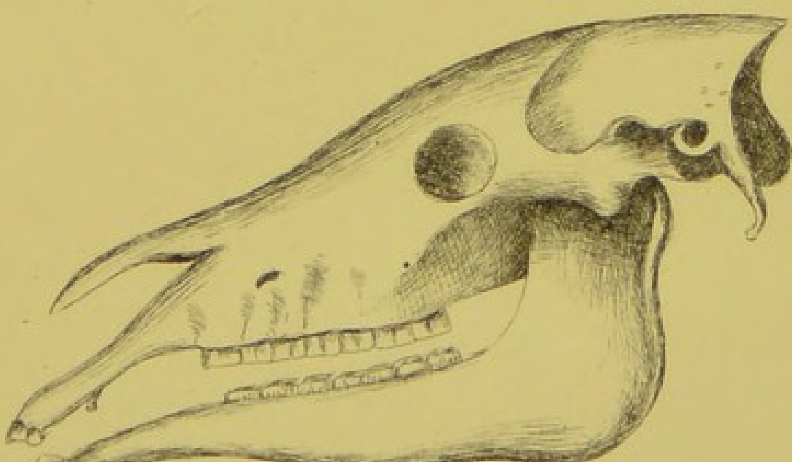

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B.T.L. sc.

W. West & Co. imp.

PLATE VIII.

The bones of the hind foot of the *Palæotherium*, *Hipparion*, and Horse, showing the gradual modification of the central toe and the concurrent reduction of the lateral ones.

Fig. 1. Skeleton of the foot of *Palæotherium crassum* (after Cuvier).

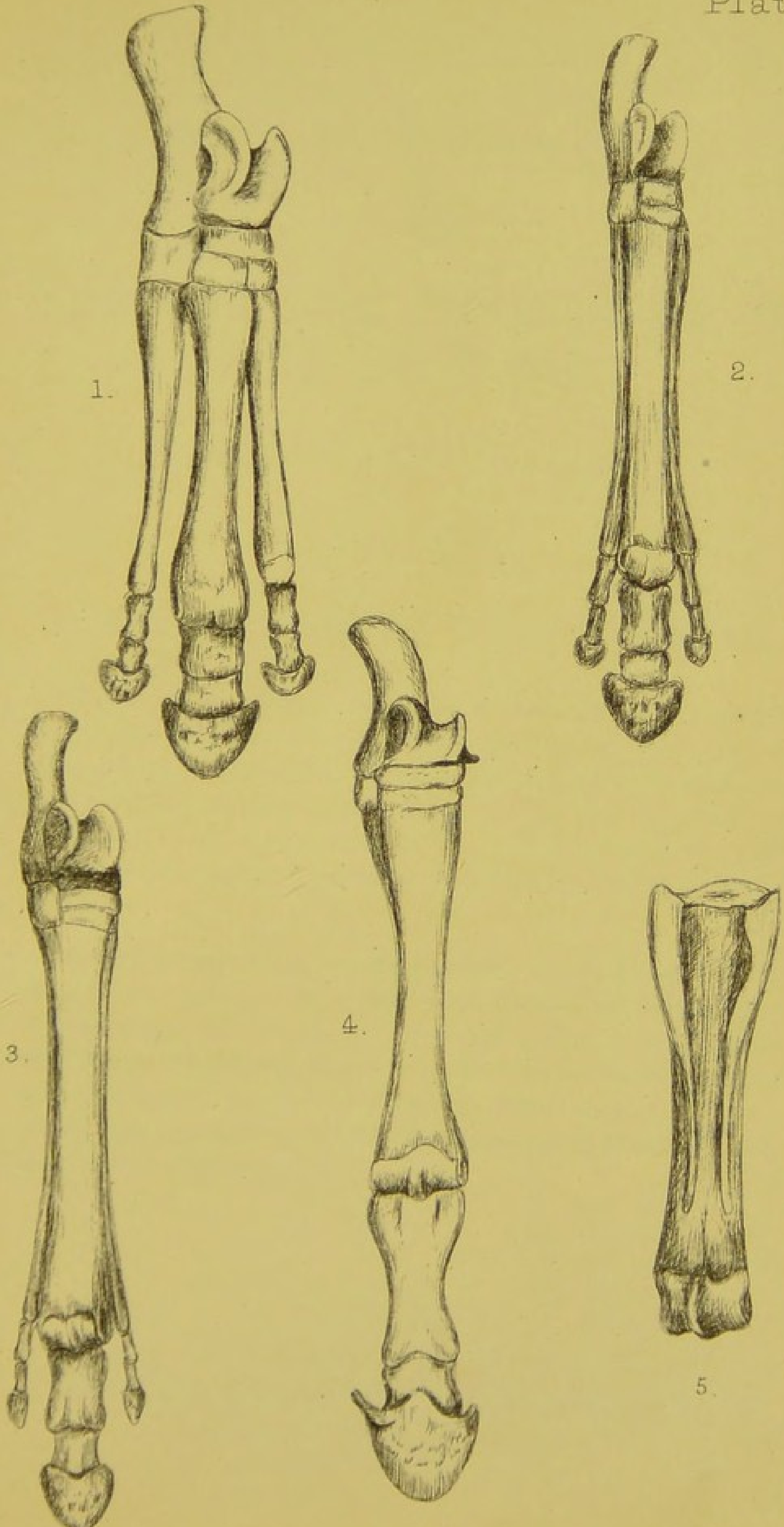
Fig. 2. Skeleton of the foot of *Palæotherium minus* (after Cuvier).

Fig. 3. Skeleton of the foot of *Hipparion gracile* (after Gaudry).

Fig. 4. Skeleton of the foot of a Horse.

Fig. 5. Posterior view of the metatarsus of the same.

Plate VIII



L. sc. W. West & C^o. imp