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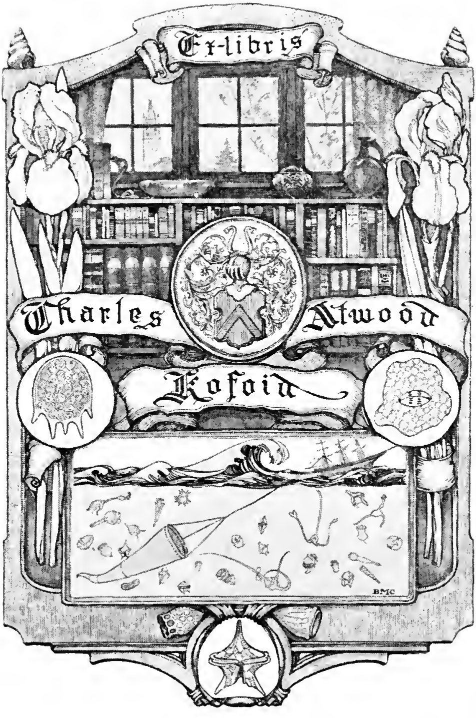
THE LESSON OF EVOLUTION

F. W. HUTTON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THE LESSON OF EVOLUTION

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THE LESSON OF EVOLUTION

BY

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"We conceive that this state of things has had a beginning; we conceive that it will have an end. But in the meantime we find it fitted, by a number of remarkable arrangements, to be the habitation of living creatures."

WHEWELL'S "BRIDGEWATER TREATISE," p. 204.

"Yet I doubt not thro' the ages one increasing purpose runs,
And the thoughts of men are widen'd with the process of the suns."

LOCKSLEY HALL.

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PREFACE

THE first of these essays was delivered at Hobart on the 8th January, 1902, as the inaugural address to the Australasian Association for the Advancement of Science. As it was not possible to give in that address any adequate account of the facts of biological evolution, I have added the second essay, which deals entirely with that subject. Of this essay, the first part, on "Early Life on the Earth," formed the President's address to the Geological Section of the same Association at its meeting in Sydney in January, 1898; but it has been corrected and brought up to date. The second part, on "Later Life on the Earth," appears for the first time.

This little book, taken together with a former volume on "Darwinism and Lamarckism," gives an account of what is known about the theory of evolution, sufficiently complete, I hope, to inculcate the lesson we learn from a study of nature, a lesson which all should know and think over for themselves.

F. W. H.

CHRISTCHURCH, NEW ZEALAND,
January 1902.

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ESSAY I

THE LESSON OF EVOLUTION

Scientific men may be divided into two groups; the investigators of theory, and the reducers of theory to practice. The workers in applied science have for their aim the material advancement of the human race. Not only do they bring health to the sick and an increase of comfort to us all; but they help to make every-day work more interesting to the intelligent, and thus they lift the toiler on to a higher level. Also, by increasing the wealth of the world, they give to some men sufficient leisure to pursue pure science or philosophy undisturbed.

On the other hand, the student of pure science—whether he be an astronomer engaged in studying the movements and composition of the starry host, or whether he be a humble entomologist—he also has a high object to attain beyond the facts he so industriously gathers together. Consciously or unconsciously he is helping to solve the riddle of the Universe by collecting evidence which may, perhaps, enable us to ascertain the laws which the Creator has imposed upon his work. He is seeking the truth, partly no doubt out of curiosity, but partly because he feels that a knowledge of the truth is of the greatest importance to the human race. We can never know the whole truth about the Universe, but we may make an approximation to it; and we may even hope to get some dim idea of why it has been called into existence, and what is the purpose of its Creator.

Thus pure science culminates in a Natural Philosophy; that is, in a philosophy built up on an observational basis, which tries to harmonise and explain all observed facts. And this Natural Philosophy must, of course, vary with our knowledge and get more and more precise as that knowledge increases.[1]

We have lately heard a good deal about the strides made in applied science during the nineteenth century, and we are all agreed as to their importance. In pure science also we have heard much of another great feat of the last century; namely, the establishment of the theory of evolution. In this case all acknowledge its importance, but all are not agreed as to its meaning, and some still think its teaching to be decidedly hurtful. This is a subject to which I have given much thought for the last thirty years, during which time a great change has taken place in scientific opinion; and it is to this change that I wish to direct your attention this evening. It is quite possible that I may have over-estimated the growth of the change; for we, who live in the Southern Hemisphere, are not so advantageously placed for recognising contemporary scientific opinion as those who live nearer the centres of scientific activity. But, whether the change be slow or rapid, it is unquestionably going on, and there can be no doubt about its importance.

[1] The term "Natural Philosophy" was formerly limited to the study we now call Physics; but as this use has been altogether abandoned, I hope that I may be allowed to revert to the still earlier and true meaning of the term.

I am quite aware that the theme I have selected is an ambitious one. But if our ideas are ever to crystallise into some definite shape, it is necessary that a general survey of the position should occasionally be made; and I do not know a better opportunity than the Presidential Address to an Association like this, where all branches of science are represented. I do not claim to speak with authority; nor do I wish to pose as a philosopher. But I will give you a simple statement of the conclusions to which I have been led, and so, I hope, enable each of you to form his own opinion of their value.

THE GROWTH OF NATURAL PHILOSOPHY

Ever since the dawn of the human intellect man has tried to increase his knowledge in two ways—by observation and by speculation. Observation came first, for that is common to man and animals. Speculation is a distinctly human attribute, and we find that it soon outdistanced observation and formed the basis of the earlier philosophies. But during the last few centuries the observational method has once more come to the front under the name of science, and its conclusions have not always been in accord with those of the speculative philosophies which preceded it.

The difference between the two methods is that whereas speculation starts a chain of reasoning from one or two propositions which are taken as absolutely true, science reasons from the basis of as large a number of observations as possible, and tries to find an hypothesis which connects them all together, or explains them, as it is usually called.

Evidently this scientific process is a very laborious one, but it is to be more trusted than speculation. For we can never be certain that any single proposition is quite true, or that it contains the whole truth; and, as it is impossible to allow for modifying circumstances, reasoning alone may lead us far astray; while, with the scientific method attention is directed to errors of observation, which can be corrected; and new facts are constantly confronting us which tend to prove, or to disprove, or to modify our theories. These theories, in time, get established as what we call "laws of nature"; that is, accurate records of observed cause and effect; and they thus form a touchstone of exact knowledge, by which the speculative philosophies must be tried.

No doubt these two processes of observation and speculation went on in a desultory, impulsive manner for several thousands of years, during which man not only learnt a great deal about the material world, but was led to speculate about the immaterial, or spiritual world, which he believed to encompass him on all sides. We can never know with certainty how the conception of an invisible, spiritual world arose in the human mind; but we know, as a matter of fact, that it did do so at an early stage of the human intellect.

Judging from the beliefs now held by the lowest races of mankind, it seems probable that when man first began, in an incoherent manner, to speculate on himself and his surroundings, the remarkable facts connected with sleep and dreams made him conclude that his intelligence was due to an unsubstantial body, or spirit, living inside him, which could leave him, travel about, and return. Dreaming of dead friends led him to believe that this spirit lived on as a ghost after the death of the body. And this belief, in time, gave rise to ancestor-worship, which passed first into the deification of ancestors, and afterwards into that of mythical personages, who were not considered as ancestors. Thus arose the belief in beneficent tribal gods, which still has great influence even among civilised nations.

Primitive man passed from the idea of human spirits to the belief that inanimate bodies also contained spirits. But as these inanimate things were often thwarting his wishes and frightening him by noises which he could not understand, he assumed that their spirits were hostile to him, and he tried to appease them by sacrifices, or to disarm them by spells.

The belief that spirits inhabit all kinds of bodies is called Animism. Both it and deification are different forms of Polytheism, which have become so mingled together that it is now often impossible to disentangle them.

This was the natural philosophy of the earlier races of man, and it came to a standstill for want of further knowledge. A very imperfect acquaintance with nature had led to erroneous ideas of religion, and a more accurate acquaintance with nature was not then possible. However, a foundation had been laid, which was subsequently built upon by metaphysicians, and in the course of time Polytheism passed into what Professor Max Muller has called Henotheism. That is, the gods are no longer regarded as of equal power, but a supreme spirit rules over the others.

Henotheism appears to have originated independently among the negroes of Africa and the Red Indians of America, as well as among the semi-civilised nations near the eastern shores of the Mediterranean. In Persia and North-West India the philosophers developed Animism into Pantheism; a philosophy which teaches that mind pervades all matter, and that nature and God are one. On the other hand, among the Semitic nations, the prophets of Israel gradually passed from a belief in tribal gods to Theism, in which God is recognised as existing outside of and unconnected with the material universe, which He has created. But with this belief they combined the idea of a rival evil spirit, who was constantly tempting men to break the moral law.

The originators of these philosophies were, however, poets or mystics who arrived at their conclusions intuitively and could offer no proofs, thinking, indeed, that their beliefs must be self-evident to all. So, at a later date, we find an atheistic philosophy, or Materialism, also in existence, due, probably, to a reaction against the excesses of the Greek Mythologists. That the truth of none of these philosophies was self-evident is shown by the fact that, in the classical world, all of them flourished together, and highly cultivated men could be found among the Polytheists, the Pantheists, the Theists, and the Atheists.

At last science awoke from its long sleep and began to study with care the material phenomena of the Universe. Scientific observations commenced with the Chaldeans and early Greeks, but it was a dreamy kind of science, confined to a few. The spirit of inquiry was not thoroughly aroused until the bold navigators of the fifteenth and sixteenth centuries sailed round the world, and demolished the old dogma that the earth was a flat disc, with Jerusalem in its centre. Then the invention of the printing-press spread the news far and wide, and from that time forwards science took an important position in the world.

Long before this, however, the idea of law and order in Nature had been gradually growing. The wonders of the thunderstorm, of eclipses, even of the rainbow, had been explained as the result of physical laws; and the consequence was that the belief in the crude polytheism of the ancients had been destroyed.

The advance of scientific knowledge was at first very slow, until, in the seventeenth century, the great improvements which were made in mathematical analysis, as well as the invention of the telescope, enlarged men's ideas enormously, and added vastly to their powers of observation and reasoning. Before the century was over the size of the earth had been ascertained with tolerable accuracy, and the law of universal gravitation had been discovered. In the eighteenth century great progress was made in the experimental sciences of physics and chemistry. Electricity was detected, as also was oxygen, and this laid the foundation of modern chemistry. Instruments of precision for weighing and measuring were invented; and, at the end of the century, the distance of the sun was approximately ascertained; and it was proved that matter was not destroyed when it was burnt, but only rendered invisible. The discovery that matter was indestructible led, in the nineteenth century, to the further discovery that the physical forces are so correlated that one can be changed into another; and, at last, it was definitely proved that energy was as indestructible as matter, that it was not lost when it was no longer exhibited, but had merely passed into the potential or invisible state.

Another important result of these investigations was to prove experimentally that matter is inert, and that it exercises no initiative of its own; that it is moved only by external agencies; and that, in physics, action and reaction are always exactly equal and opposite; from which it follows that all material things are under the reign of law. This cannot be taken as a proof that mind is absent from dead matter, for it is possible to conceive mind as present, but unable to manifest itself to us. But the experiments destroyed the supposed basis of fact on which Pantheism had formerly been built, and reduced it to a purely metaphysical speculation.

If, however, science showed that the original basis of Pantheism was erroneous, it now furnished new evidence which seemed to place that philosophy on a firmer foundation than ever.

Up to the middle of the last century it seemed probable that the Universe might be eternal. Matter and energy were known to be indestructible, and it followed that the amount of each in the Universe must be fixed and unalterable. Also the mathematicians, Lagrange, Poisson, and Laplace were supposed to have demonstrated that the Solar System was truly a perpetual motion. Even in the earth itself the celebrated geologist, Dr James Hutton, sought, as he said, in vain for any "vestige of a beginning or prospect of an end." So far as could then be seen, the world might go on for ever as it is now; an endless succession of similar years and of nearly similar plants and animals. It was not even necessary to suppose with Democritus that the Universe was the result of a fortuitous concourse of atoms; for there *was* no beginning. The Universe had always been here, and here it would remain. Life, men thought, had always been on the earth, and where life was there also was mind. And just as one form of matter, or one form of energy, passed into another, so life kept renewing itself—constant decay and death with constant rejuvenescence. If matter was indestructible, so also was mind. All was eternal. All was made to go on for ever. No controller was necessary. The Universe and its maker were one.

Thus the conclusions of science seemed to prove that mind pervades all matter; and this belief was more acceptable to our reason than the opposite one, that mind can exist outside of matter; for of the latter we have no experience. Thus a pantheistic, or monistic,[1] view of the Universe became prevalent, especially in Germany. As the study of palæontology advanced, the succession of life on the earth became a difficulty, and Darwin's theory of organic development, by means of natural selection, was hailed with delight as the explanation so long hoped for. But, in truth, the pantheistic argument was completely destroyed by the establishment of the theory of evolution, which shewed that the Universe was not eternal, and that progress, not repetition, was the law under which it existed.

The change thus brought about was sudden and perplexing, and some very able men could not see

[1] Monism is a materialistic pantheism which denies volition.

their way clearly. So they called themselves Agnostics, thinking that no well-established beliefs on theological questions were possible to the impartial investigator. If this had been correct, it would have been a fatal objection to the claim, which was at the same time being made, that science should be included in general education. Fortunately, broader and more sensible views have prevailed, and it is no longer considered necessary that a scientific man should be an Agnostic.

AN OUTLINE OF EVOLUTION

Let me now give you an outline of this theory, which has wrought such a momentous change.

The idea of evolution originated with the Greeks, but only as a speculation which led to nothing; and its scientific history may be said to commence in the early part of the last century, when the practically new theory of the origin of species by gradual development was proposed by Lamarck. This theory was at first discredited for lack of evidence; but it was developed and demonstrated by C. Darwin in the middle of the century. About the same time it was pointed out by Lord Kelvin that not only was the sun cooling, but that all kinds of energy, when converted into heat, lost a portion by radiation into space, and that this process must go on until the whole Universe was of a uniform temperature. So that, although the amount of energy in the Universe remains unalterable, it will, by redistribution, be brought into the potential state, and thus, when every possible action is counterbalanced by other actions, energy will practically disappear.

From this theory of "dissipation of energy" it follows that, as the earth is cooling, life cannot go on for ever; and also that at some former time the Earth must have been too hot for the existence of protoplasm. Consequently life can only have a limited existence on the earth. It must have had a beginning and it must come to an end.

But the inference extended further. Not only living beings but even the whole Solar System must have had a beginning, not infinitely remote; because most of its members still contain a large amount of their original heat. And if the Solar System had a beginning, so also must each star in the heavens have had a beginning; for the very fact that we can see them is a proof that they are radiating out energy. And, it was asked, why should not the whole Universe, visible and invisible, have had a common origin and a common beginning in time? This had been the opinion of Immanuel Kant in the middle of the eighteenth century; and, although modern astronomy has not altogether confirmed his speculations, it has proposed an hypothesis which is not very dissimilar. This is the "Meteoritic Hypothesis," and is chiefly the work of Sir Norman Lockyer and Professor G. H. Darwin. I will give you a short sketch of the views held by the former.[1]

INORGANIC EVOLUTION.

The close connection between the orbits of comets and those of meteoritic streams has led to the uni-

[1] See the "Meteoritic Hypothesis," Macmillan, 1890; and "Inorganic Evolution," Macmillan, 1900.

versally admitted conclusion that comets are neither more nor less than swarms of meteorites. Again, the resemblance between the spectra of comets and those of nebulæ suggests that these also are swarms, or aggregations, of meteorites. And we naturally infer that the stars with similar bright-line spectra must be collections of meteorites. From bright-line stars we pass to those whose meteoritic origin is no longer to be recognised, all having blended together. Further it is claimed that by supposing variable and temporary stars to be due to the meeting and entanglement of two meteoritic swarms we get a better explanation of the observed phenomena than any other hypothesis can give.

This meteoritic hypothesis supposes that the present material Universe was at one time in a state of "cosmic dust," spread irregularly through space, and moving slowly in many directions. It is the original irregular distribution of the cosmic dust and its irregular movements which are the source of all the energy in the Universe. We have specimens of this cosmic dust in the chondroi, or spherules, of which many of the stony meteorites are built up. They are small round bodies of crystallised minerals, varying from microscopic dimensions to the size of a marble. Of course these chondroi are not the first form in which matter existed. They are evidently due to chemical reactions, and we could frame several different hypotheses as to their origin and history. But these would be speculations, which could not, at present, be verified; and so we must content ourselves with the chondroi as the earliest form of matter known to us.

Through the action of gravitation much of the cosmic dust is supposed to have aggregated into meteorites, whose irregular movements were, in certain places, reduced to order; and so arose a number of meteoritic streams, or swarms, moving through space. Still under the force of gravitation, each of these swarms got more and more dense, until, at last, collisions took place between the meteorites; light and heat were given out, and the swarm became a nebula. The heat produced by the collisions would, at first, be slight, but would gradually increase, until the whole of the solid material was resolved into vapour, and a star was formed. Concentration, however, would still go on, and the temperature of the star would rise, until, in time, the loss by radiation more than counterbalanced the gain by concentration, when the star would begin to cool. At last light would no longer be given off, and the star would end by becoming a cold dark body moving in space. Of course, some stars would attain a higher maximum temperature than others; and either a single or a double star might be the result of the condensation; but all would follow a somewhat similar development.

Now, as a matter of fact, the spectroscope shows us that stars in all these stages actually exist at the present day in the heavens. In some the temperature is increasing, in others it is decreasing; and, although small stars must run through their development quicker than large ones, this is quite insufficient to account for all the present differences. From which it follows that some of the stars are much older than others. The sun was amongst the earliest of formed stars. When it was born, the sky must have presented an almost uniform blackness. There was no Milky-

Way; no Orion nor Southern Cross; no Pleiades nor Dog-star. All these, and many others, have been added since: not all together, but one after the other, through the long ages during which the sun was undergoing development. Judging by the relative ages of the stars, it seems probable that the process of concentration of the original cosmic dust commenced near the Solar System and spread outwards to the Milky-Way. But, however this may be, the process is not yet over. Many nebulæ have not yet condensed into stars. Swarms of meteorites still traverse space; and even in the neighbourhood of the Solar System they are so abundant, that the Earth alone is estimated to collect more than twenty millions each day.

However, slow as the process of condensation is, it is not endless. In time all the meteoritic dust will be collected into stars or planets; and in time the law of dissipation of energy will bring all these bodies to a uniform temperature. So at last the movements due to the original unequal distribution of matter will cease, and the life of the Universe will come to an end. We know of no process of rejuvenescence, by means of which dissipation of energy and the force of gravitation might be counteracted. Several attempts have been made to refute the theory of the dissipation of energy, but all have failed.[1]

The ether, which pervades space, is the only part of

[1] The last champion in the field is Professor A. W. Bickerton, who thinks that he has found a way in which this dismal conclusion, as he considers it, may be averted. But he is not very sure about it, and has to assume: first, that space contains now, and always will contain, a large quantity of cosmic dust scattered through it with some approach to uniformity; and, secondly, that the Universe consists of an infinite number of what he calls "cosmic systems," travelling

the Universe which shews no sign of evolution. It alone is eternal.

A casual glance at the stars gives us the impression of immutability. We still speak of the "fixed stars," in much the same way as our forefathers used to speak of the "everlasting hills." But we know that they are not fixed. We know that the nearer stars, including the sun itself, are in swift movement; and we infer that all are so. But we can see no connection between their movements. Single stars, or small groups of stars, are rushing through space in various directions, and we cannot detect any common centre of gravity which holds them in control. The stars have not yet attained the regularity of movement that gravitation must bring about in a very ancient system; and this idea of the comparative youth of the Universe is strengthened when we remember that large numbers of the primitive meteorites are still wandering in space uncondensed into stars. If it be true that the sun is one of the oldest stars in the Universe; and if, as geologists think, the earth is not more than a hundred millions of years old, then it may very well be that the creation of the cosmic dust out of which the stellar universe has been formed, took place less than two hundred millions of years ago. But, although it may be possible to place a limit to the age of the Universe, we can fix no time for its duration. It is impossible to form an estimate of the hundreds of millions of years that will pass before the end approaches. Still,

through space, constantly throwing off stars in all directions and occasionally colliding. As all this is pure assumption and highly improbable, I cannot think that Professor Bickerton has brought forward any serious objection to the theory of the dissipation of energy, and his hypothesis must be added to the list of failures.

a time must come when all energy will be equilibrated; and when, possibly, the visible Universe may resolve itself into invisible, motionless ether.

In the Solar System we can study the development of a meteoritic swarm in greater detail. Here we find that the whole of the meteorites did not collect into a single mass, but that several planets, as well as the sun, were formed simultaneously. It has been shewn by Professor G. H. Darwin that the effect of many collisions among a swarm of meteorites would be to gradually eliminate orbits of great eccentricity, until in time a regular system would be developed, when the whole of the meteorites would travel nearly in the mean plane of their aggregate motions. The larger of the meteorites would tend to settle towards the centre, while other aggregations might easily occur at different distances from the centre. And of these the outer planets would be larger than the inner ones, because in the more distant regions, where the attraction of the central sun was less, the movements of the meteorites would be slower, and there would be a greater tendency to agglomeration than where the movements were more rapid. As meteorites contain but little oxygen, hydrogen, carbon, silicon and alkalies —substances which are all abundant on the surface of the earth—large numbers must have been fused together to form the earth, and the lighter substances must have collected near the surface. Consequently, the collisions between these meteorites must have occurred with sufficient rapidity to melt the whole mass. For, after a solid crust had been formed, all the meteorites which fell on the earth would remain on the surface, as they do now.

As with the Solar System, so also in the Earth itself, we can trace distinctly a physical evolution. The discovery of tidal friction gave an independent proof that the Earth had had a beginning not infinitely remote; for, if that had been the case, the tidal friction would have reduced the time of the Earth's rotation on its axis to that of the moon. Also we have sufficient geological evidence to show that not more than one hundred millions of years ago the earth was in a molten condition, and probably shone with its own light. As cooling went on, the silicates crystallised out, forming a solid crust over the still molten, metallic interior, and the earth then became a dark body. At that time all the water above the crust was in a state of vapour, which subsequently fell as hot rain; forming a boiling ocean. With this rain the denudation of the primitive crystalline rocks commenced, and their *debris* was deposited on the bed of the ocean as sedimentary rocks. Gradually the continents were formed, the new ranges of mountains following each other in orderly succession; the great oceans becoming narrower and deeper as well as more and more salt. These processes are still going on; but, as the earth is cooling, the internal energy which uplifts the mountains must be diminishing, and in time it will be insufficient to counteract the denudation. Then the whole of the land will be swept into the sea, and the waves of the ocean will roll over the surface of the earth unopposed—unless, indeed, before that time arrives, the ocean should have been frozen into a mass of ice, or should have sunk slowly into the ground. All these things are approaching, but which of them will come first it is impossible to say.

ORGANIC EVOLUTION

When, during the course of physical evolution, the ocean had become sufficiently cool for the existence of protoplasm, minute living organisms appeared on its surface. These increased in size, varied in many directions, and in time discovered the bottom of the sea, on which they established themselves, changing from swimming to crawling creatures. Gradually these organisms managed to live in safety among the rough waters of the sea-coast, and then they spread over the land; first the plants and then the animals which came to feed on the plants.

Once established on land, and breathing air, improvements in the circulatory system of the higher animals became possible. The purified blood was kept separate from the impure blood, and increased rapidity of physiological processes heated the body; so that, in the birds and mammals, a stream of pure warm blood was poured upon the brain. Thus stimulated, the brain developed rapidly; and the psychological evolution thus inaugurated has reached such a height in man as to place him mentally apart from the rest of the animal kingdom.

Biological evolution differs from physical evolution in being brought about by the transmission of bodily variations from one generation to another. And in psychological evolution mind is transmitted from parent to offspring, as well as the organ in which it is to be manifested. Intelligence, however, depends not only on the structure of this organ, but on early associations and education; by which means the wisdom of one generation is handed down to the next.

Psychological evolution consists of two parts. The first is intellectual, and is found in all the higher animals as well as in man. The second is ethical, and is exclusively human.

Intellectual evolution, like biological evolution, is due to competition between different individuals and the action of selection. We probably see the first germs of ethical evolution in parental affection, which, among gregarious animals of sufficient intelligence, widened into social sympathy, and this in man gave rise to the social or civic virtues. This advance also appears to have been—or, at any rate, may have been —due to selection, and the result was the emergence of what is called utilitarian morality. Morality in the strict sense of the term—that is formal morality—also appears to have arisen from sympathy, but not by means of selection. The long and constant use by man of formal morality has made it instinctive and has thus given rise to the conscience.

How sympathy gave rise to the conscience is a difficult problem, about which we know very little at present; for few people have taken up the study of ethics from an observational basis. Darwin asks, Why does man regret, even though trying to banish such regret, that he has followed a natural impulse rather than a higher ideal; and why does he further feel that he ought to regret his conduct, while such a course never occurs to animals? And he answers, It is because the higher impulse, due to sympathy, is continuous; while the lower one, due to selfishness, is temporary. And, comparing the transient impressions of past indulgence with the ever-present feeling of sympathy, he feels that he was mistaken in following the lower impulse. And it is this that causes him regret or even shame.[1]

But the process, as described by Darwin, evidently implies a considerable intellectual capacity, and, what is still more important, the exercise of free-will; for no one could regret following a lower impulse unless he felt that he had the power to choose a higher one. Ethical development, therefore, could only commence at a stage far above the highest apes, and probably above the earlier forms of man. Meantime, while this growth of sympathy was taking place, the evolution of religion—as already described—would have been going on, and the priest would have assumed a position of great importance. It is he who would draw up the standard of right and wrong, and thus morality would be reinforced and stimulated by the religious feeling.

It therefore appears that ethical and religious development were at first separate, but quickly coalesced, until, as in Christian countries, they were completely blended. But this mutual dependence is not so pronounced everywhere. The Chinese and Japanese have high codes of morals, with very indistinct notions of religion; while the Hindus have very strong religious feelings, combined with weak ideas of morality. However, it is not possible to give even the slightest outline of ethical evolution without mentioning the religious element. The important point to remember is, that ethical development is due to a conflict of wishes in the individual himself, and is possible only because man has the power of choosing one of these wishes and acting upon it; that is to the exercise of free-will. It seems to me that free-will would be

[1] "Descent of Man," 2nd ed., p. 112.

useless to any being who did not possess a moral sense; for its only use is to cultivate morality. The exercise of this free-will by ignorant man leads to much injustice on the earth; but that is part of his education; and no doubt the end will be found to justify the means.

Now, we cannot think that the evolutionary process, of which I have given you a mere sketch, is confined to the earth alone. We must suppose that whatever may be the object for which the solar system was called into existence, it is for the same purpose that the various stellar systems exist. And in all probability, long after the sun is cold and dark, other stellar systems, each in its turn, will take up the development of life and mind. But they also in time will become cold and lifeless, until at last the process, so far as it is connected with the Material Universe, will be over. But is it not possible that evolution may still go on after life has perished? This is a point to which I will return presently.

DESIGN IN NATURE

Evolution is evidently due to the action of mind. There are some who still maintain an opposite view, but I think that their numbers are fast diminishing. It seems to me that no one who has a competent knowledge of biology and palæontology can possibly accept the doctrine that living organisms are the outcome of chance. Darwin distinctly repudiated the idea and thought that variation in animals and plants could not be explained by a mechanical theory of the universe. I must here try to make my meaning clear. We apply the word chance to those phenomena which are irregular in their appearance, and which are due to causes too complicated for us to unravel. We call throwing dice chance, because we cannot foretell what will happen. Similarly, if we say that evolution is due to chance, we mean that the Author of Nature could not foretell the results of the action of the forces he was setting in motion. Now, is the universe due to design, or is it due to what we may call a lucky throw? Has it been brought about intentionally or unintentionally? That is the question.

It may be possible to imagine a cloud formed by meteorites, which are moving rapidly in all directions but are unable to escape from the cloud, gradually changing, by mechanical laws, into a sun with its attendant planets. But we cannot imagine how the action of any mechanical causes could clothe one of those planets with vegetation, fill that vegetation with various kinds of animal life, and, at last, give rise to a being with sufficient intelligence to ask how and why it was all done. The idea that physical forces, called into existence indiscriminately, and without any ulterior object, could, by their interaction, evolve the earth and all that is on it, is evidently quite incredible. But this general statement leaves only a vague impression on the mind; and, in order to clear our ideas, I will give you two examples, one taken from inorganic, the other from organic nature, and treat them in some detail.

In the first place, let us consider the formation of the earth itself. It is evident that no organic development of importance can ever take place on the sun. For when it has cooled sufficiently to make the formation of protoplasm possible, the temperature of its surface will be rapidly reduced to a point below which protoplasm could not live, so that there would be no time for life to develop. From this we learn that biological evolution can only proceed on a cool body, the surface temperature of which is kept nearly equable by radiation from another hot body. As these conditions must last for a long time, the hot body must be large and at a proper distance from the cool body. But much more than this is required for the development of life. If living organisms were intended to progress from the ocean to the land, in the way I have already mentioned, provision must be made for the continuous existence of land from the close of the Cambrian period, and this land must be well watered. Consequently the surface of the earth must consist partly of land and partly of water, in due proportion; and the actual amount of water necessary will depend upon the size of the earth. The rain falling on the land constantly washes it down into the sea, and some agency must exist for renewing the land by elevation. This elevation depends upon the mobility of the crust, which again depends upon the internal temperature of the earth. This, therefore, it is necessary to conserve. Again, the mass of the earth must be sufficiently great to retain on its surface, by gravitation, the water-vapour which would fly off and leave the world dry if the mass were too small. And, once more, the materials necessary for supporting life and building up organisms must be present.

From these considerations it follows that, to secure a long development of life, the mass of the earth must be considerable, and that the cooled crust must be a bad conductor of heat. That is, it must be formed of oxides, and not of unoxidised metals. There must also be a certain relationship between the quantities of the several elementary substances of which organisms are composed. It is necessary that there should be a certain quantity of hydrogen for the water—not too much nor too little—as well as what was required for the tissues of plants and animals. Silicon and aluminium are necessary to form a non-conducting crust. Oxygen is necessary for the water, and to combine with the silicon and aluminium, while enough must remain over for the respiration of animals. Carbon must be in sufficient quantity in the atmosphere for the plants, but it must not be so abundant as to poison the animals; and calcium is necessary for the skeletons of animals, without which they could not have grown to any size. Too much lime, however, would have taken all the carbon out of the atmosphere, and there would be none left for the plants. A little more hydrogen or carbon, or a little less oxygen or silicon, would have rendered the earth uninhabitable. Even the right proportion of the elementary substances would have proved useless, if the earth had been too small, or if the temperature of its surface had been much hotter or colder than it is. The latter depends upon the distance and temperature of the sun, and has nothing to do with the size and composition of the earth. Also, if man was ever to become civilised, gold, copper, and other metals in accessible positions were necessary, although they are of no use in the economy of animals and plants. Gold, however, would be almost useless to man if it was abundant, while iron would be equally useless if it was as rare as gold. But we know that these, as well as the other substances, exist in their right proportion.[1]

We cannot believe that all these various and complicated adjustments were brought about by a fortuitous concourse of meteorites. When a writer of stories wrecks his hero on an uninhabited island, on which, from time to time, he finds everything he wants to make himself comfortable, we think, as we read, that the story cannot be true, because all these useful things could not possibly have come to the island by chance. It is just the opposite with the story of the earth. In this case we know that the statements are true. We know that all these useful things were found when they were wanted. First the silica and alumina for the earth's crust. Then the carbon, nitrogen, and other materials for the protoplasm. Then copper, iron, and gold for man. Here also we say that this cannot be due to chance, and the only alternative is design.

It is possible that in the meteoritic hypothesis we may find an explanation of the relations between the size of the earth, its internal temperature, and its distance from the sun ; although this is not likely, as there is no uniform gradation among the planets in these matters. But, even if the temperatures of the surface and of the interior of the earth were necessarily well adapted for the development of life, still the proportions between land and water might have

[1] Gold is the most suitable substance in the earth for coinage, as it does not oxidise. Iron is the most suitable substance for the manufacture of tools, for it can be hardened.

been unfavourable. Or, if this also was suitable, there might not have been a due proportion of the various elementary substances to allow the continuous existence of life; for these different factors are in no way related.

It may be urged that, among an almost infinity of worlds, we might expect to find an almost infinite number of different combinations; and it so happens that the earth contains exactly that combination necessary for organic development. But the objection is not a valid one, because each system of sun and planets in the universe has, no doubt, been developed under identical physical laws and from identical substances. They are, more or less, repetitions of each other, so that the number of systems makes no difference, and the earth can only be contrasted with the other planets belonging to our solar system. Now, have the other planets a similar composition to the earth? As they shine with light reflected from the sun, the spectroscope does not give us any information on this point, and we can only speculate. As the composition of the sun differs considerably from that of the earth, we have no reason for supposing that all the planets are similar. On the contrary, if the meteoritic hypothesis be true, and if the meteorites which now fall on the earth are samples of the meteoritic cloud out of which the solar system was formed, the planets cannot have identical compositions, because the meteorites differ considerably from each other, and no two aggregations of them would give rise to similar bodies. If, on the other hand, the present meteorites are not surviving samples of the original cloud, but have been drawn into the solar system after it was formed, then it is impossible to form any opinion on the chemical composition of the planets.

If, however, we were to suppose for the moment that the chemical composition is uniform throughout the solar system, it would not help us much, for the proportions which would be suitable for the earth would not be suitable for a planet which was either larger or smaller than the earth. This is evident from the fact that the ratio of the surface to the volume varies with the size of the planet. Indeed, from physical considerations alone, we may feel sure that at the present time living protoplasm could not exist in any part of the solar system, except on the surface of the earth.

We have, therefore, in the composition, size, and position of the earth overwhelming evidence of design. And as we can prove that carbon existed in the Archean era before life appeared, and that gold, iron, and copper existed long before man, we must also allow that the results of evolution had been foreseen and provided for.

Next let us examine the principal concatenation of events which led up to the production of civilised man. The human hand and foot were developed from organs adapted for climbing trees; and it was necessary that the early Primates should take to trees at once, before their limbs became specialised for terrestrial life. To induce them to climb trees fruit and birds must have been in existence; for succulent fruits have been developed through the agency of birds. So that the previous existence of birds and flowering plants, which alone form succulent fruits, was necessary for the development of the hand. Again, man could not have attained civilisation if he had not been able to domesticate animals and to cultivate food-plants. Ruminant mammalia were therefore required; and these can only exist in large flocks, through the peculiar growth of the leaves of grasses on which they feed. Most leaves grow very rapidly after the bursting of the bud, and then cease to grow altogether. The consequence is that if the leaves of one of these plants are continuously cut or pulled off, they are not reproduced, and the plant dies. But in the grasses and their allies the leaves continue to grow at their bases all through life, so long as the temperature and moisture of the soil are favourable; and cutting and biting off their ends does the plant good instead of harm, for it exposes the newly grown parts of the leaves to the sun. Thus large herds of animals are enabled to live together without destroying the vegetation; and it was this that tempted primeval man to leave the forest and live on the open land.

Now hoofed mammals required a long time for their development; and, if they had not been a very early branch of the eutherian stock, they would not have been ready for man to domesticate at the close of the pleistocene period. We have thus no less than five different groups of plants and animals, which must precede man in a certain order, to allow the possibility of human civilisation. Phanerogamous trees and birds must precede the earliest Primates. Grasses and ruminants must follow; yet they also must precede man. Now we find that this is just the order in which they did appear. Phanerogamous trees are known first in the carboniferous period. Mammals in the lower jurassic. Birds in the upper jurassic. The Primates and primitive hoofed mammals in the lower eocene. Grasses in the oligocene, Ruminants in the miocene, and man in the pliocene. The mesozoic mammals were all quite small, and we do not know the structure of their feet, so we cannot say whether they were arboreal or not; but, with this possible exception, we find that the different classes came into existence just when they were wanted.

We must remember that these groups of plants and animals form widely separated branches of the tree of life, and that the necessary correlations, of which I have been speaking, lie outside the jurisdiction of natural selection; which, although it regulates the development of each branch, has no power of co-ordination between two branches, unless one forms the food of the other. So that there is no reason at all why they should have been developed in the particular order in which they appear.

For example, the origin of birds depends chiefly on the development of highly complex papillæ in the skin, from which the feathers are formed. If these had not been developed in the naked skin of a reptile, flying birds would never have come into existence. And if there had been no birds, or even if their origin had been delayed until the miocene period, there would have been no monkeys nor man. So also, if no Ruminants had been developed, this would not have prevented the appearance of apes or even of man; but man would have remained in the stage of a hunter all his days, and could not have lived in large communities.

Now, if there had been only two of these groups, we might reasonably have said that it was by mere chance that the one was developed before the other. But when we see that there were more than two highly complex combinations, all of which happened in the particular order required for progress, it is evident that the probabilities are in favour of this particular chain of events having been brought about intentionally, either by guidance or by pre-arrangement. I see no escape from this conclusion.

SECONDARY CAUSES

But granted, what perhaps no one seriously disputes, that evolution is due to intelligent design, the difficult question arises: Has all been brought about by unalterable secondary laws, imposed on matter at the creation of the universe? Or can we recognise any evidence of guidance in a particular direction, without which the design would have failed?

When we think of the whole work that has been accomplished by evolution, we are overwhelmed by its vastness. The results of organic evolution, particularly, are so marvellous that, to our limited intelligence, the forces to which they are due seem to have been constantly directed in their course. The human mind is more disposed to accept the idea of guidance than that of predetermination, as it seems to us to be the less impossible of the two, and the more easy to understand. We ourselves wait upon circumstances, see how things are going to shape before we move, and we fancy that the world must have been made, and must be carried on, on the same principle. But the study of nature gradually causes this belief to fade away. The more we learn the more we see that secondary law extends much further than we had expected, and we begin to think that all may be due to secondary laws.

We cannot doubt but that the most complicated cases of inheritance—such as the growth of the train feathers of a peacock, or the gorgeous wings of a butterfly—are due to secondary laws, although the processes are quite incomprehensible to us. We believe these to be due to secondary laws, because we see them taking place in exactly the same order over and over again; and, in the case of the peacock, we know that if we pull out the feathers new ones, similar to the old, will replace them. So that we can bring these laws into play whenever we choose. It is not sufficient, therefore, to say that an action is not due to secondary law because it is so wonderfully intricate, or because it is incomprehensible to us. We must be able to show, either that the action is antagonistic to known natural laws, or that the result could not be due to a combination of any natural laws that we have already discovered. That is, we must show a discontinuity in the phenomena. Can any such breaks be discovered?

The origin of the material universe, which was the starting point of the present evolutionary process, appears to us to have been a new departure in natural law. But we cannot feel certain about it, for we do not know, and never can know, what went before. But with the origin of life on the earth it is different. The intimate structure of organic beings, as well as their order of development on the earth, point to the conclusion that they are all derived from a common ancestor, and that living protoplasm was formed once, and once only, on the surface of the sea. Now, in the origin of living substance on this planet, we have a case which is generally recognised as a break in continuity. It is generally allowed that it was an action which is not only incomprehensible by us, but one which conflicts with our knowledge of natural laws. That an unstable chemical compound, endowed with the power of directing energy independently of any outside agent, should have been brought into existence by the action of known physical laws is an impossibility. The processes of assimilation and fission, on which all progress depends, are quite distinct from anything that had gone before. And, as every living cell is imbued with what we call instinct, which directs its energies, it follows that in physiology action and reaction are not equal and opposite. Indeed, every organism inherits from its parents a store of energy which directs growth, and which appears to be inexhaustible. It is drawn upon during the whole period of growth, which in some plants lasts all through life, and yet abundance is left for transmission to its offspring, no matter how numerous they may be. The store increases instead of diminishes; and we cannot tell why.[1] Until some explanation can be given, it is not only permissible but reasonable to view the origin of life as due to some guiding action outside of natural law; especially when we remember what that break in continuity has led to.

[1] Life appears to consist in the power of directing the movements of the molecules of protoplasm. It is impossible for us to understand how these movements can be controlled without the application of physical force; and yet life cannot be a form of physical force because it disappears altogether at death. Perhaps life might be defined as the action of mind on protoplasm.

Again, it has been often pointed out that the genesis of consciousness is as great a mystery as the genesis of life, and that it seems to be equally opposed to the law of conservation of energy. In the lower animals, and in some of the lowest plants, we see physiological processes producing movements which appear to be intelligent, but which, in reality, are no more so than the movements of the leaves of a sensitive plant. And it is generally allowed that for the exhibition of consciousness a brain-cortex is required; but how matter in the brain-cortex becomes self-conscious we cannot understand. However, it is possible to suppose that mind is a necessary concomitant of life, so that the origin of the two may be one and the same problem. Also, as consciousness may be lost—as in habit—and regained by attention, it is possible that consciousness may be a constant function of mind, but one that cannot become efficient until a large number of specially formed cells are accumulated in a brain-cortex. I cannot therefore see that the genesis of consciousness in animals necessarily marks a break in continuity, notwithstanding that its origin is quite incomprehensible to us.

Free-will in man is so contrary to what we know of the laws of nature that some metaphysicians believe there is no such thing. However, I must confess that I am one of those who think that the possession of free-will by man is a truth as fundamental as self-existence. Every one, I think, knows that by means of his imagination he can, at his will, strengthen one set of impulses and weaken another; and that he can, within limits, control his actions. Consequently, he knows that he is not altogether an automaton. If it could be shewn that the hypothesis of necessity explained matters which the common-sense view could not, then I might be inclined to believe in it. But such is not the case; and it seems to me that what the metaphysicians have really done is to prove that free-will in man could not possibly have arisen through the action of physical causes.[1] Here, therefore, we have another possible break in continuity. Life, and perhaps free-will, could not have arisen from antecedent conditions alone; and so the idea of the continuous action of secondary causes fails.

When we try to follow the subject further we are beset with innumerable difficulties arising from the complicated nature of the problem. However, it seems probable that the whole of biological evolution may be due to the working of natural laws which we already know, but the action of which we cannot trace out in detail. Nevertheless we must remember that we have as yet no theory of variation that fits all the facts. At present variations appear to be as capricious and unamenable to law as did the wind and rain to our forefathers. And, until they are reduced to order and we understand how and why they arise, we must be careful not to push the doctrine of secondary causes too far. Mr Herbert Spencer would account for everything by what he calls "equilibration"; but that is

[1] If mind is always present in living protoplasm, it may be that it was originally free to act, but, being gradually influenced by former experiences, its independent action was gradually lost among the numerous impulses due to memory, and so it became almost entirely instinctive. Volition, however, was only latent, and as the brain developed, it began to reassert itself, until in man it was enabled to burst the bonds of custom and became once more capable of assuming the initiative. Thus free-will emerged as a potent factor in evolution.

merely a word and not an explanation. Possibly, in the future, when we understand why variations occur, it may be found to be a useful word; but, as used by Mr Spencer, it is only a cloak to hide our ignorance.

But this doubt as to how far secondary law extends need not disturb us. If we are satisfied that we see in the progress of evolution, or in the origin of life, or in the existence of free-will in man, a convincing argument for the belief in design, it is enough; and we may allow, without compunction, that it is impossible to say how far back secondary law extends.

EFFECTS OF THE NEW TEACHING

This new doctrine of evolution has changed the whole aspect of Natural Philosophy. We are now compelled to assume as First Cause a power outside of nature without which the material universe could never have come into existence. For, in the first place, if this universe has in itself no power of rejuvenescence, it and its Creator cannot be one and the same. The mind which moves the universe cannot have come into existence with it; nor can they perish together. And, secondly, while the origin of life on the earth remains as evidence of discontinuity, it is impossible to believe that the evolutionary process is due to an uninterrupted original impulse, such as we must suppose would result from an effort in nature to evolve itself. And we must further believe that the mind, which originated this gradual development of matter from the simple to the complex, must be sufficiently powerful to direct the stupendous forces of nature; sufficiently intelligent to foresee their results when set in motion; and sufficiently moral to have conceived the moral evolution of man.

It is true, as Pantheists urge, that our only experience of mind is in connection with matter. But, so far as we know, mind is connected only with one kind of matter, called protoplasm, which cannot possibly exist throughout the universe. Consequently, mind must either be absent from large portions of matter, or it must be associated with that matter in some way which quite transcends our experience. So that we have no more experience of mind universally distributed through matter, than we have of mind distinct from matter. And the argument for Pantheism breaks down.

But this is not all. The demonstration that man has been derived from the lower animals has enabled us, at last, to reach a monotheistic conception of the universe. While it was thought that man was an independent creation, and originally sinless, it was necessary—in order to account for the origin of sin—to suppose the existence of a malignant spirit. But now we have a simpler solution of the problem. Man himself is the author of sin. We see it in the unrestrained exercise of the animal passions, which he has inherited from his non-moral ancestors, and which it is his duty to repress. Consequently the ditheistic idea of two spiritual powers constantly at war is no longer necessary, and we can substitute for it a pure monotheism.

So the proof of evolution has ushered in a new era of thought, and has shewn that Theism is the true philosophy of the universe. It is, indeed, this theory of evolution which now forms the foundation of our belief, and not the vague and unsatisfactory speculations of Mr Arthur J. Balfour.

THE PURPOSE OF EVOLUTION

I come now to another aspect of the problem. As years pass on we shall, no doubt, know the story of evolution in much greater detail than we do now. Mistakes will be corrected and many new facts will be discovered. But nothing can alter its main outline, and a more complete knowledge will not make it more impressive. How it was brought about and by what means it moves are, perhaps, above our comprehension. What little we have learnt about these things is chiefly the work of three men: Sir Isaac Newton, Lord Kelvin, and Charles Darwin—Gravitation, Dissipation of Energy, and Selection—that is all we know at present.

There still remains the question, Why was the universe called into existence? What does it all mean? For, if the fundamental doctrine of Theism is established, it necessarily follows that the Universe exists for some purpose towards which evolution is working; and, so far as the earth is concerned, it seems possible that we may arrive at some conception of what that purpose is.

We have already discovered that the physical evolution of the Solar System was followed, as soon as the earth was sufficiently cool, by the production of protoplasm and the biological evolution of living organisms. These we know soon divided into plant life and animal life; and, when the brain was sufficiently developed, animals showed the commencement of a psychological evolution of mind. At first this latest development of evolution was entirely intellectual, and was chiefly employed in the preservation of the race. At a later stage a higher development took place and a moral evolution commenced. Physical evolution, biological evolution, and psychological evolution are still going on. So far as the earth is concerned, physical evolution has reached, probably it has passed, its *optimum* ; for the earth cannot in the future be better fitted for the development of life than it is now. Biological evolution has also reached its *optimum* in man, whose body has been practically stationary since the middle of the pleistocene period, and cannot now be affected by natural selection. Indeed, ever since the beginning of the neolithic age man has been engaged in combating natural selection by endeavouring to alter the surrounding conditions to suit himself. This he does by making artificial warmth, building houses, making clothes, and cultivating land.

Psychological evolution, however, has not yet reached its *optimum*. The development of the human mind is but in its infancy. Man's origin dates back only some tens of thousands of years, while he has several millions of years before him. During that time it is impossible to predict what will happen ; but so long as the external conditions are favourable for the working of the brain, we may feel sure that psychological evolution will continue.

Any other kind of evolution besides those of matter, life, and mind is unimaginable, because we know of nothing else on the earth to evolve. The physical evolution was evidently intended to prepare the way for the biological evolution which led up to man. And the brain of man was thus prepared for the psychological evolution which is still in progress, and which, as I have said, appears to be the last form which evolution can take. So that the development of man's moral nature must be the purpose towards which evolution tends on the earth.

This idea is by no means new. In the middle of the eighteenth century Immanuel Kant said that "the cosmic evolution of nature is continued in the historic development of humanity and completed in the moral perfection of the individual." And, a little later, Gœthe, another pioneer of evolution, said that the sole purpose of the world appeared to be, to provide a physical basis for the growth of spirit. However, our ideas on the subject are much clearer now than was possible a hundred years ago, and what was then a speculation has now become a demonstrated truth.

But if we believe in a purpose at all, we must believe that everything which has contributed towards realizing that purpose was designed to do so. If the carbon in the earth's atmosphere was intended for the building up of organic beings, so also were iron and gold intended for the use of man. And further, there are numerous things in the world which, by their beauty or variety, so excite our admiration as to induce us to examine them closely; and thus they have helped to lay the foundations of science. This appears to be the only use these things have in the world. As examples, I may mention crystals and the beautiful colours and shapes of many animals. Attempts have been made to show that all the latter are either of use to their possessors or else that they have been of use to some ancestor, and are, therefore, in no way connected with the evolution of man. They are thought to be merely side branches, which led to nothing, from the main stem of evolution. These attempts to make the utilitarian doctrine universal were never agreed to by Darwin, and, to the best of my judgment, they have not been established.[1]

It seems to me certain that in the progress of biological evolution many characters have been developed, which have never been of any use to their possessors, but which have been of the greatest use in developing the mind of man.

We all recognise what science has done for civilisation. But how did the scientific study of nature begin, and why is it carried on? No doubt it is largely due to man trying to make himself more comfortable by improving his surroundings. But this is the work of applied science only; and for workers in pure science mere utility has no charms. It is the wonderful and the beautiful in nature which are, and always will be, the moving forces of pure science. Utility has never been the only agent which excites men's minds to observe and to reason; and all the great laws of nature have been discovered without any reference to it. Without the beauty and wonderful complexity of natural objects man would never have risen above the level of an intelligent beast. Biologists too often forget that wonder and admiration are the principal moving forces in psychology. And, as we may feel sure that beautiful objects were intended

[1] See *Jour. Linn. Soc. Zool.*, xxvi. p. 330, and *Ann. Mag. Nat. Hist.*, Ser. 7, vol. vii. p. 221.

to do the work they have done, it follows that the wonderful and the beautiful must be recognised as prospective agents in biology.

But if all these elaborate arrangements have been designed for the purpose of constraining man to evolve his own mind, there must be some reason for it. If it is part of the scheme that each of us should do his best to cultivate his intellect and his moral sense, it must be for some ulterior object which we do not yet know. We see some men and women devote themselves to the welfare of mankind. They go through the whole ethical evolution and follow strictly their consciences, refusing to do wrong, even under great temptation. And then they die. Is that the end? The whole progress of evolution, from the creation of the cosmic dust, has for its goal the production of these men and women; and, if they have perished, all appears to have miscarried. Was man given life, thought, and freedom of action for nothing? I cannot think so, because I cannot believe that the process of evolution is meaningless. I cannot believe that evolution will have no permanent effect. I cannot believe that after the material universe has passed away, the universal mind, which ordered it, will be exactly as it was before psychological evolution began. If mind is indestructible, the evolved human mind must re-act on the universal mind and change it. And thus I feel constrained to believe that psychological evolution may continue after the death of the body, in which the mind is temporarily encased.

If evolution was gradually leading to a state of perfect happiness on earth, if we might suppose that a millennium was approaching, then we might possibly believe that this millennium was the final purpose of terrestrial evolution, however inadequate it may appear to be. But there is no evidence of a millennium, even in the very far distance. So long as man exists, ethical and intellectual evolution will both be going on, and they will always be in antagonism. The struggle for wealth and power will never cease, and while it continues there can be no millennium. The wolf will live as long as the lamb, and the two will never lie down together. So we must look elsewhere for the object of evolution.

Indeed, psychological evolution is not making towards happiness. Birds and other animals are as happy as man. Civilised man cannot boast that he is happier than the savage. The greatest happiness of the greatest number may be the ideal of the politician, but it has never been the ideal of the moralist. With him happiness may come as an adjunct, but it cannot be a prime motive for action. His ideal is duty. Consequently, ethical evolution seems to be leading up to something which is not displayed on the earth, and which we can only conceive as a further development of psychological evolution when mind is freer from matter.

It will be objected that we cannot even imagine a spiritual life unconnected with any material substance. That is quite true, but it proves nothing. As I have just said, we know that physical evolution prepared the way for life, and that biological evolution prepared the way for the development of mind. In each case the evolution had a prospective purpose, which could not have been predicted by an intelligent onlooker. Indeed, the intelligent onlooker might have been sufficiently self-confident to affirm at each stage that no further evolution was possible. And it seems to me highly probable that psychological evolution on the earth may also have a prospective purpose; that it also will lead to a further evolution, which we cannot even imagine, but which must be connected with a spiritual existence beyond the grave.

And thus, at the dawn of the twentieth century, we come back to the old belief, held by the rude men who inhabited Europe in the neolithic age, that man's spirit does not die with his body. But we hope that we have surer grounds for that belief than had our ancient ancestors; who, as I have already pointed out, founded their opinion solely on their dreams.

SUMMARY

I will now, in conclusion, shortly summarise what I have said. We have seen that natural philosophy was, at first, polytheistic and then became dormant for many centuries. After the revival of the study of nature, scientific teaching was decidedly pantheistic; but it has now come round to theism; and this last change was brought about by the establishment of the doctrine of evolution. It appears highly probable that the material universe is not eternal but will in time come to an end. The earth, and consequently the sun, is probably not much more than one hundred millions of years old; and, as the sun is one of the oldest of the stars, it is probable that the origin of the universe does not date back for two hundred millions of years. What went before and what will come after we can never know; but we may believe with some confidence that there is no natural process of rejuvenescence; no possibility of the present universe coming back again to its original starting point.

Now, for anyone who believes that mind has been the organiser of energy, there can only be two competing theories of the universe—Pantheism, now usually called Monism; and Theism, now often called Dualism. But either there is some process of rejuvenescence which has not yet been discovered, or Pantheism is impossible. As reasonable men and women we must follow the best available evidence; and I do not see how it is possible for anyone to believe in Pantheism, or Monism, so long as the origin of life remains unexplained.[1] Consequently, Theism is left as the only possible theory of the universe. And I have, I hope, shown that there is sufficient evidence of design in nature to convince us that evolution has not been due to haphazard effort, but to deliberate action leading up to some ulterior purpose, which it is the great wish of man to fathom.

We know that the sun is in its old age, and that in a few more millions of years it will cease to have any vitalising effect on its planets; also, we know that biological evolution has nearly run its course on the earth. The race of life is over, and man has won. No other animal can ever arise to compete with him, for he could destroy it long before it became formidable. Psychological evolution alone is in the ascendant, and this has yet much to do, especially in the domain

[1] If the monists are to maintain their position, they must explain the relation between matter (which is endowed with gravity and absorbs or emits heat), and ether (which is not endowed with gravity and can neither absorb nor give out heat), as well as the relation between living and dead protoplasm.

of morals. Ethical evolution—founded on free-will, which changed the human mind into the human soul—is the highest and last form of evolution possible on the earth, and consequently, so far as terrestrial evolution is concerned, the development of the human soul must be the object for which we are seeking; and, if this is so, there ought to be no difficulty in believing that everything which, either directly or indirectly, has been instrumental in this development was designed for that purpose.

But, if all has been planned for the development of the human soul, there must have been some reason for planning it. There must be some further purpose which is hidden from us. We cannot believe that the ultimate object was the happiness of man on the earth, for there is no evidence that psychological evolution has increased his happiness. It is not the pursuit of pleasure, but the feeling that duty comes before pleasure, which is the moving force in ethical evolution.

So we come to recognise that the ultimate purpose of evolution cannot be fulfilled on the earth; and we are thus led to believe that our spirit will not perish with the body, but will, in some way or other, lead a new existence. And, as we know that on the earth better has constantly succeeded better, so we may hope it will be in the spiritual world.

Such seems to me to be the teaching of the modern doctrine of evolution. It is a philosophy which does not come to a close on this earth, but points forward and dimly shows us, from a study of the past, what we may expect in the future. Without any doubt it teaches us that man has been introduced on to the earth for some special purpose; and it appears that that purpose can only be attained by the exercise of his free-will. This being so, we infer that human beings have been formed to educate the mind and fit it for a future spiritual existence, unconnected with the material earth.

No doubt we are at present merely at the commencement of our researches in Natural Philosophy; and, during the coming century, we may look forward to great advances in knowledge. But, in my opinion, we can never know more than we do now about the future immaterial life, and with that knowledge we must be content.

ESSAY II

THE PROGRESS OF LIFE.

PART I.—EARLY LIFE ON THE EARTH

WE turn to the Science of Geology to learn what is known about former life on the earth, and we get some most interesting information, notwithstanding the imperfect state of the palæontological record.

When palæontologists began to study fossils they naturally commenced with the younger formations and worked downwards. From the time of Cuvier and Brongniart in France, and William Smith in England, the palæontology of the Cainozoic, Mesozoic, and newer Palæozoic rocks made rapid progress; and in 1833 Murchison and Sedgwick began to unravel the older Palæozoic of Wales. The fossils were described by several palæontologists in Britain, in Europe, and in North America, until a fairly rich fauna was known down to the base of the Cambrian. Here fossils suddenly stopped; but so rich in species was the Cambrian fauna that it was predicted that, sooner or later, fossils would be found in pre-Cambrian rocks; and this prediction—which was based on the theory of organic evolution—has been verified within the last few years.

The first attempt at verification ended in disappointment. In 1865 Sir W. Logan and Sir J. W. Dawson announced that a gigantic foraminifer, which they called Eozoön, had been discovered a few years previously in the Laurentian rocks of Canada; but the announcement, at first received with favour, has, as I shall presently explain, fallen into discredit. Other discoveries, however, have proved more satisfactory. So far back as 1864 Mr E. Billings found fossils in Newfoundland, which both he and Sir W. Logan thought at the time to be Cambrian, but which have since (in 1888) been shown to be pre-Cambrian. In 1883, and again in 1890, Professor Walcott announced the discovery of undoubted organic remains in the pre-Cambrian of Arizona. In 1889 Dr G. F. Mathew read a paper to the Royal Society of Canada on some lower Cambrian fossils from New Brunswick, which are now, like those from Newfoundland, considered to be pre-Cambrian. Also, in 1892, Dr C. Barrois discovered supposed radiolarians and sponge-spicules in the pre-Cambrian rocks of Brittany, descriptions of which were published in 1895 by Dr Cayeux.

Here, at last, we seem to have reached a palæontological base; for although radiolarians and sponges are not the lowest of animals, they are the lowest which contain any hard parts capable of being preserved, and are, therefore, the lowest in organisation of any animals we can hope to find fossil. Their position too is, probably, in the oldest system of rocks in which we can ever hope to recognise fossils; and they are, no doubt, as old or older than any other known organisms. Consequently, the palæontological sounding-line appears to have touched the bottom. A glance at what we know, or what we may legitimately surmise, about the early history of the earth will help to give us clearer notions on this dictum of a palæontological base.

We know as a fact that the earth is a hot body travelling through space which is intensely cold. It must, therefore, be cooling. Consequently, in the early days of its history, it must have been very much hotter than it is now. There are, indeed, reasons for thinking that at a very remote period the earth was actually molten owing to the intense heat, when, of course, the whole of the water of the ocean must have been in a state of vapour, and formed part of the atmosphere. As the temperature lowered, this aqueous vapour would condense and fall on the surface of the earth as hot rain. The first ocean would, therefore, be almost at its boiling-point, and would gradually cool down; but no life could exist in the ocean or on the land while the temperature much exceeded 200° F., which, so far as we know, is the highest temperature in which plants can live. This period of the hot ocean was, therefore, the Azoic era of the earth's history, which, as the cooling progressed, passed into the Protozoic and then into the Palæozoic era, which includes the Cambrian period. At first the ocean must have been nearly uniform in temperature from the equator to the poles; but climatic zones appear to have been established in the Silurian period, if not earlier.

The pre-Cambrian rocks have received various names in different parts of the world; but, as they are better developed and more easy to decipher in North America than elsewhere, it is probable that, so soon as the officers conducting the geological surveys of Canada and the United States agree on a classification and a nomenclature, it will be universally adopted. At present this is not the case, and in this essay I have followed for the most part the Canadian authorities, who first discovered these rocks, and who have for many years devoted an immense amount of labour to mapping them.

The oldest rock system known to us is composed chiefly of gneiss, sometimes passing into granite; and it probably represents the Azoic era. It is called the Laurentian system. Above it, in discordant sequence, is found in Canada a series of schists, arkoses, quartzites, greywackes, and schistose conglomerates called the Huronian system, which probably represents the Protozoic era. However, in order to avoid using theoretical names, which may be incorrect, the Laurentian and Huronian are called collectively the Archæan era.

Immediately above the Huronian there is a great unconformity, marking a considerable interval of time; and the succeeding rocks are called Keweenewan in Canada and Algonkian in the United States. They are composed of a great thickness of sandstones and slates—sometimes locally altered into schists—which underlie the Cambrian system, the base of which is marked by what is known as the *Olenellus fauna*, from the occurrence in it of the trilobite called *Olenellus*. Let us look at these more in detail.

THE LAURENTIAN PERIOD

The Laurentian in Canada consists of two formations. The lower—known as the fundamental gneiss—is of igneous origin, and probably represents the more or less altered remains of the original crust of the earth. The upper formation consists of limestones and clastic rocks, evidently of aqueous origin, which are called the Grenville and Hastings series. The argillaceous beds interstratified with the limestones have been changed into a rock, which is also called gneiss, although different in chemical composition from the fundamental gneiss. The Grenville series is supposed by Messrs Adams and Barlow, of the Geological Survey of Canada,[1] to have been deposited at a time when the fundamental gneiss, which formed the bed of the ocean, was in a semi-molten or plastic condition, and the sediments sank down into the gneiss, so that in places they were entirely enwrapped by it. It is in this Grenville series that the structure called *Eozoön canadense* has been found.

It was the macroscopic characters of *Eozoön*—the regular concentric layers of which it is generally composed—which first gave rise to the idea that it was of organic origin. But these regular layers are sometimes very few in number, the greater part of the supposed organism being quite irregular in structure; indeed some specimens are without any arrangement at all and have been called *Archæospherinæ*, under the idea that they belonged to a different genus to *Eozoön*. In its microscopic appearance *Eozoön* must closely resemble some of the Foraminifera, or it could not have deceived such experienced observers as Dr Carpenter and Professor Rupert Jones. However, Mr H. J. Carter and Professor Möbius never allowed that *Eozoön* was organic; and Professor Zittel, although at first

[1] *American Journal of Science and Art*, Ser. 4, vol. iii. p. 173.

favouring the view that it was a Foraminifer, afterwards changed his opinion. Other specimens from Bavaria, Bohemia, Ireland, Scandinavia, and Brazil, which at first were supposed to be *Eozoön*, are now acknowledged to be inorganic; and somewhat similar structures have been found in a calcareous veinstone in eastern Massachusetts and in an altered limestone from Vesuvius.

It is, however, chiefly the position in which *Eozoön* is found which makes it impossible to believe that it is of organic origin. Professor Bonney has pointed out that the original *Eozoön* occurs on the periphery of blocks of a variety of pyroxene called Malacolite, surrounded by crystalline limestone, and that it is formed by grains of this Malacolite, generally altered into serpentine, scattered through the limestone.[1] On the organic hypothesis these blocks of pyroxene were the rocks in the ocean on which *Eozoön* grew; but evidently this cannot be the case, for the blocks are segregation masses, and were, no doubt, formed at the same time as the grains of serpentine which are supposed to infiltrate the organism.

Also, the supposed canals are sometimes filled with dolomite, a mineral which is usually altered calcite, and is rarely deposited in cavities of unaltered calcite.

The great thickness and extent of the limestones with which *Eozoön* is associated forbid the idea that they are entirely the result of hydrothermal action on lime-bearing silicates; but it does not necessarily follow that they must be organic. Also, we can hardly suppose the large quantities of graphite found in these limestones to be organically derived; for, if

[1] *Geological Magazine*, 1895, p. 292.

this had been the case, it must have come from marine plants—no others being in existence—and, as we have no knowledge of any mineral carbon-compounds having thus originated in large quantity in any other period, we should have to suppose that seaweeds were either more abundant or more capable of being preserved in the Archæan era than at any later time. The occurrence of graphite and limestone together suggests a common origin for both; and, as we know that metallic carbides occur, not only in meteorites, but also in the terrestrial iron of Ovifak in Greenland, it seems probable that both graphite and limestone may be due to the decomposition of calcium carbides by hot water. At any rate, if the officers of the Canadian survey are right in their ideas as to the genesis of the Grenville series, we cannot possibly suppose that the limestones are of organic origin, for no organism could have existed under such conditions.[1]

HURONIAN LIFE

No undoubted traces of life have been found in the Huronian of America; but it is probable that the supposed Radiolarians and sponges, discovered by Dr C. Barrois, in Brittany, should be placed in it.

The animal origin of Dr Cayeux's specimens has been doubted by some palæontologists; but, if we may rely on the accuracy of the published figures—which has not been challenged—they certainly appear to be

[1] I have not seen Dr Mathew's paper on Archæozoön and Sponges from the Upper Laurentian, near St John, New Brunswick, in the *Bulletin of the Nat. Hist. Society of New Brunswick*; but their organic nature has been disputed by Dr H. Rauff, of Bonn.

Radiolarians and sponge spicules. The figures of the Foraminifera seem more doubtful.

The Radiolarians are very minute, about one-fifteenth of the diameter of similar forms in Cambrian and younger rocks. Most of them have a thin spherical shell pierced with holes, and are sometimes furnished with spines; but the forms are various. Twenty-four genera have been distinguished, two-thirds of which are still living; and there are many others, the genus of which cannot be determined, although they are unquestionably Radiolarians. By far the commonest forms belong to *Cerosphæra,* a still living genus, known also in the Silurian period, which belongs to the legion Spumellaria, the fundamental form of which is spherical or ellipsoid. But the legion Nassellaria, in which the fundamental form is ovoid, is also represented by nine genera, although the individuals are not so numerous as those of the first legion.

Sponge spicules are probably common, but they are generally broken. They belong chiefly to the simple forms of Monactinellidæ, or to the Lithistidæ, or the Tetractinellidæ; but a few fragments belonging to the Hexactinellidæ have been recognised. Many are of branched or radiate type, and they are surrounded by pyrites, which probably represents the sponge. The fauna is, therefore, an extensive and varied one; and it is evident that both Radiolarians and sponges had existed for a long time when the rocks of Brittany were being laid down. Even if they are wrongly referred to the Huronian period, this great variety of form may be taken as good evidence that the ancestors of these Radiolarians and sponges existed long before the Mollusca and Trilobites of the Algonkian period came into existence.

ALGONKIAN LIFE

In Nevada and Utah on the west, and in Vermont and New Brunswick on the east of North America, as also in North-west India, the Algonkian beds are overlaid conformably by the Cambrian; but in all other known places, not only in North America, but also in Europe, there is an unconformity at the base of the Cambrian, thus distinctly separating the two systems.

In the rocks of Animikie, near Lake Superior, a shell something like *Lingula*, as well as some obscure fragments of Trilobites and worm-like tracks have been found. In the rocks of the Grand Canyon of Colorado, where it passes through Arizona, Dr Walcott has detected in a limestone, about 4000 feet below the base of the Cambrian, abundant fragments of a genus which differs from *Stromatopora* in having thinner and coriaceous laminæ without any connecting pillars or pores. Four hundred and fifty feet higher up he found a fragment of what seems to be the pleural lobe of a segment of a Trilobite; also a minute discinoid or patelloid shell and a small Lingula-like shell, possibly a *Hyolithes*. In North Vermont, at about 500 feet below the base of the Cambrian, he obtained fragments of a Trilobite and another so-called Pteropod—*Salterella*. In Conception Bay, Newfoundland, a patelloid shell—*Aspidella terranovica*—and worm tracks have been found in rocks underlying uncomformably the Cambrian. And the Annelid (?) tubes of the Torridon sandstone in north-west Scotland as well, probably, as the worm burrows in the quartzites of Holyhead, in Anglesey, must also be referred to the Algonkian.

Just below the base of the Cambrian a more varied fauna occurs in two different parts of the world. In the Salt Range of the Punjab, Dr Fritz Noetling has shown that there are four fossiliferous zones underlying the *Olenellus* fauna. These he calls (1) the *Neobolus zone*, (2) the Upper Annelid Sandstone, (3) the zone of *Hyolithes*, and (4) the Lower Annelid Zone. Also Dr G. F. Mathew has described what he calls the *Protolenus* fauna from St John, New Brunswick. It contains thirteen species of Trilobites, belonging to six genera, as well as Ostracoda; six genera of pelagic Gastropoda, one doubtful Cephalopod (*Volborthella*), seven of Brachiopods, three of sponges, and two of Foraminifera. Dr Mathew points out that the Trilobites of this fauna can be distinguished from those of Cambrian by having continuous eye-lobes, and he says that the fauna as a whole is more primitive and more pelagic in character than the *Olenellus* fauna.

Nevertheless, as the *Olenellus* fauna has not been found in the neighbourhood, he thinks it possible that the two might be contemporaneous, and that the difference between them may be due to difference in geographical station.

It appears, therefore, that out of the eight sub-kingdoms into which animals are divided by zoologists, six were represented in the pre-Cambrian times; but, until we come close up to the Cambrian, the Protozoa and Porifera alone show much diversity; and they were certainly the dominant feature of the animal life of the early seas. No recognisable vegetable remains have been found in any pre-Cambrian rock, but pelagic algæ must have existed, for otherwise there would have been no food for the animals.

CAMBRIAN LIFE

When we pass upward into the Cambrian period we find that life has made considerable progress, including the appearance of a new sub-kingdom—the Echinodermata; and in the Upper Cambrian we have the first Bryozoa and Pelecypoda. However, the only fossils which show much variety are the Brachiopoda and the Trilobites.

The Hydrozoa were represented by Sertularians, Graptolites, and Medusæ, the latter being so abundant that the National Museum at Washington has more than 8000 specimens. These Cambrian Medusæ belong to a distinct family of the Discomedusæ called *Brooksellidæ*, and are distinguished by having a lobate umbrella without any marginal tentacles. It is remarkable that such soft things as jelly-fish should have been preserved as fossils; but although they have no hard parts, their tissues, when saturated with water, are sufficiently firm to make impressions on the mud or sand on which they have been thrown by the waves, and when the umbrella is turned upside down the gastric cavities get filled with the mud or sand and leave star-like marks, which are easily recognised. The Actinozoa are represented only by the curious *Archæocyathinæ*, which appear to be related to the perforate corals.

The hingeless Brachiopods were the first of their class to appear. According to Professor C. E. Beecher, *Paterina* of the Lower Cambrian approaches nearest to the primitive stock, for it closely resembles the embryonic shell of later forms; and during the Cambrian period it gave rise to at least five different types of Inarticulata, one of which—represented probably by *Kutorgina*—led up to the Articulata, the first known of which, *Orthis*, had become well established in the Upper Cambrian.

Trilobites form by far the most important part of the fossil fauna, and can generally be distinguished by the shortness of the pygidium. Some were as much as eighteen inches in length. The minute *Protocaris* of the Lower Cambrian is a Phyllopod with a subquadrate carapace.

The Cambrian mollusca are remarkable for the proportionately large number of elongated shells formerly classed as Pteropoda. Lately, however, many biologists have been led to the conclusion that the Pteropoda have had a comparatively late origin. It is now generally allowed that the *Hyolithidæ*, which includes all the pre-Cambrian and Cambrian forms, do not belong to the Pteropoda. They must, however, be considered as pelagic mollusca, and probably as the ancestors of the Cephalopoda. True Cephalopoda appeared in the upper Cambrian but did not attain any importance. Undoubted Gastropoda are represented by conical and spiral shells, all of which are very thin, and probably belonged to pelagic animals. The spiral shell is strongly in favour of these early Gastropoda having been proso-branchiate; and this agrees with the discovery that some of the Opisthobranchs still inherit the twist in the visceral nerve-loop which is characteristic of the Prosobranchs. The early Pelecypoda were very minute, none of them being more than a quarter of an inch in length. The shells of all the Mollusca consist chiefly of a horny substance, containing but a small quantity of phosphate of lime, and much less of carbonate of lime; thus differing from the later shells, which are composed almost entirely of calcic carbonate.

No satisfactory evidence of plant life has been found in any of the Cambrian rocks, unless *Oldhamia* and the Lower Cambrian oolitic limestones of South Australia [1] are proofs of the existence of calcareous algæ. *Eophyton*, which was formerly thought to be a plant, has been shown to be due to the trailing of the oral lobes of a Medusa over soft mud.

SPECULATIONS ON PRE-ORDOVICIAN LIFE

The first life was pelagic.—Let us now see what these dry facts teach us. In the first place, it is very remarkable that the only extensive pre-Cambrian fauna is composed of Radiolarians and Sponges; and, as the Sponges are more complex animals than the Radiolarians, we must suppose that they are descended from them, and not the Radiolarians from the Sponges; consequently the Radiolarians are the oldest organisms we know. No doubt the Radiolarians of Brittany are not the first of their class; nevertheless we seem to have got as near, perhaps, as we ever can get to the first organisms; and we find that they

[1] *Pro. Linn. Soc. of N. S. Wales*, vol. xxi. pp. 571 and 574 (1897).

belong to a group which at the present day floats near the surface of the sea. This pelagic aspect of the early faunas is carried out by the Mollusca of the Algonkian and Cambrian periods, as well as by the great development of free-swimming Medusæ in the Cambrian; and we should remember that these delicate pelagic animals must have been very numerous to have left any record at all.

The earliest known Radiolarians are accompanied by the remains of sponges which must have lived on the bottom of the ocean, and these were followed by creeping worms and Trilobites. The early Brachiopods have diaphanous shells, like the pelagic mollusca; but it seems probable, from a study of their development in living forms, that at first they had no shell at all, but consisted of the peduncle encased in a sand-tube. The shell was afterwards added to protect the branchiæ, and in course of time the intestinal tract in the peduncle atrophied. Perhaps the so-called annelid tubes of the Torridon sandstone represent the first Brachiopods.

From all this we may infer that the first animals were pelagic protozoa, which in time varied and gave rise to pelagic worms and mollusca. At a very early date, however, some of the protozoa followed down the dead organisms and settled on the bottom, giving rise to the sponges. Afterwards worms moved in the same direction, feeding, probably, on the sponges; and from them are descended the Brachiopods and the Crustaceans.[1]

[1] This theory was originated, I think, by Biologists, and was first brought prominently before Geologists by Professor W. K. Brooks, in the *American Journal of Geology* for July and August, 1894.

The remains of the Brachiopods and Trilobites are found chiefly in shallow-water deposits; but some of them may have pushed their way into the deep sea, feeding on the dead pelagic organisms which rained down from above; indeed, it has been thought that the eyeless condition of some of the early Trilobites is a proof of this. But the eyes are always placed on the second segment, called the free cheek; and in several of the earlier forms this free cheek is ventral only, in which case no eyes could appear on the dorsal surface; the absence of eyes is not, therefore, always a proof of degeneration, but there are some species of *Illænus* in which the eyes have disappeared.

The hard spines of the early Trilobites could not have been for defence, for there were no enemies capable of attacking them; but, perhaps, they were used indirectly in locomotion. As their weak little legs paddled backwards and forwards in the mud, the spines, all of which are directed backwards, would necessitate motion in a forward direction only.

There is no evidence of the existence of any animals sufficiently protected to live among the breakers round the shore, nor is there any evidence of life on the land. If a human spectator could have stood on the shore at that time he would probably have seen no animal life at all. The rocks below low-water mark would be covered with delicate red and brown seaweeds, and the ocean between tide-marks would, then as now, be girdled with a belt of vivid green; but all the land above would be brown and barren, without even a moss or lichen growing on it. Upon the sands at his feet might lie a dead jelly-fish or Trilobite, or, perhaps, a delicate transparent shell thrown up by the waves; but they would be rarely seen; and the great ocean, although really swarming with minute life, would to the naked eye appear tenantless.

Did Plants Precede Animals?—It is generally supposed that plants must have preceded animals; for they alone are able to decompose the carbon-dioxide in the atmosphere, and thus furnish the carbo-hydrates and proteids on which animals feed. Or, in other words, plants must have preceded animals because they alone can live on mineral substances. But this supposition lands us in the difficulty of having to assume that the very first organism contained chlorophyll, which is necessary for the formation of protoplasm, but which is itself a product of protoplasm. This difficulty would be overcome if we could suppose that the primeval ocean, in which the first organisms appeared, contained, in addition to its present salts, mineral hydro-carbons which would slowly oxidise and supply the organisms with food, without the necessity of decomposing carbon-dioxide. Now Professor H. Moissan has shown that much, if not all, of the carbon of the earth existed at first as metallic carbides, many of which are decomposed by water at ordinary temperatures, and yield hydro-carbons and hydrogen. Most of the hydro-carbons thus obtained are gaseous (acetylene and marsh-gas); but in some cases both liquid and solid hydro-carbons are formed abundantly.[1] The gases would be partly taken up by the water, while the liquid and solid forms would float on the surface, and, if converted into carbo-hydrates, may have served as food for the first

[1] *Proceedings of the Royal Society of London*, vol. lx. p. 156.

organisms. It is, therefore, quite possible to suppose that protoplasm capable of secreting chlorophyll was a later development, when the supply of mineral hydrocarbons was getting exhausted; and, consequently, the first organisms may have been animals.

ORDOVICIAN AND SILURIAN LIFE

I now pass on to glance at the life of the Ordovician and Silurian periods. The Ordovician was ushered in by the appearance of the highest subkingdom of animals, the vertebrata, represented by minute teeth, called conodonts, from the green sands at the base of the Ordovician, near St Petersburg. Fossils called conodonts have been found in various places, and in rocks of different ages, from the Upper Cambrian to the Carboniferous, but they differ much from one another. Some are, no doubt, the jaws of Chætopod worms; others are thought to be of crustacean origin, although no explanation is given of why these crustacean jaws should always be found dissociated from the other parts of the exo-skeleton. Possibly some may belong to Cephalopoda; but the conodonts, just mentioned, from St Petersburg, have been shown by Dr J. von Rohon to have enamel and dentine, with a pulp-cavity of an essentially vertebrate character, and this has been confirmed by Dr Otto Jaekel; so that in all probability they belonged to an extinct order of lamprey-like animals.

In the upper Silurian we find armour-plated *Ostracodermi* and *Elasmobranchs,* the latter represented by fin-spines and small thorny scales.

The invertebrates which first claim our attention are the Graptolites and the Brachiopods. The Graptolites are known in North America from the Lower Cambrian to the Carboniferous; but in Europe they first appear in the Upper Cambrian as a monoprionidian form allied to *Dichograptus.* In the lowest beds of the Ordovician they suddenly attain their greatest development, after which they gradually declined, and only a few forms pass into the Devonian. The earlier forms had many irregular branches, which during the Ordovician period decreased in number, and became regularly arranged; while throughout the greater part of the Silurian we find only simple, unbranched forms. The thecæ also, which were at first straight and with straight apertures, became curved and with curved apertures often produced into a spine, and in the Silurian period the aperture was in some cases still more complex. The species of Graptolites are widely spread geographically, and occur in very dissimilar rocks, such as limestones, shales, and grits. Sometimes they are accompanied by a varied fauna; but in other places they occur in thin zones without any other fossils; while the different species which characterise these zones are the same, and have the same vertical distribution, wherever they are found. The explanation of these facts appears to be that the Graptolites floated on the surface, and consequently were independent of the depth of the sea and the nature of the sea bottom. We find additional evidence in confirmation of this in the fact that some of the early species were furnished with a disc, which probably acted as a float.

The Brachiopoda show a remarkable development during both the periods under consideration. *Orthis,* in which the triangular opening for the peduncle remains open all through life, gave rise to the *Rhynchonellidæ,* which has a pair of deltidial plates in the opening, and to the *Strophomenidæ,* in which the opening becomes, during growth, entirely closed by a shelly plate, thus leaving the animal free. From the *Rhynchonellidæ* sprung, in the Silurian period, the *Terebratulidæ,* in which the deltidial plates remain separate, and the *Spiriferidæ,* in which they unite during growth, and close the opening for the peduncle, as in the *Strophomenidæ.*

All classes of the Mollusca increased greatly, especially the Cephalopoda, which are, after the Brachiopods and Trilobites, the most numerous of Silurian fossils. Now, too, we find, in the Lower Ordovician, thick-shelled Gastropods, and in the Silurian we have *Chiton,* an ancient form of soft-bodied mollusc, specially modified for protection among the waves of the shore. It has been suggested on very good authority—S. P. Woodward, H. von Jhering, and Professor A. Hyatt—that *Tentaculites,* and, perhaps, *Hyolithes,* represent the primitive Cephalopoda. Anyhow, it is highly probable that the first Cephalopods were pelagic in habit, for we know no ground-animals from which they could have been derived. These pelagic Cephalopods are but little known, and possibly some of the conodonts belonged to them. The ground Cephalopods appear first as Nautiloidea, which were very rare in the Upper Cambrian, increased rapidly in numbers during the Ordovician, and attained their maximum development in the Silurian.

Marine Arachnida are represented by the *Eurypterida* in the Ordovician, to which the *Xiphosura* were joined in the Silurian. All the Xiphosura of the Palæozoic era show a remarkable resemblance to the Trilobites, as also does the young of the modern *Limulus*, or King Crab. But as the latter gets older the cephalic shield becomes united to that of the thorax, and seven of the abdominal segments also fuse together in an abdominal shield; while the primary division into three longitudinal lobes gets obscure, so that it no longer resembles its ancient ancestors.

The *Eurypterida* are closely related to the *Xiphosura,* but show also remarkable affinities to the Scorpions. Behind the small head-shield they have twelve free abdominal segments which bear no appendages except, perhaps, gills. They were the largest and most powerful animals of their day, some of them attaining a length of nearly six feet. They obtained their maximum in the Silurian period, and became extinct before the end of the Carboniferous.

Of plants we have at last certain knowledge. Not only have numerous impressions been found in Silurian rocks, which appear to have been made by seaweeds; but even as low down as the Ordovician there is a land plant, called *Buthotrephis*, which is closely related to *Annularia*; and another, called *Protostigma*, related to *Sigillaria.* In the Silurian period we find the extraordinary *Nematophycus,* which appears to have been a terrestrial alga, but as tall as a tree; and there were two genera of *Lycopodiaceæ* (*Psilophytum* and *Glyptodendron*), and at least two genera of *Equisetaceæ* (*Annularia* and *Sphenophyllum*). Ferns, apparently, were not yet in existence, for the so-called *Eopteris* is now known to be nothing more than a growth of dendritic crystals.

Land Animals.—In the Ordovician of Sweden the remains of an insect (*Protocimex*), belonging to the Hemiptera, has been found. And in the Silurian of France there is *Palæoblattina douvillei*, which, although its affinities are rather uncertain, is thought by Brongniart to belong to the Orthoptera. No other order of insects appears at that time to have been in existence. Scorpions, with stings at the end of their tails, like those of the present day, and, therefore, carnivorous, have also been found in the Silurian, and spiders in the Carboniferous.

SPECULATIONS ON ORDOVICIAN AND SILURIAN LIFE

The peopling of the shore-line and the land.—Probably all the different sub-kingdoms of animals had come into existence before the close of the Cambrian period. Henceforward no more fundamental types were to be introduced; multiplication and variation of the existing types was for the future to be the rôle, until all habitable parts of the earth were filled with life. It is in the early part of the Ordovician period that we first see animals fitted to live in the rough waters of the littoral zone of the sea-shore: these were thick-shelled gastropods, followed in the Silurian by the *Ostracodermi*. It is in the Ordovician that we have the first proofs of the existence of land-plants and insects, followed in the Silurian by scorpions feeding on the insects.

Rate of Variation.—When we think that certainly seven, and probably all eight, of the sub-kingdoms of animals were in existence before the close of the Cambrian period, it would seem at first that variation had gone on more rapidly during the earlier periods of the earth's history than afterwards; but this is an erroneous impression, due to the very unequal lengths of time represented by the different periods. Making every allowance for the possibility that the rates of denudation and deposition may have been greater in past times than now, still we must admit that the relative thickness of the sedimentary rocks of each period is a rough measure of the relative length of time it represents; and I suppose that every geologist will agree that the Huronian, the Algonkian, the Cambrian, and the Ordovician were collectively at least equal in duration to all the periods that came after them—that is, they represent at least one-half of the time since life first appeared on the earth. But certainly the changes which have taken place in animals, and especially in plants, since the commencement of the Silurian period, are far greater than those that went before, both in the addition of new groups and in the extinction of old ones; so that the rate of variation must have increased and not diminished with time. It was this slow rate of variation in ancient times that enabled the early Palæozoic genera to spread so much more widely over the earth than do the genera of the present day.

Extinction of Groups.—The diminution or decay of a whole group of animals first began with the Graptolites in the Upper Ordovician, and they finally became extinct in the Carboniferous. The same process commenced with the Trilobites in the Silurian period, and they became extinct in the Permian. Can we trace any cause for this gradual process of decline in numbers? The existence, in the earliest times, of

Radiolarians, almost identical with their descendants of the present day, is but another example of the persistence of types with which palæontologists have been familiar for a long time. It is true that we only know the hard parts of the ancient forms; but we have reason for thinking that if the soft parts had varied much, the hard parts would have changed also. From the fact of the persistence of certain types it necessarily follows that there is no inherent necessity for organisms to vary or to decay; while the idea that, if they vary they must subsequently decay, is opposed to the whole teaching of organic evolution; for it is the variable groups which have progressed. But if there is no internal necessity for decay, then the extinction of a whole group must be due to external agencies; and, if the group is widely spread, these agencies cannot have been local in their operation.

These external agencies may be changes in climate, or changes in the biological environment, due to the introduction of new forms of animals, which may either prey on the older inhabitants or be successful competitors for their food supply. Change in climate may, perhaps, sometimes account for the extermination of a group of terrestrial animals or plants, but it cannot have a wide influence on those groups which lived in the sea. These must have perished either from violence or from famine. The struggle for existence with other animals has, no doubt, generally been the most efficient cause of extinction, and with Pelagic animals it is probably the only cause. At the present day, and during all the latter half of the earth's history, the struggle for existence has been so complicated that it is hardly possible to trace out its effects; but in the earlier times, which we are now considering, the problem was much simpler, and it may not be impossible to solve it.

The Graptolites were the first great group to suffer extinction. Pelagic in habit, they could not have suffered more than other pelagic animals from a change in climate. Living on the minute organisms which swarmed in the sea, and which they captured with their tentacles, we can hardly suppose that they succumbed to a want of food; and we are thus led to the conclusion that they must have formed food for others. Who were these others? They must have been either Medusæ or pelagic Cephalopods, the owners perhaps of some of the conodonts; and of the two I should be inclined to choose the latter, but we know very little about them.

With regard to the Trilobites, Professor Walcott says that owing to their great differentiation the initial vital energy of the group became impaired, and that this was the cause of their extinction. With this I cannot agree, for the reason already given, and must, therefore, try to find some other and more efficient cause at work. As the Trilobites lived on the bottom of the ocean, where the temperature is uniform, we cannot invoke a change of climate as the cause of extinction, and there does not appear to have been any group of animals which could have been successful competitors with them for their food, for we know that they fed upon mud, which no doubt contained numerous organic particles. So again we must have recourse to predaceous foes. This reasoning is much strengthened by the fact that in Ordovician and Silurian times the Trilobites had learnt how to defend themselves by rolling themselves up, a feat which the Cambrian Trilobites were not able to perform. Now the earliest powerful predaceous animals we know were the ground Cephalopods, which first appearing in the Upper Cambrian rapidly increased in importance during the Ordovician, and especially during the Silurian; the relative numbers of the Nautiloidea in these three periods being as 1 : 9 : 33. In the Cambrian and Ordovician periods the Trilobites had greatly increased, but in the Silurian they began to decline in numbers, and rapidly diminished during the Devonian and Carboniferous, although a few lingered on to the Permian. This decline of the Trilobites coincides in time with the expansion of the Nautiloidea, and was, I have little doubt, caused by it. These ravenous Cephalopods, the precursors of our gigantic cuttle-fish, were the earliest rovers of the sea. Some lived near the surface and fed on Graptolites. Others sank to the bottom, where the inoffensive Trilobites had reigned for ages undisturbed, quietly sucking mud. But the ruthless intruders turned the Trilobites over and tore out their insides, in spite of their attempts to defend themselves by rolling up into a ball.

SUMMARY

We have thus arrived at the conclusion that the ocean was the mother of life; that on its surface floated the first organisms, whose descendants, but little changed during all the millions of years that have since past away, still float and multiply. Presently some of these animals found their way down to the bottom, where all the *débris* from the floating organisms collected; and here, in still water, they lived and increased for a long time. Slowly they invaded the rough waters of the coast-line, and, at last, gained a footing on the land.

It was plants which formed the army of invasion that conquered the land. This army was followed by a mob of camp-followers and ragamuffins, in the shape of cockroaches and scorpions, who fed and fattened on the plants; but who, notwithstanding their boasted superiority, were quite incapable of reclaiming a single acre of desert. The real victory belongs to the plants, who, with undaunted courage, left the congenial water to dare the vicissitudes of temperature and moisture on land, and thus made civilisation possible.

Plants left the ocean to live on land once only, in the Cambrian or early Ordovician. Several times, in later days, land plants—both Cryptogams and Angiosperms—went back to the water; but never again did water plants succeed in gaining the land. And, even at the present day, every seed-bearing plant passes, in its development, through a spore-bearing stage. And every bird and mammal passes through a gill-bearing stage, which they have inherited from their marine ancestors.

PART II.—LATER LIFE ON THE EARTH

The commencement of the Deutozoic, or newer Palæozoic era, forms a very convenient division in the progress of life; for before that time biological development took place almost entirely in the ocean, and it is not until we come near the close of the older

Palæozoic that we find any trace of land animals. But when we pass to the second half, embracing the time from the commencement of the Devonian to the Pleistocene, we shall find that our attention will be almost entirely directed to the land.

Of course, during this time organic evolution went on steadily in the ocean also; but no new types appeared there, except some air-breathing vertebrates which were descended from land animals. The simple and lowly forms of the Palæozoic era, which came first in the ocean, did not altogether die out; for a type once introduced almost always continued to exist. But the various species and genera—that is, the particular shapes which represented the type—changed; each, after living a certain time, became extinct, and gave place to its successors. Usually the simple types continued, living side by side with the more complex or higher types, which successively came into existence; so that life in the ocean, as well as on the land, became more and more varied as time went on.

This evolution may be compared to the growth of a hypothetical tree, in which the shapes of the leaves slowly alter year after year. The leaves which die out represent the extinct genera and species; while the branches represent the classes and orders which continue to exist. Occasionally a bough may die also; but it is not a regular occurrence as it is with leaves.

During the first half of the biological evolution, when comparatively simple forms alone existed, the struggle for existence was but slightly felt: species existed for a long time, and spread far and wide over the earth. But as the more complex and specialised forms came into existence, during the second half of the biological evolution, competition grew keener, species more quickly succumbed to others better adapted to the circumstances, their term of life grew shorter, and their geographical distribution was, in consequence, more limited. Thus the differences between the faunas and floras of distant countries, hardly recognisable during the Palæozoic era, gradually became more and more pronounced up to the present day.

The principal features of the evolution of marine animals during the last half of geological time are the steady increase in numbers and variety of the reef-building corals, the sea-urchins (*Echinoidea*), the bivalve and univalve mollusca, the decapod crustaceans, and the actinopterygian fishes; with the simultaneous decline of the *Crinoidea* and the *Brachiopoda*; while the *Cephalopoda* maintained a very important position up to the close of the Mesozoic era, and then collapsed.

The subject naturally divides itself into three parts —Deutozoic, Mesozoic, and Cainozoic. The Deutozoic opens with a great development of fishes; the Mesozoic with the expansion of reptiles; and the Cainozoic with that of mammals and birds. The passage between the Deutozoic and the Mesozoic is not marked by the rapid extinction of any group, because the new development of life was on land, and did not interfere with the fishes of the ocean. But the great expansion of mammals and birds was coincident with the extermination of the huge Mesozoic reptiles of the land, the sea, and the air; so that the break between the life of the Cretaceous and that of the Eocene is greater than that between any other two consecutive periods.

DEUTOZOIC LIFE

The two great features of the life of the Deutozoic era are the abundance of land vegetation and the first appearance of air-breathing vertebrates; but, before saying more about them, we will first take a glance at the fishes.

The armour-plated *Ostracodermi* of the Silurian became numerous in the Devonian. These curious animals are of very uncertain affinity, and by some naturalists are excluded from the class of fishes altogether, and placed alongside the Lampreys; because, like them, they had no lower jaws; while Mr Traquair considers them to be true fishes, descended from some primitive Elasmobranch. Their internal skeleton was entirely cartilaginous, but they had a strong armour of calcareous plates over the anterior part of the body, and scales on the posterior part. In *Cephalaspis* and *Pteraspis*, which commenced in the Silurian, the ventral shield is simple, and the dorsal shield is either simple or is formed of a few plates, which unite firmly together in the adult. But in the later forms (*Pterichthys*) both ventral and dorsal shields were formed by several bony pieces covered with enamel, and they had pectoral appendages which were also encased in armour. All of them became extinct at the close of the Devonian period. Many specimens of what is thought to be a Lamprey (*Palaeospondylus*) have been found in Scotland; but this animal, although not more than three inches in length, had well developed vertebræ, and was, therefore, more specialised than the lampreys of the present day.

The *Elasmobranchii* are true fishes, represented in our seas by the sharks and rays. The primitive Elasmobranchs, called *Ichthyotomi*, are limited to the Deutozoic era. In them the notochord was formed by a cylindrical rod of equal thickness, sheathed with cartilage, which was very slightly calcified and was not constricted into vertebræ. Also the pectoral fins had a segmented axis, like those of the *Dipnoi*. The early *Selachii*, from which all our sharks and rays are descended, have the sheath of the notochord more calcified and constricted in the centre of each vertebra. The pectoral fins have no segmented axis, and the skin is covered with thorny scales. Of these, the sharks and dogfish, in which ossification of the vertebral column takes place chiefly in radiating plates, appeared in the Carboniferous period, and at once became common; but they had no sharp teeth in the jaws, only blunt crushing teeth on the palate. The Rays, in which ossification of the vertebræ takes place chiefly in concentric plates, although first known in the Carboniferous, remained rare for a long time, and only became abundant in the Cainozoic era. But the most interesting group of Elasmobranchs is the *Acanthodii*, in which the basal cartilages of the pectoral fins are much shortened; the rays are arranged like those of ordinary fishes, and the scales are enamelled. These became extinct at the end of the Deutozoic era.

The sub-class *Teleostomi*, which contains all the bony fishes, appears first in the Devonian as Crossopterygians, with their paired fins formed by a long segmented axis, fringed on both sides with rays, like the vane of a feather. They attained their maximum in the Devonian, and then slowly declined, being at the present day represented only by *Polypterus* of the rivers of Africa. A little later came the Actinopterygians, in which the paired fins are supported by numerous radiating rays, as in the Acanthodii; and in the Carboniferous period they became common. All the Deutozoic Teleostomi had cartilaginous skeletons, enamelled scales, and either diphycercal or heterocercal tails.

The Dipnoi, or lung-fish, breathe air as well as water. Remains of them have been found in Devonian rocks; but, as their teeth are the only hard parts of the skeleton, very little is known about them. The *Coccosteidæ*, which lived from the Devonian to the lower Carboniferous, are placed in the Dipnoi by Mr A. Smith Woodward. They had the anterior portion of the body protected by an armour of large plates, like the *Ostracodermi*, but their paired fins are unknown, and so could not have been armoured. They had, however, well developed jaws and teeth.

We will turn now to the land.

The flora of the Devonian period shows a considerable advance on that of the Silurian. More than a hundred species are known, including, probably, most of the principal types of Cryptogams as well as true Gymnosperms; among the former being ferns and *Archæocalamites*, as well as the large cryptogamic trees, *Lepidodendron* and *Sigillaria*.

Owing to the numerous excavations made in coal-mining, we know the flora of the lowlands and swamps of the Carboniferous period remarkably well; but it is practically the same as that of the Devonian, and was continued with little alteration into the

Permian. Some of the plants—e.g., *Psilophyton* and *Ptilophyton*—cannot be placed in our modern classification, for they are unlike anything living; while, at the same time, they are not sufficiently well known to warrant new orders being made for their reception. Sir J. W. Dawson's opinion that the *Rhizocarpeæ* existed in abundance in Carboniferous times has not been confirmed by later observers; and *Sphenophyllum* has been placed in a special class, connecting the Equisetaceæ with the Lycopodiaceæ. In fossil ferns the fructification is rarely preserved, so that the arrangement of the venation of the fronds has to be largely used in their discrimination; and this makes their classification doubtful. Most of the Carboniferous ferns look much like modern ones, and some certainly belong to living families; but *Megaphyton* was a remarkable tree-fern with only two rows of large fronds, one on each side of the stem. *Sigillaria* connects the vascular Cryptogams with the Gymnosperms; for it has the fruit and leaves of a Lycopod, while the internal structure of the stem closely resembles that of the Coniferæ; and *Lyginodendron* connects the ferns with the Cycads.[1]

The forests were formed by tall spore-bearing trees, chiefly *Sigillaria*, with its unbranched stems clothed with long grass-like leaves; *Lepidodendron*, with rough branched stems; and many tree-ferns. In the swamps were numerous dense clumps of *Calamites* and *Annularia*, with hollow, reed-like stems, sometimes a hundred feet in height, and distinct whorls of needle-shaped leaves. On the uplands Gymnosperms grew abundantly. *Dadoxylon* was perhaps related to the fan-

[1] *Philosophical Transactions*, Series B., vol. clxxxvi. p. 765.

leaved Gingko-pine (*Salisburia*) of China, but it had a large pith; while *Cordaites* appears to have been a Cycad, with relations to the broad-leaved yews on one hand, and to *Sigillaria* on the other. *Cordaites* and the large Lycopods attained their maximum in the Carboniferous period.

This flora spread over North America, Europe, South Africa, India, and Australia; but no trace of it has as yet been found in New Zealand, nor in South America.

At the close of the Carboniferous period the large Lycopodiaceæ and *Cordaites* died out; and only a few species of *Calamites* lingered on into the Permian, the flora of which was composed of ferns, cycads, and coniferæ, especially the last.

In the Devonian period Neuropterous insects (May-flies) came on the scene; and in the Carboniferous forests were many others belonging to the Orthoptera (Cockroaches and Locusts) and Hemiptera. But there were no beetles, moths, flies, ants, or bees; while, in addition to millipedes and scorpions, we now find spiders and land-shells.

The first land-vertebrates were Amphibians, or Batrachians; which change their mode of respiration from aquatic to aërial during their life, and are easily distinguished from fishes by their nostrils. They were represented in the lower Carboniferous period by the *Labyrinthodontia*, so named from the labyrinth-like appearance of a transverse section of a tooth, owing to its complicated folded structure, which is something like that of the early Crossopterygii. The Labyrinthodonts died out at the end of the Triassic period, and were most abundant in the Permian, when they spread as far as Tasmania. Many kinds have been described, ranging in size from a few inches to seven or eight feet in length. In shape, too, they were very varied, some representing lizards, others snakes, and others were very like crocodiles. The larger ones had bony plates on the head, chest, and abdomen; and some of the smaller ones had armour over the whole body. In many the hind feet were larger than the fore feet, and all had five toes. Probably they lived either on the sea-shore or in rivers.

In the Permian period we find reptiles belonging to two different orders—the *Anomodontia* and the *Rhynchocephalia*. The former are thought to be the parent stock of all other reptiles, as well as of mammals and birds; for while the lower forms (*Pariasaurus*) are closely connected with the Labyrinthodonts, others (*Theriodontia*) resemble mammals. They are quite extinct, and it will be more convenient to postpone any further remarks about them for the present. The *Rhynchocephalia* shew a very generalised type of reptile, connecting the lizards with crocodiles, turtles, and Sauropterygians. In the Permian they were rare, but became common in the Triassic period, and are represented at the present day by the Tuatara (*Sphenodon punctatus*) of New Zealand. According to Professor H. G. Seeley they appear to be connected with the Anomodonts through *Proterosaurus*, of the middle Permian of Thuringia; and, according to Mr R. Lydekker, the Anomodont *Procolophon*, from the Triassic of South Africa, shews marked signs of affinity with the Rhynchocephalia.

MESOZOIC LIFE

In the Mesozoic era the chief thing we should notice in the ocean is the great abundance of the Ammonites. Beginning in the Deutozoic, they had acquired considerable importance in the Triassic period, attained their maximum in the Jurassic, and still remained numerous in the Cretaceous. Generally they were rapidly changing animals, the genera, and even the families, being, for the most part, different in each of the three periods; while, during the time of their greatest development, several species had such short duration that they are used to discriminate thin zones in the Jurassic rocks. So rapidly did they change that, in many species, we find the form of ornamentation altering during growth, that of the young shell—preserved on the inner whorls—gradually changing into a different pattern on the outer whorls. But the genera *Phylloceras* and *Lytoceras* form exceptions to the rule; for they existed with very little alteration from the end of the Trias to the upper Cretaceous. Perhaps the most remarkable thing about the Ammonites is their sudden and complete disappearance, together with the Belemnites, all over the world at the end of the Cretaceous period. They had declined during the Cretaceous with the increase of predaceous sharks, and it is possible that, encumbered by their shells, which were too fragile to be any protection, they could not escape from these new enemies.

The fishes were chiefly Actinopterygii. In the early Mesozoic they had imperfectly ossified skeletons, enamelled scales, and heterocercal tails; but these gradually passed into forms like modern fishes, with a well ossified skeleton, bony scales, and homocercal tails. In the Jurassic period sharks appeared with sharp, pointed teeth in their jaws; but they were not common until the Cretaceous. The first skates are also Jurassic.

The Triassic and Jurassic forests consisted chiefly of short-stemmed cycads and pines, with an undergrowth of ferns. There is little or no advance on the flora of the Deutozoic era, the difference being chiefly due to the absence of the large Equisetaceæ and Lycopodiaceæ of the Carboniferous, combined with a great increase of Gymnosperms. In the Cretaceous period, however, we find a great improvement; for here we have the dawn of the modern flora. In addition to palm trees and other Monocotyledons, Dicotyledons are abundant in the lower Cretaceous of North America and of Portugal; and in the upper Cretaceous this flora spread through Europe into Greenland, even as far as 81° 45′ N.

Part of the early Mesozoic flora of Europe is thought by some naturalists to have originated in the southern hemisphere, and to have migrated northwards from Australia through India. But there appears to be no good evidence of this except with the genus *Glossopteris*, which is Permo-carboniferous in Australia, and associated with *Cordaites*, *Cyclostigma*, *Lepidodendron*, *Calamites* and *Sphenopteris*. Among the vegetation insects were common. In addition to the Orthoptera and Neuroptera, already noticed, we now have beetles, cicadas, flies, and ants.

The Mesozoic has been well called the age of reptiles, so numerous and varied were they. A very short glance at them will, however, be sufficient; for, owing to their extraordinary forms, they have become familiar to most people.

The *Sauropterygia* commenced in the Trias with land animals (*Nothosaurus*) which are connected with both the Anomodontia and the Rhynchocephalia; but in the upper Trias, and during the rest of the Mesozoic era, we find marine forms, including the long but stiff-necked *Plesiosaurus*, which sometimes attained a length of thirty feet. The turtles (*Chelonia*) are related to the Sauropterygians in structure, although widely different in appearance. They are first known in the upper Trias. The *Ichthyopterygia*, including *Ichthyosaurus*, range from the upper Trias to the close of the Cretaceous; and represent in habits and in appearance the whales and porpoises of to-day. They were viviparous; and this was probably due to the impossibility of their going ashore to lay their eggs, as no doubt the other marine reptiles did. Their affinities are doubtful; but they appear to be most nearly related to the early Rhynchocephalians. That they were descended from land reptiles and were not fishes is sufficiently proved by the bones of the shoulder and pelvic girdles, the teeth, and the absence of a bony *operculum*: the last showing that they did not breathe by gills.

The *Squamata*, or scaly reptiles, are closely related to the Rhynchocephalians. Lizards are first known in the Jurassic, and snakes in the upper Cretaceous. The branch called *Pythonomorpha* were large, snake-like marine animals, swimming by means of four paddles Some of them attained the enormous length of seventy feet. They were cretaceous only. The *Ornithosauria*, or flying reptiles, lived in the Jurassic and Cretaceous periods. They stand apart from other reptiles, showing only very slight relations to the Anomodontia. They have some bird-like characters—such as a keeled *sternum* and hollow bones—but these are only adaptive, and essential for flight; they show no real relationship to birds. The skull also looks something like that of a bird, but it is really more like that of a lizard.

All the *Dinosaurians* lived on land, and some of them were the largest of land animals, being over a hundred feet in length. They differed greatly in appearance; for, while the earlier forms had the shape of crocodiles, to which they were closely related, others resembled in shape the rhinoceros, and others again the kangaroo; for they walked on their hind feet, which had only three toes, and their fore-legs were sometimes small. In some of these, the bones of the *pelvis* make a considerable approach to that of birds; and Professor Marsh has described, from the American Jurassic rocks, some small Dinosaurians, apparently closely related to birds, which he thinks may have been arboreal in their habits. "The difference," he says, "between them and the birds that lived with them may have been at first mainly one of feathers."[1] The early *Crocodiles* are difficult to distinguish from Dinosaurians, but afterwards they become more specialised; and there is abundant evidence to show that the modern crocodiles, alligators, and gavials are derived from the early generalised type. At first the *centra* of the vertebrae were hollowed at both ends, then they became nearly flat, and then hollow in front and

[1] *American Journal of Science*, vol. xxii. (1881), p. 340.

convex behind. The inner opening of the nostrils has also gradually moved backwards, from the middle of the roof of the mouth in the early forms, to the base of the skull in living forms.

Archeopteryx, from the upper Jurassic of Bavaria, is the earliest known bird. At first it was thought to be a reptile, because it has three free fingers with claws on each hand, biconcave vertebræ, a long lizard-like tail, abdominal ribs, and teeth in its jaws. Also the bones of the *pelvis* are not united together, and even the *metatarsi* of the leg seem to be but imperfectly joined; all of which are reptilian characters. Nevertheless, the presence of feathers on the wings and tail, the structure of the foot, and the fact that all the bones of the skull are fused into one, are such truly avian characters that all naturalists now agree that it should be considered as a bird. Only two specimens are known. In the middle Cretaceous of North America the remains of other birds have been found, all of which had teeth in their jaws. There were two distinct types, one of which—*Ichthyornis*—had the teeth in separate sockets and biconcave vertebræ, while the other—*Hesperornis*—had the teeth in a single groove in each jaw, and the *centra* of the vertebræ were saddle-shaped, as in ordinary birds. Hesperornis was a swimming bird, which had lost the power of flying, and its wings were in a very degenerate state; but Ichthyornis must have been a powerful flyer, apparently feeding upon fish. In the upper Cretaceous of North America remains of other birds have been found, some of which may belong to the living group of carinate birds.

For a long time it was thought that mammals existed in the Triassic period; but this appears to be doubtful, as Professor H. G. Seeley has shown that *Tritylodon* and others are reptiles (*Anomodontia*), as is proved by the existence of pre-frontal and post-frontal bones in the skull, a small quadrate bone, and sometimes a composite mandible. On the other hand, they had the mammalian characters of two occipital condyles, and complicated molar teeth with divided roots.[1]

In *Dromatherium* the roots of the teeth are imperfectly divided, and it may be put down as reptilian without much hesitation; while the molar teeth, known under the name of *Microlestes,* resemble those of *Plagiaulax,* and may be mammalian.

In the Jurassic, however, we have undoubted mammals. The Plagiaulacidæ have only two long incisors in the lower jaw, separated by an interval from the pre-molars, which are large and obliquely grooved; the true molars being small and tuberculate. The family is also represented in the upper Cretaceous of North America, and in the Cainozoic of Patagonia. This family has been placed in the sub-class Prototheria on account of the resemblance of the molars to the deciduous teeth of *Ornithorhynchus*; but it forms a special order, called the Multituberculata, the teeth of which are difficult to distinguish from those of the Theriodont reptiles. The sub-class, Metatheria, or Marsupials, are represented by the families Phascolotheridæ and Amphitheridæ. In the former the lower molars have three main cusps, and some accessories, all in a line; while, in the latter, the lower molars are trituberculate in the anterior portion, and with one tubercule in the posterior portion. Professor H.

[1] *Trans. Royal Society,* Series B., vol. clxxxv. p. 1019.

F. Osborn, however, includes many of these in the primitive Insectivora, thus classing them with the Eutherian mammals. All these Marsupials belong to the section called Polyprotodonta, with numerous small, sub-equal, incisor teeth, and are allied to the opossums, bandicoots, and native cats of Australia.

CAINOZOIC LIFE

In comparison with the fauna, the flora of the Cainozoic era is very imperfectly known, owing to the difficulty of distinguishing plants by their leaves only; while their classification depends chiefly on their flowers, of which very few have been preserved as fossils. In the Eocene period the land was either covered with forests, or else by wide stretches of brown ferns, except in the swamps, where rushes and other herbaceous monocotyledons grew. Probably there were no herbaceous dicotyledons until the upper Eocene. Before then the land must have looked much like the north island of New Zealand at the present day, where it is untouched by civilised men; and but few butterflies and bees could have existed.

The dicotyledons are usually divided into three groups:

(1) The Apetalæ, in which the perianth consists of the calyx only.

(2) The Polypetalæ, which has a corolla formed by four or five separate petals, in addition to the calyx.

(3) The Gamopetalæ, in which the lower portions of the petals are united together to form a tube, which protects the honey secreted at its base.

In the Cretaceous period nearly half of the Dicotyledons belonged to the Apetalæ, such as willows, poplars, oaks, walnuts, figs, &c. About half belonged to the Polypetalæ; while the Gamopetalæ formed but five per cent. of the whole. The heaths, clovers, rhododendrons, myrtles, olives, and Compositæ appear in the Oligocene; the azaleas and convolvulus in the Miocene; but the Gamopetalæ were still in a minority, and did not attain their present position until recent times. A table will show this better than any description.

	Apetalæ.	Polypetalæ.	Gamopetalæ.	
Cretaceous	45 p.c.	50 p.c.	5 p.c.	of the flora.
Miocene	37 p.c.	48 p.c.	15 p.c.	"
Recent	14 p.c.	50 p.c.	46 p.c.	"

The introduction of herbaceous grasses must have materially affected mammalian life. According to Mr J. Starkie Gardner[1] grasses are first known in the upper Cretaceous of Europe, North America, and Greenland. The specimens are very fragmentary; but all appear to have been arborescent, like the bamboos of the present day. None are known with certainty from the lower Eocene, a few appear in the upper Eocene; but in the Oligocene and Miocene herbaceous grasses are abundant. It also appears that none of the Eocene mammals have their teeth specially adapted for eating grasses; but that they gradually became modified in this direction during the Miocene.

The first known butterflies and bees are from the

[1] *Proceedings of the Geologists' Association of London*, 1886, p. 433.

Eocene, but insects were not abundant before the Oligocene. Sea-snakes occur in the Eocene, and land tortoises in the Miocene. The great development of birds was very remarkable; for remains of all the existing orders of Carinatæ have been found in the Oligocene, except divers, gulls, pigeons, and parrots; and these are recorded from the Miocene. All the Miocene and many of the Oligocene birds appear to belong to genera still existing.

Of the mammalia the multituberculata died out in the Cainozoic (Miocene ?) of Patagonia. The metatheria are represented in the Eocene of the northern hemisphere by several forms of polyprotodont marsupials; but they were quite overshadowed by the eutheria. It was in the southern hemisphere that the marsupials flourished, and gave rise to the diprotodont section, which is known only from Australia and South America. The eutheria, or placental mammals, suddenly appear in abundance in the lower Eocene; and, before the close of that period, most of the existing orders were represented, as well as some sub-orders which are now extinct. In the Oligocene we find some existing genera, and many more in the Miocene. The extinct sub-orders are chiefly from North America, and are generalised groups connecting the existing orders. They had very small brains and smooth bones without ridges; all had five toes on each foot, and their molar teeth were trituberculate.

The Eocene *Creodonta* are the primitive Carnivora; but they had no canine teeth, and in their dentition they are related to both the Insectivora and the polyprotodont marsupials. With them were the *Condylarthra*, the early ungulate or hoofed mammals, which gave rise to the *Artiodactyla* (pigs, camels, and ruminants), and to the *Perissodactyla* (rhinoceros, tapir, and horse).

The Condylarthra and Creodonta are almost identical; and both were plantigrade, that is, they walked on the soles of their feet, and not merely on their toes, as do all the Ungulates and most of the Carnivora at the present day. But in the Creodonta the teeth are sharper, and the toes appear to have carried sharp claws, while they are flattened in the Condylarthra. The *Tillodontia* are the primitive Rodents, which are connected by *Typotherium* with the Condylarthra.

We must, therefore, suppose that the Creodonta gave rise to the Carnivora, the Ungulata, and the Rodentia. The Insectivora and the Creodonta probably had a common origin in the primitive Insectivora; from which stock the Lemuroidea also appears to have been derived; but as all these orders appear together in the lower Eocene, their actual lines of descent are doubtful.

In the upper Eocene nearly all the existing mammalian groups are clearly separated from each other. True Carnivora, true Insectivora, true Rodentia, and Chiroptera (bats) appear, as also do the Cetacea. But among the Carnivora there is as yet no distinction between bears, dogs, hyænas, and cats; these were only separated off in the Miocene. The Chiroptera are flying insectivora.

Of the Primates, the Lemuroidea are known in the lower Eocene; the Simiidæ in the middle Miocene; where, amongst others, we find the living genus Hylobates (gibbon). Man probably originated in the

Pliocene, somewhere in Central or Southern Asia; but it is not until the Pleistocene that human relics become abundant. The line of descent of the sea-cows (Sirenia), which date from the Eocene, is quite unknown.

Several of the smaller groups of mammals have been worked out in great detail. Professor Cope has shewn the genealogy, in North America, of the living camels and llamas from *Poëbrotherium* of the lower Miocene. The ancestors of the horse have also been traced from the five-toed *Phenacodus* of the lowest Eocene, through the four-toed *Hyracotherium* and the three-toed *Anchitherium*, of the Miocene, to *Hipparion* and *Equus* of the Pliocene.

It has also been found that in several deer the course of development of the antlers, in each individual, recapitulates the forms of the antlers of its ancestors. Thus, at the present day, the young red-deer at the end of its first year has a simple unbranched antler placed on a short pedicel. At the end of its second year the new antler is two-pronged, and at the end of the third year it consists of a beam or stem with two or three tines or prongs. And this gets more complex year after year. Now, in the lower Miocene, *Procervulus* had simple horns, which were not shed. Then came the true deer, in which the horn became a long pedicel with a two-branched deciduous antler at the end. At a later period the pedicel was shorter, and the antler longer, consisting of a stem and two branches or tines; and it is not until we reach the upper Pliocene that we find complicated branching antlers.

Dogs, cats, oxen, and the goat are first known in the Pliocene. The sheep is of a very late origin, and is hardly known in the fossil condition. *Pithecanthropus erectus*, of the pliocene of Java, was a form intermediate between man and the apes (gibbon?). It was an ape-like man, which walked erect. But there is not much difference in structure between man and the higher apes. The bones and muscles in both are the same; the differences between them being chiefly due to adaptations necessary to enable man to stand upright, and to use his legs alone for locomotion. Man, like the apes, has several vestigial organs which are of no use to him, but which are well developed and useful in other animals. Among these are the remains of a third eye-lid, as well as muscles for moving the ears and the tail. Several other muscles, which are always found in the lower animals, but which are generally absent in man, are occasionally developed in him; and it is chiefly the presence of these vestigial and useless structures which has convinced naturalists that man has a common origin with other mammals.

It is a mistake to think that man was the last species of mammal to appear on the earth. He certainly dates from the Pliocene; while several animals, including the sheep, are not known to be older than the Pleistocene.

The oldest known human skeletons are those of the Neanderthal and Spy caverns. They belong to what is known as the Neanderthal Race, and are of Pleistocene age. The skulls have strong ridges over the eyes, a retreating forehead, and also a retreating chin. At that time Palæolithic man appears as a savage, living in caves and hunting wild animals, which he killed by means of pointed flint weapons, held in the hand, and which he cooked by means of hot stones. For even then man knew the use of fire. How he advanced in knowledge, at first very slowly, and then with ever increasing rapidity, is so extensive a subject that it forms a separate branch of science, called Ethnology, the facts of which form the foundation for theories of the psychological evolution that commenced with the advent of man.

INFERENCES AND SPECULATIONS

Proof of Evolution.—From the foregoing very rapid statement of facts it will be seen that palæontology shews clearly that the explanation of the order seen in nature is to be found in the theory of descent with modification.

Suppose we take the horse as an example. The evidence for its development from the five-toed Phenacodus is clear; this is connected through the Condylarthra with the early carnivora, and these with the primitive insectivora and polyprotodont metatheria. Then comes a break between the metatheria and the prototheria; but the latter are closely related to the theriodont reptiles. Indeed, Professor H. G. Seeley at first thought that *Theriodesmus* was a mammal; and it was only the discovery of *Pareiasaurus* that proved both to be reptiles. But the theriodonts form such a close connection between reptiles and mammals that it is difficult to decide which of the two to call them; while they are also, in the lower forms, related to the Amphibians. Between the Amphibians and the fishes there is a considerable gap, as yet unbridged; and palæontologists are undecided as to whether the former are descended from the Dipnoi or from the Crossopterygii; for the origin of the five-toed limb in the amphibians is obscure. Also we feel no certainty about the course of development among the fishes themselves, and about the line of descent of the lowest fishes from invertebrates.

The reason for this is obvious. From the amphibians upwards we have animals with a hard skeleton, easily preserved; while from the amphibians downward the skeleton is cartilaginous. Our clue is lost, and our knowledge is almost entirely confined to those exceptional animals which developed a hard dermal armour. The whole of the facts may be summed up in this sentence: The more complete our knowledge of extinct animals, the clearer is the evidence for development. This really amounts to a proof of the theory, which was originally arrived at by biologists from a study of living animals, and is now confirmed by palæontologists through a study of the animals which formerly inhabited the earth.

Migrations from the Land to the Sea.—Perhaps the most remarkable thing in the development of the land vertebrates is the number of times in which they returned to the sea. Vertebrates, commencing as marine animals, have, like plants, only once achieved the task of becoming thoroughly adapted for terrestrial life; while land vertebrates have taken to living in the ocean many times. In the upper Trias we find Ichthyosaurus and Plesiosaurus; in the Jurassic, the turtles; in the Cretaceous, the Pythonomorpha; in the Eocene, snakes and sea-cows; in the Oligocene, penguins and whales; and in the Pliocene, seals.

Each of these made an independent entrance into the ocean. The reason for this difference is probably due to the difficulty of water-breathing vertebrates becoming air-breathers, while air-breathers can more easily live in the sea. This, however, was not the case among the invertebrates; for, in addition to insects and arachnida, several different groups of crustacea, mollusca, and worms have attained a footing on the land; while only a few of the land shells have gone back to an aquatic life. Perhaps more interesting than all is the fact that in the Miocene some of the turtles returned to the land and became tortoises.

But why did these migrations take place at all? Were they to escape from enemies or were they to obtain food? In the case of the large reptiles we cannot suppose that they took shelter in the sea from their foes on land. It is far more probable that they began by trying to catch the fish which had so largely increased in the Mesozoic sea; and the same may be said for the whales, penguins, and seals. The migrations in all these cases were probably due to seeking out new supplies of food; and it is this which made Pterodactyles, birds, and bats take to flying.

Early Vertebrates and the Use of Armour.—Again, why did so many early vertebrates—the Ostracodermi, the Dipnoi and the Labyrinthodonts—acquire such a strong armour? Surely not to defend themselves from their enemies; for the Eurypterygians were the only large animals living at the time, and they do not appear to have been very formidable, as they have no apparatus for catching a moderately active prey. The principle of "following the food supply," will, I think, give us an answer. They may have fed upon the sea-weeds, or upon the animals living upon the sea-weeds of the sea-coast, and their armour was to protect them from the rocks in the rough and shallow waters which they frequented. Possibly the ancestors of the amphibians would never have reached the land if they had not been protected by armour, especially by armour on the ventral surface.

Different Rates of Development.—Another thing we notice is that the rapidity of development of different groups varies very much. Among the vertebrates some developed slowly at first, and then with great rapidity (*e.g.* Mammals and Birds). Others made a rapid advance, and then remained nearly stationary (*e.g.* Ichthyosaurians, Dinosaurians, and Pterodactyles). The majority of invertebrates developed slowly and steadily from the first to the present day (*e.g.* Echinoidea, Pelecypoda, Gastropoda, Decapoda, and Insects); but others rapidly attained a maximum, and then declined (*e.g.* Brachiopoda, Trilobita, and Crinoidea). It is the same with the extinction of groups. Most perish slowly, as is illustrated by the gradual change from Deutozoic to Mesozoic life; but at the close of the Cretaceous there was a rapid extinction of cephalopoda and reptiles; a fact very difficult to explain. This rapid extinction seems to have occurred nearly simultaneously all over the world—in Europe, in North America, in Australia, and in New Zealand. In none of these countries do we find the Cretaceous reptiles and cephalopods living with the Eocene birds and mammals; although such is said to have been the case in Patagonia.

We can only speculate on the causes. Perhaps the cephalopods were killed off by the predaceous sharks, which began to be common in the Cretaceous, and were very abundant in the Eocene. Dr C. A. White has pointed out that in North America the climate and other physical conditions of the Cretaceous period were continued into the Eocene; so that the Cretaceous dinosaurians could not have been killed off by a change in climate, but probably succumbed to the Eocene mammalia in the unequal struggle for existence. But if so, we ought sometimes to find their remains commingled; and we know that the marine reptiles could not have been killed off by the marine mammalia, for the former died out before the whales came on the scene. It seems to me more probable that the rapid extinction of the Mesozoic reptiles was due to the destruction of their eggs by the early birds or mammals; and that the turtles and crocodiles survived, by learning to bury their eggs in sand or mud. This, however, will not account for the destruction of the Ichthyosaurians, which were viviparous.

Probably we have in the principle of natural selection, acting through the food-supply, a solution of all these varying phases; but it is a principle difficult to apply, on account of our ignorance.

One thing is evident. There is no general law, either for development or for extinction, and, consequently, there can be no general organic principle regulating the length of duration of groups, as there is with individuals. An analogy between the two cases may sometimes be traced, but it is very incomplete, and becomes misleading if treated as more than an analogy.

Nevertheless, Professor Cope has put forward an hypothesis, which he calls "Expression Points,"[1]

[1] "Origin of the Fittest," p. 25 (1892), and "Primary Factors of Organic Evolution," p. 25 (1898).

which is founded on this analogy, and which I confess I find hard to follow. If I understand his argument rightly, it is this. He commences by saying that, during the development of every individual there are one or more periods when development is more rapid than at other times. He then makes the statement that if reproduction takes place during one of the rapid periods of development, the offspring will be highly variable; but if reproduction takes place during one of the slow periods of development, then the offspring will not be variable. And, finally, he declares that it is the same with a genus as with an individual. The genus also has periods of rapid change, and periods of persistency; and species originating when the genus is undergoing rapid change will be variable, while those originating during periods of persistency will be constant.

Even if there were facts to support the statements that offspring will be variable or not, according as they are born at stated periods of life; that genera shew periods of rapid change and of persistency; and that species diverging at those periods are themselves variable or persistent—even if all these points could be established, the reasoning from analogy seems to me very feeble, and hardly to require refutation; for the two classes of facts are not in any way connected.

Mr A. Smith Woodward also thinks that the evolution of animals shews a rhythm. He supposes that the development of every group has two phases. (1) A new type hides away, as it were, in some other district than that in which it originated; but it has great developmental energy, and finally spreads over every habitable region, displacing the effete race from which it sprang. (2) The now dominant race, at the beginning of its greatest vigour, gives origin to a new type, which retires to some other place; while the future evolution of the dominant race is insignificant.[1]

These two hypotheses are different; but they both agree in thinking that there is some real resemblance between the life of an individual, and the life of a group; that in both there is early vigour and subsequent decline. But when we remember that all living organisms are descended from those first formed in the pre-Palæozoic ocean, and that life on the earth is, as a whole, quite as vigorous now as when first produced, we see that the idea of the necessary decline of a group in physiological vigour must be a mistake. The decline is in numbers, and not in the vigour of each individual. The decline is due, not to any natural exhaustion, for it does not always take place, but to the action of natural selection.

A closer analogy might be made between species and the leaves of trees, which die off while the stem remains alive. But this also, if pushed too far, would be misleading; for the leaves do not nourish themselves directly, but only the main body of the tree; and they become exhausted and die off, because in them the destructive (catabolic) processes are in excess of the constructive (metabolic) processes: while the opposite is the case in the growing tissue of the stem. A change of leaves thus becomes necessary, but a change of species is not necessary, unless something alters the surrounding conditions. It is, however, always the lower or unspecialised forms which give

[1] "Outlines of Vertebrate Palæontology," Introduction, p. xxi. (Cambridge, 1898).

rise to new groups; and these unspecialised forms are usually small. The specialised forms, which answer to the leaves in the analogy, die out, because, when a change in their habits becomes a necessity, they cannot change their bodily shape. This is not a proof of degeneracy, or of decline in vigour. When man takes these highly specialised plants or animals in hand, and domesticates them, they shew no sign of loss of vigour; and in time they regain the power of variation.

It is generally acknowledged that the sudden appearance of a new group, in large numbers and in considerable variety, is due to migration; and this implies that the group was developed in some district which is now either inaccessible or unexplored. This can be the only explanation of the sudden appearance of eutherian mammals in the lower Eocene rocks of North America and Europe; and of the graptolites in the lower Ordovician of Europe. The appearance of dicotyledonous plants in the lower Cretaceous of North America and Europe is more difficult to explain. This flora is thought by some to have originated in the arctic regions, and to have spread southwards; but, however this may be with the deciduous trees, a varied evergreen dicotyledonous flora existed in New Zealand with Belemnites and marine Saurians (*Cimoliosaurus, Liodon,* &c.), which can hardly be younger, and may perhaps be older, than the cretaceous flora of Greenland.

From what I have said above in the Preface, my readers will understand that this second Essay is to be taken as a kind of appendix to the first, supporting and illustrating the theory therein contained, by a statement in outline of the facts of biological evolution in so far as they have hitherto been ascertained.

TABLE SHEWING THE RELATIVE THICKNESS OF THE ROCKS IN EACH GEOLOGICAL PERIOD.

CAINOZOIC.	Pliocene Period . .	Man.
	Miocene ,, . .	
	Eocene ,, . .	Primates.
MESOZOIC.	Cretaceous ,, . .	Flowering Plants.
	Jurassic ,, . .	Birds and Mammals.
	Triassic ,, . .	
DEUTOZOIC.	Permian ,, . .	Reptiles.
	Carboniferous ,, . .	Amphibians.
	Devonian ,, . .	Gymnosperm Plants.
PALÆOZOIC.	Silurian ,, . .	Fishes.
	Ordovician ,, . .	Insects. Land Plants ; Cryptogams. Vertebrates.
	Cambrian ,, . .	Echinodermata. Brachiopoda.
	Algonkian ,, . .	Crustacea. Mollusca. Vermes.
ARCHÆAN.	Huronian ,, . .	Sponges (?) Protozoa (?)
	Laurentian ,, . .	

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