THE LESSON OF EVOLUTION

F. W. Hutton.

THE LESSON OF EVOLUTION

By

FREDERICK WOLLASTON HUTTON,

F.R.S.

SECOND EDITION.

RE-ARRANGED AND ENLARGED

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"In matters of evidence, as in all other human things, we neither require nor can attain the absolute."

Mill's "LOGIC," vol. 2, ch. xxi.

"All attempts to rule out prospective organisation, or teleology, from the world would be fatal to natural science, which has arisen by provisional interpretations of just this kind of organisation; and to the historical interpretation of the world found in the evolution hypothesis; for the category of teleology is but the prospective reading of the same series which, when read retrospectively, we all call evolution."

Mark Baldwin. "DEVELOPMENT AND EVOLUTION," p. 287.

The first edition of the "Lesson of Evolution" was published by Messrs. Duckworth and Co. in 1902. The following year my husband had a serious illness, from which, however, he recovered sufficiently to resume his work, and in his leisure he occupied himself by correcting and enlarging the book. In 1905 he went to England on a visit, but a recurrence of the illness from which he had suffered terminated fatally when he was returning to this Colony. He died at sea, October 27th, 1905. Although confined to his couch practically the whole time of his stay in England, his mind was clear and active, and the last thing he wrote was a contribution to the "Hibbert Journal" for October, 1905,—"What is Life?" It is in the belief that his latest and most matured thoughts on this subject are contained in the present volume, that it has been printed for private circulation.

A. G. HUTTON.

Christchurch,
New Zealand.
July, 1907.

MEMOIR OF THE AUTHOR

FREDERICK WOLLASTON HUTTON, second son of the Rev. H. F. Hutton, was born at Gate Burton, Lincolnshire, November 16th, 1836. On his mother's side he came of a family (Wollaston) which claims to have given to the Royal Society more Fellows than any other. William Wollaston (d. 1724) author of "The Religion of Nature Delineated," was his great-great-great-grandfather, and Thomas Vernon Wollaston (d. 1879), a friend of and fellow-worker with Charles Darwin, and author of "The Variation of Species, with special reference to the Insecta" (1856), was his uncle, and it was from him that he first learned to take delight in the accurate observation of natural phenomena.

Educated at Southwell and at the Naval Academy, Gosport, but prevented from entering the Royal Navy through being over age at the date of his nomination, he served three years in the India Mercantile Marine, and then entered King's College, London, whence he was gazetted ensign in the 23rd Royal Welsh Fusileers in 1855 (lieutenant 1857, and captain 1862). He served in the Crimea, 1855-56, and was also present at the capture and relief of Lucknow, and at the defeat of the Gwalior mutineers under Sir Colin Campbell, near Cawnpore, November and December, 1858, and received the medal with two clasps for the campaign. In 1860 he entered the Staff College at Sandhurst, and passed out sixth in the examination list in 1861. In 1863 he married Annie Gouger, daughter of Dr. William Montgomerie, who had been Superintending Surgeon of the Bengal Medical Service under the H. E. I. C. S., and who had received in 1843 the Gold Medal of the Society of Arts for having introduced gutta percha into Europe as an article of general utility. But, from the date of his leaving the Staff College, his interests and studies were more scientific than military, and, after having served for a year on the staff at Dublin as Deputy-Assistant Quartermaster-General, he resigned and sold out of the Army in 1865, and emigrated to New Zealand with his wife and two children in January, 1866. At first he resided at Auckland and on the Waikato, but without achieving any success as a practical colonist. In 1871 he was appointed Assistant Geologist to the New Zealand Geological Survey, and removed to Wellington; in 1873 he became Provincial Geologist of Otago and Curator of the Otago Museum, and removed to Dunedin, being also appointed Professor of Natural Science at Otago in 1877. Three years later he became Professor of Biology and Geology at Canterbury College in the University of New Zealand, and settled at Christchurch. This office he held until 1893, when he became Curator of the Christchurch Museum. In 1900 he was elected President of the

Australasian Association for the Advancement of Science, and in that capacity he delivered an address at Hobart, Tasmania, in January, 1902, which forms part of the present volume. In 1904 he was unanimously elected the first President of the Board of Governors of the New Zealand Institute. In March, 1905, he left New Zealand on board the s.s. "Rimutaka" on a first visit to the old country after an absence of nearly forty years, and he died on board the same boat on the return journey within a few hours sail of Cape Town, and was buried at sea, October 27th, in lat. 30° 6′ S., long. 16° 52′ E.

In the year 1861, when he became a Fellow of the Geological Society, he was among the first to recognise the significance of Charles Darwin's work on the "Origin of Species," and his review of it in the "Geologist" elicited from the author a letter which is printed in the abridged edition of Darwin's "Life" (1892) p. 250. He was elected a corresponding member of the Zoological Society of London in 1872, and a Fellow of the Royal Society in 1892. At various dates he became a corresponding member of numerous learned societies on the Continent of Europe, in the Colonies and in America. His life was mostly spent in scientific research, and the accuracy of his observations and the tenacity of his memory made his judgment of the greatest value in the identification of specimens. The skeletons of the extinct moa in many European museums are from his hand, and were sent out in exchange for *desiderata* for his own museum.

In addition to thirteen Descriptive Catalogues and Geological Reports, published by the Government of New Zealand between the years 1868 and 1887, more than a hundred scientific papers in the "Transactions of the New Zealand Institute" and other Australasian scientific periodicals, contributions to the "Philosophical Magazine," "Geologist," "Geological Magazine," "Journal of the Geological Society of London," "Proceedings of the Zoological Society of London," "Ibis," "Nature," etc., "Captain Hutton"—as he was always called in New Zealand—wrote a "Class-book of Elementary Geology," 1875, "Darwinism and Lamarckism Old and New," published simultaneously in London and New York, 1899, and, in conjunction with Mr. James Drummond, "Nature in New Zealand," 1902, and "Animals of New Zealand," 1904, the two last-named being published in the Colony. And in 1904 was published in London his "Index Faunæ Novæ Zealandiæ," edited by him for the Philosophical Institute of Canterbury, New Zealand. "The Lesson of Evolution," of which the present volume is a revised and much enlarged issue, was first published in London in 1902, and extended to only 100 pages. The last published sentences that came from his pen were written during his visit to England, and appeared in the "Hibbert Journal" for October, 1905, under the title "What is Life?" They are reprinted here by the courteous permission of the editor.

As a memorial of their first President, the Governors of the New Zealand Institute, on the initiative of the Philosophical Institute of Canterbury, and with the assistance of the Government of New Zealand, have caused a bronze medal to be struck, known as the "Hutton Memorial Medal," which is to be conferred occasionally in recognition of specially valuable work in scientific research done in the Colony.

"*Peace, peace! he is not dead, he doth not sleep,*
He hath awakened from the dream of life."

PREFACE

In this second edition I have followed the advice of the reviewer of the first edition in "The Week's Survey" and, abandoning the shackles imposed by publishing a series of separate essays, each calculated to take rather more than an hour to read, have completely re-arranged the work, and have added to it considerably, so as to make it practically a new book. And I hope that these additions have strengthened the argument.

For many years I was content to hold Darwin's position of recognising the variations of animals and plants as facts, the origin of which it was hopeless to try to explain. But lately I have again studied the question, and found, in Professor Ewald Hering's well known essay on Memory, the germ of a theory which simplifies everything, and throws quite a new light on definite variation. In fact, it reduces our difficulties nearly to one—the everlasting mystery of the nature of mind; a difficulty which can never be solved. So I have explained this theory more fully, and have tried to substantiate it. This has led me to believe that what we call life is merely the action of mind on protoplasm; and that it has no distinct existence in itself.

The principle of psychogenesis, proposed in Chapter VII., although new, is only a corollary from Professor Hering's theory; but it gives a new conception to the old Lamarckian doctrine of use and disuse, and explains what Darwin used to call the "indirect action" of the environment on organisms. The adoption of this theory led me on to an examination of the old problems of free-will and dualism, and the conclusions at which I have arrived are so satisfactory to myself that I think they may be of some use to others who are doubtful which view to take.

The subject is a large one, owing to the multiplicity of details which would have to be considered if this book were the first on the subject. But it is unnecessary to repeat what is well known, or what can be easily ascertained elsewhere; and, although the number of facts is large, the principles derived from the facts can be condensed into a small compass, and the argument gains much from this being done.

An apology may be due from me, who am not a psychologist, for discussing mental evolution at all. But the biological and psychological evolutions were inseparably bound together until the former culminated in Man. For it was not until then that psychology branched off on its own account. Biology, therefore, includes the early history of psychology; and I approach the subject altogether from the position of the biologist. Indeed, I think that the question of dualism belongs properly to the biologist; for it is in the fundamental facts of life that all the evidence is to be found.

I am quite aware that the subject is an ambitious one, and that many people may think that it ought either to be treated more fully or not at all. But if our ideas on the subject are to crystallise into definite shape, it is necessary that a general survey of the position should occasionally be made. I do not claim to speak with authority, nor do I wish to pose as a philosopher. But I give a simple statement of the conclusions to which I have been led, and leave the reader to form his own opinion on their value.

There is one point in nomenclature that must be mentioned, to prevent misunderstanding. Physiologists have long recognised that there are two kinds of life, tissue life and bodily or somatic life. And if mind is identical with life, as I suppose, then there must also be a tissue-mind and a somatic-mind. Physiologists have not found it necessary to give different names to these two kinds of life; and I think that the term *mind* is sufficient to cover both somatic-mind and tissue-mind, or cell-mind. But in the course of my argument I try to show that cell-mind is essentially free from law; and this makes a slight difficulty in nomenclature. For the freedom of the cell-mind, although fundamentally identical with free-will in man, is so widely removed from it in action, that the same term can hardly be applied to both. I have, therefore, used "volition" to express the freedom of cell-mind, and restricted the name "free-will" to the human faculty of spontaneous action.

In justice to myself I wish to state that nearly the whole of the MS. for this edition was written out before I had read Professor C. S. Minot's admirable address on the "Biological Aspects of Consciousness" to the Pittsburgh meeting of the "American Association for the Advancement of Science," published in "Nature" for July 24th, 1902. (Vol. 66, p. 300.) It is remarkable that Presidential addresses, both in America and in Australia, should have been simultaneously on somewhat similar subjects, and that they should both have independently arrived at the same conclusion; although Professor E. Haeckel says that fully nine-tenths of the men of science do not believe in it.

INTRODUCTION

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 to a higher level. Also, by increasing the wealth of the world, they give to some men sufficient leisure to pursue the study of science or of 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 become more and more precise as that knowledge increases.[1]

The latter half of the nineteenth century will always be memorable for the establishment, by scientific evidence, of the theory of evolution. By which is meant the discovery that the whole Universe is gradually undergoing a progressive change, and that each stage of this progress is the outcome of what went before, and is the cause of what will come after. It is on this foundation that all forms of Natural Philosophy must be built up in the future.

It was not until the publication of Mr. Darwin's "Origin of Species" that a clear view of evolution was obtained. It was then seen that all animals and plants were genetically related to each other, and that the physical evolution of the solar system had been followed by a biological evolution. When this truth had been firmly established, the inference

[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.

necessarily followed that the object of biological evolution was the development of man. The reason for the inference was, not that man is the highest product of evolution, for other animals have in their turn been in that position; but that the advent of man had made a complete change in the course of evolution, and has added a new form—psychological evolution—to the older forms. This has culminated in free-will in man, by means of which he has, to some extent, the power of altering the course of evolution. The changes brought about are as follows:

1.—The process of natural selection is over, so far as man's bodily structure is concerned. No important change has taken place in his body since the middle of the Pleistocene period; and none can take place in the future, because his hand is quite capable of carrying out the ideas evolved in his brain; and it is by these that he lives and competes with his neighbours.

2.—The diversity of animal and plant life on the earth seems to have reached its maximum. Man is a destructive force in nature, and already he has exterminated several of the larger animals. As time goes on we may expect that all animals and plants that are hurtful to him will be destroyed, and that the whole earth will become a garden, the sea alone being able to resist his encroachments.

3.—There are a number of elementary substances in the world which appear to be of no use except to man: for example, gold, silver, lead, zinc, etc. These must have been intended for his use, for they were useless in the economy of nature until a sufficient amount of intelligence had been reached.

If we allow that all this has a meaning or an object, we arrive at the conclusion that the object of psychological evolution is the development of the human mind, to which the development of his body was only a preliminary.

But the intellect of man, however noble, is not the highest part of him. This is only an exaltation of characters which he shares with the brute creation. It is in his moral and religious nature that we see the true human characteristics which separate him from all other animals. This psychological evolution is partly utilitarian, partly ethical, partly religious. Ethical evolution is founded on animal instincts, such as the love of offspring ; and, although to some extent the product of intellect, it is chiefly due to sympathy as opposed to selfishness, and to conscious efforts at improvement, to what is called the prompting of the conscience. For even in the higher phases of ethical and religious development, progress is effected by the same process of conflict by which it is secured in biological evolution. Material and intellectual progress are due to conflict between one individual and others, while moral and religious progress are secured by the conflict of each man with himself. This was not possible until man had obtained the power of free choice ; and this, therefore, was the true beginning of ethical evolution. Ethical character is acquired after birth, and is not transmitted physiologically from parent to offspring. Each human being has to work out his own development, but he is helped in this by the thoughts of former generations. With the moral comes also the religious development. Beginning at first with very low and perhaps unworthy motives of self-advancement, it has gradually led up to an endeavour to understand and to do the will of God.

Biological evolution is due to mind, which is resident in protoplasm. Physical or inorganic evolution is due to gravitation, which tends to bring all matter together; and, as matter has not yet been brought together, there must have been a beginning, when gravitation did not exist. But, although gravitation is the proximate cause of physical evolution, there is evidently mind behind it, because the problem has been thought out. Consequently, physical evolution must also be due to mind acting on the matter of which the Universe is composed. But this universal mind does not seem to be resident in matter, because matter obeys fixed laws, and because physical evolution is coming to an end, and cannot, so far as we can see, be renewed except by a change in these fixed laws. Terrestrial mind is not subject to inexorable law. Of course the matter with which it is associated, and which it manipulates, is subject to physical laws which must be obeyed; but mind itself, as exhibited in living protoplasm, is subject to no laws except those which it has imposed upon itself—called reflexes or reflex actions— from which, in most cases, it can emancipate itself.

We find a single break in this long series of cause and effect; and that is the introduction of living substance on to the earth; an action which defies all our efforts to connect it with any previous stage. But some scientific men, who hold that mind exists in all matter, assert that the break is apparent only. These, who are called Monists, generally allow that living substances cannot now originate from dead matter, and that we cannot explain how mind became manifested in protoplasm. But they think that if we knew the conditions under which life first appeared we might then explain its origin.

The Dualists, who hold that mind is distinct from matter, abide by the evidence of their senses, and take things to be as they appear to be. And, as science is founded on evidence and not on conjectural hopes, it is probable that the opinions held by the Monists will, in time, die out.

It is my object in the following pages to discuss these questions, and to examine the evidence on which they rest; and I hope to do this in an impartial spirit, although, as the evidence seems to me to be all on one side, I am afraid that I may seem to be partial. The conclusion I come to—the lesson of evolution—is that mind is distinct from matter, and that it is itself undergoing evolution on the earth. It is, therefore, probable that this mental evolution will be continued after physical and biological evolutions are over. For the introduction of mind on to the earth must have been for some purpose. Man has not been given free-will for nothing. He is intended to work out his own ethical evolution, and this can only be done by the exercise of free-will: by a constant individual conflict between his higher and lower ideas. Man cannot be undergoing these mental struggles for nothing ; and therefore we must admit the probability of a future mental existence, although it may be beyond the power of our intellect to conceive it.

I think that this lesson of evolution will in time be believed in by everyone, as implicitly as we believe in the revolution of the earth round the sun ; and that thus the theory of evolution will also become one of the foundations of our theological beliefs.

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THE LESSON OF EVOLUTION

CHAPTER I

PHYSICAL EVOLUTION

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[2] 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

[2]*Pro. Roy. Soc. of Edinburgh* for April 19th, 1852, and *Phil. Mag.*, October, 1852, p. 304.

every possible action is counter-balanced 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," which was first suggested in 1848 by J. R. Mayer, but which is chiefly the work of Sir Norman Lockyer and Professor G. H. Darwin. I will give a short sketch of the views held by the former.[3]

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

The close connection between the orbits of comets and those of meteoritic streams has led to the universally 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.

Evolution of the Universe.—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 chrondroi, 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. As the temperature of the star increases the metals gradually disappear. Then the silicon vanishes; then carbon, nitrogen and oxygen, until in the very hottest we find only proto-hydrogen—that is a form of hydrogen not known on the earth, but revealed by the spectroscope—helium, asterium, and perhaps some others. When the star cools these substances re-appear in the same order in which they disappeared.

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. It is the same with gravitation. In time all the ponderable matter in the Universe will either collect into a single mass, or it will revolve round a common centre of gravity which will be occupied by those portions of matter which have come into collision during the process of equilibration.

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.

The ether, which pervades space, is the only part of 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, a time must come when all energy will be equilibrated; and when, possibly, the visible Universe may resolve itself into invisible, motionless ether.

Evolution of the Solar System.—In the Solar System we can study the development of a meteoritic swarm in greater detail. Here we find 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.

Evolution of the Earth.—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.

CHAPTER II

ANCIENT LIFE ON THE EARTH

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.

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 a structure called *Eozoön canadense* has been found.

It was the microsopic 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 *Archæosphérinæ*, 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 Pro-

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

fessor Rupert Jones. However, Mr. H. J. Carter and Professor Möbius never allowed that *Eozoön* was organic; and Professor Zittel, although at first 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.[5] 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

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

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 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.[6]

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,

[6] 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.

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 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 4,000 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, three of sponges, and two of Foraminifera. Dr. Mathew points out that the Trilobites of this fauna can be distingushed from those of Cambrian by having continuous eyelobes, 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 and Graptolites in the Lower, and Medusæ in the Upper Cambrian, 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. Marine Arachnida are represented by *Aglaspis*.

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[7] are proofs of the existence of a 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

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

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 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.[8]

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 conditions 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 for locomotion. As their weak little leg paddled backwards and forwards in the mud, the spines, all of which are directed backwards, would

[8]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.

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 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.[9] 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 organisms. It is, therefore, quite possible to suppose that protoplasm capable of secreting chlorophyll was a later development, when the supply of mineral hydro-carbons were 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 sub-kingdom of animals, the vertebrata, represented by minute teeth, called conodonts, from the green sands at the base of the Ordovician, near St. Petersburg.

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

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 Upper 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, 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 terrestial 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 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

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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 biological 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 any 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 passed 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.

CHAPTER III

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, and 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 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 Permiam. 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.[10]

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 distant whorls of needle-shaped leaves. On the uplands Gymnosperms grew abundantly. *Dadoxylon* was perhaps related to the fan-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.

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

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 Labyrinth-odonts died out at the end of the Triassic period, and were most abundant in the Permian, when they spread as far as Tasmania, and perhaps to New Zealand. 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 *Cordiates*, *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."[11] 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 croco-

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

diles, 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 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.[12]

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

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

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. F. Osborn, however, includes many of these in the primitive Insectivora, thus classing them with 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 in 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,[13] grasses are first known in the upper Cretaceous of Europe, North America, and

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

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 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 the 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.

Probably the insectivora are the earliest of the Eutheria, and they gave rise to three larger and two smaller branches. The larger branches are, first, the herbivorous animals, whose chief food is leaves and young shoots of trees, the canine teeth are small or absent, and the molars usually have the enamel folded and with cement between the folds. The toes have hoofs or blunt claws. This branch subdivided into several smaller ones, one of which—the sea-cows—is aquatic. The second great branch is the carnivorous animals, living on other vertebrates. They have large canine teeth and sharp claws. There are two aquatic sub-branches, the seals and the whales. The third branch is the Quadrumana or Primates, which are arboreal, and whose principal food is fruit, but they are more or less omnivorous.

The two lesser branches from the insectivora are the bats and the edentata, the latter having no enamel on their teeth, but large claws for digging.

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 its 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.

A very condensed account must suffice.

The Migrations of Man.—Man is divided into several varieties—called races—which differ much from each other; and we know from ancient sculptures that the Negro and Egyptian races had each their characteristic features in the time of Menes, nearly six thousand year ago. Also, these different races speak different languages, which cannot be traced to a single source. Nevertheless, it is generally believed that all human beings had a common origin, and belong to one species, called *Homo sapiens* by Linnæus, and defined by him as the Tyrant of Nature.

Probably the differences we see are due to early migrations, which brought about the isolation of different groups of men.

As these races spread over the earth they again came in contact with each other, and crosses between them arose which have made it extremely difficult to distinguish the original races, and to decide which is the best or most correct manner of grouping them. It is impossible at present to give a correct account of the wanderings of man, but the following is an outline of the opinions held by some of the best Ethnologists.

Man appears to have originated in the neighbourhood of Burma or Java, where alone we find early pliocene man. From here he spread in three directions. 1. South into Australia and Tasmania. 2. West through India into Africa and Europe (forming Palæolithic man). 3. Into the high lands of Thibet and West China (the Turanian Race); from whence some spread to Central Asia, forming the Mongolians, while others crossed over into North America, forming the American Indians. Others of the early Turanians passed into the mountainous region between the Hindu Kush and the Caucasus, including Armenia, and these gave rise to the Caucasian Race.

The Caucasians migrating north into the Kirghiz Steppes and central Russia became the Teutons. Others went back through northern India and Burma to the Malay Archipelago (Indonesians), and finally to Polynesia.

From Armenia a branch spread south into Arabia (the Semites), another to Egypt and N. Africa (the Hamites), crossing the Mediterranean into Europe at the close of the palæolithic age. At a later date another migration from Armenia into Southern Russia gave rise to the Sclavs and Kelts.

Origin of Civilisation.—We learn from the records of the Lake Villages that the first animal to be domesticated was the dog; then successively the ox, the goat, the sheep, the pig; and, last of all, the horse. Agriculture came later.

It it hard to realise the slowness and difficulty of the transition from the state of the hunter to that of the shepherd, and from that of the shepherd to that of the husbandman. Wild animals must have become difficult to procure before the trouble of taming them would be undertaken, and necessity must have been very pressing before the shepherd would dig up his pasture, and tie himself down to one spot to wait for the harvest. It was long after this that he discovered how to make use of metals.

Gold and copper, as they exist in an uncombined state, were first noticed; and tin-ore, which is heavy enough to attract attention and is easily reduced, was afterwards melted with the copper, and bronze was produced; the proportions of the two metals being nearly always nine of copper to one of tin. The bronze implements were cast in moulds cut in stone or made of hardened clay, and their edges were hammered fine and polished with stone. The far more difficult art of making and tempering iron arose probably in Eastern Asia; but the discovery is comparatively modern. Iron was unknown to the ancient Egyptians, to the Assyrians, and even to the inhabitants of Troy; and the earliest mention we have of it is in about B.C. 1600, when Thothmes III.

received iron vessels as tribute from Syria. It was known to Homer, but evidently it was not common in his day. From these facts it is customary to divide the early history of man into three ages, called respectively the Stone age, the Bronze age, and the Iron age, according to the nature of the material from which he manufactured his weapons. But these ages overlap; both bronze and iron were introduced into southern Europe first, and their use spread northwards slowly, gradually displacing the inferior materials. Thus about B.C. 1000 to 500 a Bronze age existed in central Europe, while a Stone age existed to the north, and an Iron age had commenced in the south. Brass came later than iron, and was obtained only by smelting copper ores which contained "cadmia" or zinc. It was used in Europe during the Roman Empire, but did not become common until the sixteenth century, when the art of making zinc was discovered.

Gold, as well as copper and bronze, was used from a very early date for ornaments; and throughout the Bronze age flint arrow-heads continued to be used. Silver did not come into use until the Iron age.

Pottery was made in the later Stone age, and at first was only sun-dried.

Glazed earthenware is first known from Egypt (about B.C. 1200) as well as a kind of porcelain; but true porcelain is an invention of the Koreans, and was introduced from China into Europe at the close of the 15th century.

The art of making glass appears to have been discovered by the ancient Egyptians, as it was known to them in about B.C. 3500. It was generally opaque, always coloured, and only small articles were made of it. Transparent glass was not made until about B.C. 660, and even in Pliny's time, colourless, transparent glass was highly valued and called crystal.

The commencement of the art of writing is to be found in the pictographs of the dolmens of the Stone age. Pictographic writing is a series of representations of the objects intended to be mentioned, and is independent of language, it could only be used for objects, not for ideas or abstractions. Hieroglyphic writing is first known in Egypt, where it was used by the priests, or hierarchy, at a very early date. In this the picture represents a sound, the meaning of which has been agreed upon, but each sound is either a word or a syllable. The figures were gradually reduced to symbols in which the figures are unrecognisable. The Phœnicians invented the alphabet, about B.C. 1500. They chose some twenty of the Egyptian symbols, and used them for the principal articulate sounds of human speech. This alphabet gave rise to (1) the Hebrew, from which the Sanskrit and Arabic alphabets were derived. There are no signs for vowels, and it is written from right to left. And (2) the Greek, from which is derived the Latin and other European Alphabets. In this there are separate signs for the vowels, and the writing is from left to right.

Nations have been classified into—1. Savage, who live by fishing and hunting wild animals. 2. Barbarian, who cultivate the soil, and have domestic animals. 3. Civilised, who use alphabetic writing for conveying information. Other ethnologists have used the terms Stone, Bronze, and Iron ages to express the same thing; and these distinctions are useful, although they cannot always be strictly applied.

The Stone age appears to have been universal at first, for implements of palæolithic type have been found in North and South Africa, in Syria, and in India, as well as in Europe and North America. The Melanesians, Polynesians, and the nomad tribes of America are still in the Stone age. The inhabitants of Central America, from Mexico to Peru, had attained to the Copper age when discovered by the Spaniards, while all Africa, Asia, and Europe passed long ago into the Iron age, without any intermediate Bronze age in Africa. Pictorial writing was as widespread as stone weapons, and it lasted to modern times in Australia, Polynesia, Africa, and North America. The Chinese have never advanced beyond hieroglyphic writing, in which each syllable has a separate symbol; and this kind of writing was still in existence in Central America and in Easter Island a few centuries ago. Civilisation originated with the Egyptians, and was carried on by the Semites of Western Asia. But it is the Aryans of Europe who are now spreading it over the world.

It thus appears that while some of the nations have progressed, other have remained almost stationary, and some may have retrograded. The stationary nations present us, as it were, with pictures of former stages in the history of the progressive nations, or at any rate they afford us the most reliable evidence attainable, and it is this that makes the study of ethnography so interesting. Man is a gregarious animal, and families have developed into the clan, clans into the tribe, and tribes into the nation. No doubt society stimulates the intelligence, while the physical conditions of a country determine the amount of population it can sustain; but these causes go very little way towards explaining why some nations have progressed and others have remained stationary. As Dr. Virchow has said: "It was not the work of the masses which determined the great lines of civilisation, but the work of individuals." We must, however, remember that both savage and civilised races are separated from primeval man by the same number of generations.

TABLE SHOWING THE RELATIVE THICKNESS OF ROCKS IN EACH GEOLOGICAL PERIOD

Rock.	Period.	Scale.	Life.
CAINOZOIC	Pliocene		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 .		

CHAPTER IV

THE GENERALISATIONS OF PALÆONTOLOGY

CHARLES Darwin was the first, in his "Origin of Species," to bring forcibly before naturalists the imperfection of the palæontological record. It is now allowed by all that our knowledge of the animals and plants which formerly inhabited the earth is very fragmentary and must always remain so. This is partly because many organisms cannot be preserved as fossils, either because they had no hard parts—and this applies particularly to the lower animals which came first on the stage—or because they live on the land or other places where their remains can only be buried under exceptional circumstances. This applies particularly to plants and insects.

But this is not all, for denudation has destroyed enormous masses of rocks, and the fossils they contained have gone with them. We find whole mountain-chains made up of fragmentary rocks which are the proceeds of denudation, and it follows that masses of rock at least equal in size to these mountain-chains must have been destroyed. And, in addition, the greater part of the fossiliferous rocks are inaccessible to us. We can only examine the outcrops in cliffs or quarries, while the rest is buried too deep for excavation. We must, therefore, put limited trust in negative evidence, and cannot say that an animal or plant did not exist at a certain time because we have not found its remains.

But, on the other hand, we have already collected an enormous number of fossils from nearly every part of the world, and each of these fossils forms positive evidence which cannot be gainsaid. More than that :—this mass of positive evidence is sufficient to enable us to make inferences bearing on the negative evidence, and so often enabling us to judge how far we can trust to it. For example when we find numerous leaves of dicotyledonous plants with comparatively few ferns, in the rock younger than the Jurassic, and abundant ferns without any dicotyledonous leaves in the rocks older than the Cretaceous and younger that the Silurian, we may feel sure that dicotyledons either did not exist or were very rare in the older periods. It is the same with the terrestrial mammals, the bones of which we find in the Cainozoic rocks, where terrestrial reptiles are hardly represented, an exact opposite to the rocks of the Mesozoic Era. Here also we may make a similar inference.

Again, the order in which animals and plants appeared on the earth is a remarkable one, because it coincides with the arrangement arrived at in the classification of living plants and animals, and this is evidently not a chance. This shews that we can trust the palæontological evidence, when viewed on a large scale, although it may be imperfect in details. We have not discovered the first bird or crab, or the first fish, but we have discovered the order of their first appearance.

The following may, I think, be considered as the principal generalisations of palæontology, founded on good evidence.

1.—Extinct animals and plants were constructed on the same plans of organisation as living ones. We infer this from the hard parts which have been preserved. In shells and bones we find marks of the former attachment of muscles in the same places where muscles are now attached to somewhat similar bones and shells; and we cannot resist the conclusion that both extinct and living species had similar muscular systems. Some extinct mammals have sharp cutting teeth, others have flat bruising teeth; the one evidently adapted for catching and eating animals, the other for grinding down vegetable food. Consequently we must infer that the ancient Carnivora had an alimentary system fitted for digesting flesh, while the Herbivora had one fitted for digesting vegetable food. Their alimentary systems may not have been so well developed as in living animals, but they must have been formed on the same types. So in extinct bivalve shells we find some with and some without a pallial-sinus, and we infer with certainty that those shewing the sinus had long siphons. Also we find that some of the shells of ancient Gasteropods had round apertures, while others are notched or else drawn out into a canal. Both kinds are still living and of these the round mouthed forms feed on sea-weeds, the others on animals; so we may safely infer that the ancient species had similar habits. The presence of eyes in Trilobites is sufficient proof that they had optic nerves, a brain, and a fairly well organised nervous system. And we know that all must have had reproductive systems. Indeed there is no known extinct animal or plant which cannot be referred to some class which has living representatives, and which, consequently, must have had the same type of structure.

2.—Every extinct species has a limited duration in time, and it is the same with extinct genera, families, and orders. This generalisation depends largely on negative evidence, yet this evidence points so uniformly in the same direction that it has been unhesitatingly accepted.

But although every extinct species or genus had a limited life, the duration of specific or generic life differs much in different forms. Of course, as a general rule, the life of a genus is longer than that of a species, because a genus contain several species, but this is not always the case. In the Ammonoidea there are several families which are limited to a single period, as also are some orders of Reptilia, and even a sub-class in the birds. Usually we find that the lowly organised species endured longer than the more specialised forms. Some of the Protozoa of the lower Palaeozoic are with difficulty separated from living forms; and Lingula, a low form of Brachiopod, may also be cited in illustration. But this is not always the case, as, for example, Nummulites and Graptolites which had a comparatively short life. On the other hand the much higher forms of Cidaris and Ceratodus have existed, the former from the Permian, the latter from the Triassic period.

It follows from this that a species, or larger group, once extinct, never reappears. No doubt there are a few cases of long gaps between the representative of a form, but these are not more than we should expect from the imperfection of the record. One remarkable case is Ceratodus, a dipnoid fish known by its remarkable teeth, which have been found in rocks of Triassic and Jurassic age, and then no more are known, except that living species occur in the rivers of Queensland. But the teeth of Jurassic age are very rare, and their subsequent disappearance may be accounted for by the fish having changed its habitat from the sea to rivers, where there would be less chance of the teeth, which are the only hard parts of the skeleton, being buried and preserved. Indeed the reappearance of a form in a locality from which it had long been absent is no proof of the form having been extinct, for the reappearance may be due to migration. For example : no Trigonias lived in the northern hemisphere in the Cainozoic era, but there were some in Australia which still survive ; and if their descendants were to increase and invade the northern hemisphere, we should have there the appearance of an extinct genus having come to life again.

3.—Life has been continuous on the earth ever since its first appearance. This can be easily proved if we assume that all the individuals of a species are descended from common progenitors; a proposition which only a few naturalists have doubted. If this be assumed, it follows that life must have existed on the earth during the whole of the specific life of any particular species; and we can find a series of species whose specific lives overlap one another, and so carry on the inference from the Cambrian period up to the present day.

4.—The more generalised types appeared before those more specialised. A generalised type is one that is related to several different groups, and is thus distinguished from a specialised type, which shews some marked peculiarity. Thus the early reptiles are related to several of the different families which follow them. The Trilobites connect the Crustacea with the Arachnida. The Eocene mammals were not separated distinctly into the specialised groups that we find in the Oligocene and Miocene; and this can be carried into considerable detail.

5.—The succession of forms of life is the same in different parts of the world. In all regions Trilobites, Graptolites and Spirifers have been succeeded by Ammonites, Belemnites and Reptiles, and these, again, by Birds and Mammals. So that there has been a general and uniform advance in life on the earth.

Proof of evolution.—Now all these generalisations are explained by the theory of descent with modification. That extinct animals and plants were constructed on the same plan as the living ones is because the latter are the descendants of the former.

That every extinct group had a limited duration in time is explained by competition and the struggle for existence. That life has been continuous on the earth is a necessary deduction from the theory of descent. That the generalised types were followed by the specialised types is also a necessary result of descent with modification, as also is the general and uniform advance of life on the earth.

There is only one objection to the theory and that is that some groups of animals and plants appear to have come in suddenly. There are not many instances, the chief of them being the Graptolites in the early Ordovician, the dicotyledonous plants in the middle of the Cretaceous, and the eutherian Mammals at the commencement of the Eocene. The explanation of this difficulty is, no doubt, the imperfection of the record; and it will be noticed that two out of the three groups live upon the land where their remains are not easily preserved. The sudden appearance of the dicotyledonous plants and eutherian Mammals is probably due to migration; the early forms having been developed on land, which is now under the Pacific or Atlantic Oceans. That of the Graptolites is due either to the same cause, or to there being an unrepresented period of time between the Cambrian and the Ordovician. Indeed the fewness of these abrupt changes is good evidence that our palæontological knowledge is more complete than we might expect it to be. For the more imperfect it is the more there would be of these sudden appearances.

That the palæontological succession is really due to evolution is confirmed by the study of living animals. 1. By what are called homologies in the skeleton. That is, when the habits of a group of animals change, the skeleton becomes modified to the necessities of the change, not by the formation of new bones instead of the old ones, but by the modification of the old bones so as to enable them to undertake new functions. The fore-limb has changed into a flying organ in different ways in birds, in bats, and in flying reptiles. 2.—By the development of the individual, in which we often see that the living animal passes rapidly through changes which were permanent in fossil forms. This has been proved in the case of the shelly loop which supports the arms in the Brachiopods; in the shells of Ammonites; and in the skeletons of many reptiles and mammals. I might give as an example the tail in the bony fishes of the present day, which is at first diphycercal, then becomes heterocercal, and finally homocercal. Another example is the Tuatara of New Zealand (*Sphenodon punctatus*) the embryo of which passes through stages in which the skeleton shews characters, some of which were permanent in the Stegocephalian Amphibians of the Carboniferous, others in the early Rhynchocephalians of the Permian and Triassic periods. 3.—The geographical distribution of animals is explained by the theory of descent. We find that not only are the individuals of a species grouped together in a specific area, but the species forming a genus are also grouped together in a definite generic area. This is not likely to have been the case if each species had originated quite independently of the others. There are a few exceptions to this rule, and these cases of "discontinuous distribution" are accounted for by the extinction of the species in certain parts of the area and not in others. Also there is always a close connection between the present fauna of a district and its fauna in the Pleistocene and Pliocene periods, intimating that one is descended from the other.

The proof by Gradation.—By this is meant the exhibition of a series of fossils, arranged according to their age, shewing the gradual change of one form into another. Of course the acknowledged imperfection of the record forbids us from expecting to find many of these cases, or of very long lines of gradation; still there are some. This is especially the case in the Brachiopods, some of the Ammonites, and the horse; and in a more broken line with the Crocodiles. But I will take the Camel as an example. The genus *Camelus* appears first in the lower Pliocene and is preceded by the closely allied *Procamelus* in the upper Miocene. *Pœbrotherium*, of the lower Miocene, connects this form with the primitive Artiodactyles of the Oligocene; and these are 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.

SPECULATIONS

Migrations from 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 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).

Again, in some cases a group, after varying much at first, became almost extinct, but was preserved by the persistence of, perhaps, a single genus, which was not at all variable. Such are the Crinoidea, represented to-day by Pentacrinus; the Nautilidea, represented by Nautilus; and the Rhynchocephalia, represented by Sphenodon. However, most of the classes of animals and plants have undergone but little change since their first appearance. In comparatively few cases has change been rapid; but it is these rapidly changing forms which seem so remarkable in our eyes, and give the impression that great change is more universal than it really is. Except the large Lycopods and Crustaceans of the newer Palæozoic, the reptiles and birds of the Mesozoic, and perhaps a few of the Eocene hoofed mammals, there is nothing among extinct plants and animals that would appeal to the untrained eye as anything remarkable and unlike living plants and animals. Our views on this subject are much exaggerated, owing to the numerous drawings and models that have been made of a few of the most extraordinary of the animals; and we forget that they were only a few among a host of quite ordinary beings.

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,"[14] 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

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

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.[15]

These two hypotheses are different; but their authors 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

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

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 of the growing tissue of the stem. A change of leaves thus becomes necessary, unless something alters the surrounding conditions. It is, however, always the lower or unspecialised forms, which give 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.

CHAPTER V

HEREDITY AND VARIATION

THE proximate cause of biological evolution is the appearance of variations. These arise during growth, and are transmitted from parent to offspring, so that the younger gradually diverge from the older forms. This is called descent with modification.

I will first describe shortly some of the principal facts connected with these processes, and then give the hypotheses which have been proposed to explain them.

Epitome of facts.—Life is invariably associated with the substance called protoplasm. This is a semi-fluid material with a very complicated chemical composition, but it always contains a considerable quantity of water. It is not a definite compound, for the proportion of its ultimate constituents varies. And it is unstable only when it is alive and doing work. This indeed necessitates its being unstable; for when work is going on, assimilation and secretion must be going on also. But when these stop, protoplasm is as stable a substance as any other. Tinned meat keeps good for many years.

According to the hypothesis of C. Nägeli, all organic bodies are built up by a number of "micellæ,"[16] that is little groups of molecules surrounded by a film of water; and among these there float minute

[16]Called Elementary organisms by Brücke, Physiological units by Herbert Spencer, Organic units by Galton, Plastidules by Haeckel, and Biophores by Weismann.

globules of various substances, which are, probably, the intermediate products of assimilation.

Structure of Protoplasm.—A network of threads or mitomes, formed by granules of chromatin, held together by linin. This "spongioplasm" holds in its meshes a more fluid portion called "hyaloplasm" or paramitome. The nucleus is formed by altered and concentrated mitomes, in which the chromatin granules are larger and the linin in small quantity or absent. The hyaloplasm is also much reduced and is now called nuclear sap, while the altered mitomes are called chromoromes.

Judging from what we know about the lowest forms of animals and plants—and this is the only kind of evidence we can ever have—it appears probable that at first all protoplasm consisted of delicate fibres of a substance called mitome, running through a more fluid and granular substance called paramitome. There was no nucleus. The first step in development was that, after a certain amount of growth had taken place, the protoplasm kept dividing into two similar and nearly equal halves, self-fission being necessary for the health of the growing organism. Protoplasm is a substance in which chemical re-actions are constantly taking place, and the results of these are, in most cases, detrimental. If the protoplasm by taking in nourishment was to grow into a large mass, these deleterious products would accumulate in the interior. So, for sanitary reasons, the protoplasm divides; and in the lowest plants and animals, separates into two individuals. But the association of individuals, for a common purpose, is useful. So in all the higher organisms these little masses of protoplasm, called corpuscles or cells, do not separate but hold together, some performing one function, some another, and grow up into a plant or an animal; inter-cellular spaces being left, which act as conduits for air or for excretory products.

The first change which took place was a physiological one, and resulted in the separation of a denser nuclear-plasm from a more watery substance known as cytoplasm. The nuclear-plasm collected into a nucleus, surrounded by the cytoplasm, which protects it from external irritants.

At a later stage nuclear-plasm again differentiated into a nuclear-sap, formed of Achromatin, and a fine net-work of threads formed of a substance called Linin. Among these threads lie a number of Chromosomes—granules or threads made of Chromatin. And now, in many cases, during cell-division, these different parts of the nucleus go through a series of complicated processes, called mitosis. Two minute bodies of Achromatin, called Centrosomes, appear in the cytoplasm of the cell, at opposite ends of the nucleus, from whence they send out radiating arms, which appear to direct the movements of the other parts; arranging them, splitting them, and finally separating them into two portions. These star-like bodies are called Astrospheres.[17]

While the physiological variations were taking place, a parallel series of morphological changes was

[17]The Centrosomes, together with the Astrospheres, are called Centrospheres

going on. In the first place special reproductive cells became enclosed in special reproductive organs. Then followed the differentiation of the other organs: stem, leaf, and root in plant; alimentary, muscular, circulatory, respiratory, and nervous systems in animals. This was accompanied by unequal division of the cells; the two daughter cells often differing from each other in size or in shape, or in potential energies.

As a simple example of the growth and development of an organism, I will take *Nitella*, one of the Characeæ or Stone-Worts—submerged water plants not uncommon in limestone districts.[18]

The germinating oöpore is oval, and its first step is to divide into two portions of very unequal size, separated by a cell-wall at right angles to the longer axis of the spore. The larger of these cells grows no more, but merely supplies food-material for the smaller one. This latter divides by a cell-wall perpendicular to the first. One of these daughter cells grows into the primary root, the other into a short primary stem, or proembryo. Upon this primary stem a lateral bud appears, which grows into the plant. The stem of the plant increases in length by the apical cell continually cutting off segments transverse to the axis. Each of these segments immediately divides into two halves by a cell-wall, also transverse to the axis of the stem, and the lower of these halves elongates into an internode filled with cell-sap; the protoplasm forming a lining to the cell

[18]For further details and figures, see Jeffery Parker's "Elementary Biology," Macmillan and Co.

wall. The upper half behaves quite differently. It does not grow in length, but divides into two by a vertical wall, and then each of these halves again divides vertically, so as to form a inner cell, surrounded by a ring of outer cells. This forms a node of the stem, and from it the leaves are developed; each from one of the outer circle of cells. Lateral branches may also arise from the axils of the leaves.

The leaves repeat the development of the stem; but while in the stem the growth is unlimited, in the leaves the growth is limited. After a definite number of segments have been cut off, the apical cell ceases to divide, and grows into a different shape from the other cells of the leaf. The lateral branches repeat the growth of the stem in every respect. Root-like structures, called rhizoids—which are long tubes growing at the apex—also arise from the outer cells of the lower nodes. Each young cell contains a nucleus in the centre, surrounded with cytoplasm, which fills the rest of the cell; and in each bi-partition the nucleus divides first. As the cells of the internodes and of the leaves elongate, a cavity, filled with sap, appears in the protoplasm; which then forms a thickish layer lining the cell wall. A longitudinal rotatory movement commences in the protoplasm. The outer layer, containing the nucleus, is stationary, but the inner portion moves; the current being more rapid near the outer stationary layer, and becoming gradually slower towards the interior. These movements are quite independent of gravitation or light, and are not due to differences in temperature. Indeed the fact that the most rapid movement is next to the stationary layer is impossible to explain by the action of any physical energy. In the hairs of the stamens of another kind of plant called *Tradescantia* we see threads of protoplasm crossing the cell cavity, and in these the streaming movements are all directed either from or to the nucleus. From this we conclude that the nucleus directs, and perhaps causes, the movements. In *Nitella* chlorophyl granules are formed in the stationary layer of the protoplasm. The rotating protoplasm, however, gives rise to a number of granules, formed of chromatin, which are carried along passively in the current.

The reproductive organs grow on the leaves. The male organ, or antheridium, is formed from the terminal segment of a leaf, while a pair of female organs, called oögonia, grow from the lowest node of the same leaf. These are complicated structures which need not be described here. It is sufficient to say that the antheridium gives rise to a number of spirally-coiled antherozoids, which swim to the oögonia and fertilise the single oösphere in each. These now become oöspores, and the cycle is complete.

These various operations occur over and over again with the greatest regularity, even in the most minute details into which botanists have been able to penetrate. Indeed we may feel sure that if the minute details were irregular the results would be irregular also. Still variations do arise, and it is to these that we must now turn our attention.

Definite and indefinite Variation.—The first point in the problem of morphological variation which can be investigated by observation is whether these variations are definite or irregular. If variations in shape are indefinite, observation will shew that they are equally arranged on each side of a mean or zero point; while in definite variation the majority, or perhaps all, will be in one direction, either positive or negative. Definite colour variations will shew one colour only, indefinite variations will shew several colours. Much information has been obtained on this point, and many investigators are at work on the problem. Up to the present the results seem to shew that variation is indefinite; but, perhaps, none of the definite kinds have been examined.

Professor W. F. Weldon, and Mr. Herbert Thomson, from a large number of measurements of the carapace of a crab, have shewn that the variations are here indefinite;[19] and many other examples are given by Dr. A. R. Wallace in his "Darwinism." Nevertheless, Professor Osborn, Professor Weismann, and a number of other biologists agree, from theoretical considerations, that definite variations must also take place.

The importance of this question induces me to give an example of the results of my own investigations on the variation of the leg-bones in the different species of Moa, although they are not conclusive.

There are three localities from which large quan-

[19] *Pro. Royal Soc.*, vol. 60, p. 195; and *Rep. British Assoc.* 1898, p. 887.

tities of Moa-bones have been obtained for the Museum at Christchurch, N. Z. There is Glenmark in north Canterbury; Kapua in south Canterbury; and Enfield in north Otago. The distance from Glenmark to Enfield is about 170 miles. The geological evidence shews that the Enfield deposit is the youngest of the three, as the bones were found in a peat-bog close to the surface; while the fact that the two different species of *Syornis* are less differentiated from each other at Glenmark than they are at Kapua, is good palæontological evidence that Glenmark is older than Kapua.

I cannot give here the measurements of all the species, but select the length of the leg in *Syornis casuarinus*, as this was the most abundant species; and consequently gives the most trustworthy results.[20]

An inspection of these tables will shew that at Glenmark the majority of the metatarsi had a length of eight inches, and that there were considerably more positive than negative variations. This may be taken as definite and pointing to a future increase in the length of the bone. And we see that this actually took place; for at Kapua one half of the metatarsi are eight and a half inches in length, but the majority of the variations are now negative. Still this seems to have had but little effect, for the metatarsus is about the same size at Enfield as it was at Kapua, and shews indefinite variation.

[20]See *Trans. N. Z. Institute*, Vols. 28 and 29.

METATARSUS

Length in Inches.	9·0	8·5	8·0	7·5	Total.
Glenmark - -	3	32	47	5	86
Kapua - - -	33	154	116	15	318
Enfield - - -	21	36	17		74

TIBIA

Length.	20·5	20·0	19·5	19·0	18·5	18·0	17·5	17·0	16·5	Total
Glenmark			3	8	34	29	22	8		104
Kapua	1	8	41	96	77	47	55	26	16	367
Enfield	2	15	26	26	8	4				81

FEMUR

Length in Inches.	12·0	11·5	11·0	10·5	10·0	Total.
Glenmark - -		1	30	33	8	72
Kapua - - -	2	51	131	95	7	286
Enfield - - -	3	28	25	14	8	78

At Glenmark the greatest number of tibiæ are eighteen and a half inches in length, with marked negative, definite variation. But at Kapua the average length had increased to nineteen inches, although still shewing negative definite variation. In spite of this, the average length of the bone was still greater at Enfield than at Kapua, but it now shews indefinite variation.

The femur at Glenmark is from ten and a half to eleven inches in length, with hardly any variation. At Kapua it is larger, and shews more variation, but the majority of these are on the negative side. Nevertheless, at Enfield the bone is still larger, eleven to eleven and a half inches, with a majority of negative variations.

Thus we see that *Syornis casuarinus* became larger, especially in the tibia and femur, from Glenmark to Kapua, and from Kapua to Enfield; although in one case only—the metatarsi at Glenmark—do we find definite variation pointing in that direction. There are five cases in which negative definite variation was followed by increase in size. At the same time there is only one case—the metatarsi at Enfield—in which the variations are about equal on each side of the mean. Perhaps definite variation was here over-ruled by selection; but the results are so irregular that they must, I think, be called indefinite.

"Definite variation" only means that a variation, gradually increasing in intensity, is transmitted by a number of individuals from one generation to the next. While "indefinite variation" means that each variation is individual only, and may or may not die out with the individual. Individual variations are often transmitted from one generation to another; and the oftener they are transmitted, the more constant they become; until, at last, a large number of individuals constantly acquire the same character. Here we have cases of indefinite changing into definite variation, showing that the two are fundamentally the same; the difference between them lying in the strength and constancy of the directing cause.

Variations must be due either (1), to the action of the environment, directly on the individuals, or indirectly, by causing a change of habit, and thus leading to the greater or less use of certain organs. Or (2), to internal causes affecting the action of some law of growth which counteracts the law of heredity. Each of these causes may possibly give rise to indefinite or to definite variation, according to the strength with which it acts. We have no reason to suppose that external causes must act identically on different individuals, or that because one individual changes its habits, therefore many must do the same; but no doubt the environment, if it acts at all, would generally affect a large number of individuals simultaneously, and post-natal variations would generally be definite. On the other hand, indefinite variations would generally arise during the development of the individual; and consequently they must generally be congenital in origin, although the effects may not show until long after birth.

Definite variation is due to the directive force being sufficiently strong to overcome all obstacles. The greatest obstacle is free intercrossing with individuals which do not possess the variation. This is overcome, either by the isolation of a few individuals, or by a large number of individuals changing together in the same direction, and so forming a group by themselves. This last is the necessary foundation of Lamarckism; and the term "determinate variation" might be restricted to it, provided it was well understood that determinate variation was only a special form of definite variation. The first is the foundation of modern Darwinism; but that theory does not exclude definite variation, or even that particular form of it which we have just called determinate variation, if it should be shown that such variations can be transmitted from one generation to another. Indeed, it is well known that Mr. Darwin allowed far more influence to use-inheritance than the new Darwinians are inclined to do.

Discontinuous Variation.—Another point to be investigated is whether variations are continuous or discontinuous. That is, are they small and numerous, or are they large and abrupt, without any intermediate links?

The whole tendency of the experience of breeders and horticulturists is in favour of continuous variation; but several cases are known of the opposite. These were called "Sports" by Darwin, who came to the conclusion that they rarely originated new species. Mr. Bateson, in his "Materials for the study of Variations" (1894), takes exactly the opposite view: namely, that the sports are the most important, if not the exclusive, variations from which new species of animals arise. And Professor H. de Vreis advocates the same view for plants. This question, which is not yet settled, seems to me to be of only secondary importance, and I need not discuss it here further than to point out that definite variations might be easily confounded with sports; for they would resemble each other in appearance, although they differed in their method of development.

CHAPTER VI

EXPLANATORY HYPOTHESES

I WILL next state shortly, but as fairly as I can, the principal hypotheses known to me, which have been put forwards as explanations of the facts given in the last chapter.

Lamarck (1809) was the first person with a competent knowledge of botany and zoology, who tried to solve the problem of the transmutation of species. He supposed that the changes in the environment, which were constantly taking place, gave rise (1) among the higher animals to new wants or needs, which caused the employment of organs in different ways, for new actions would be necessary in adapting themselves to new circumstances. This gave rise to the greater or less use of these organs. Use gradually strengthens an organ, develops and enlarges it; while disuse weakens it, causes it to become reduced, until finally it disappears. (2) With plants and the lower animals he taught that change in climate and in the nature of the food acted directly on the organisms, changing them also. (3) These changes, he said, brought about by use or by the long continued action of the environment, would in time be transmitted to future generations, and so would accumulate. Habits also were inherited and became instincts. The outgrowth of new parts he attributed to the flow of nutrient matter to the part when irritated.

Mr. Herbert Spencer, in his "Principles of Biology" (1864), proposed the hypothesis of "Organic Polarity," which he defined as "a proclivity towards a specific structural arrangement," and said that it "results from the proclivity which the component units, contained in a germ-cell or a sperm-cell, have to arrange themselves into a structure like that of the structure from which they were derived." Variations, he thinks, may be due either to the action of external causes (now called physiogenesis) or to spontaneous variation, due to differences in the ova, no two of which can be exactly alike; or to the mixture of characters in sexual reproduction (what is now called amphimixis). And he further says (2nd ed., vol. I., p. 189), "The one ultimate principle that in an organism equal amounts of growth take place in those directions in which the incident forces are equal, serves as a key to the phenomena of morphological development." This hypothesis is now usually called Epigenesis, and Dr. Hertwig is its chief exponent. It supposes that growth and development are entirely dependent on outside physical agencies, and that they are entirely controlled by the environment. Mr. Spencer has put the theoretical view of variation by physiogenesis very clearly. He says (2nd ed., vol. I., p. 351) "While an aggregate of physiological units continues to grow, no equilibrium can be arrived at between the whole and its parts. Under these conditions an undifferentiated portion of the aggregate will be able to arrange itself into the structure peculiar to the species, and will so arrange itself, if freed from controlling force, and placed in fit conditions of nutrition and temperature. But let growth be checked and development approach completion, let the units of the aggregate be severally exposed to an almost constant distribution of forces, and they must begin to equilibrate themselves. Arranged, as they will gradually be, into comparatively stable attitudes in relation to one another, their mobility will diminish, and groups of them, partially or wholly detached, will no longer readily rearrange themselves into the specific form." And further on (p. 519) he says, "Every change is towards a balance of forces; and of necessity can never cease until a balance of forces is reached." And (p. 522) "This equilibration between the functions of an organism and the actions in its environment may be either direct or indirect. The new incident force may either immediately call forth some counteracting force, and its concomitant structural change; or it may be eventually balanced by some otherwise produced change of function and structure. These two processes of equilibration are quite distinct and must be separately dealt with." However, indirect equilibration is explained as identical with the survival of the fittest, and therefore relates to the preservation, not to the origination of variations.

Darwin's hypothesis of Pangenesis, given at the end of the second volume of "Variations of Animals and Plants under Domestication" (1868), is very different. He supposes that each cell of the animal or plant gives off minute particles, called gemmules, which are capable of multiplying by self-division. These gemmules circulate through the whole system and are collected together in the reproductive cells. In this way they are transmitted by the parent to the offspring, and each gemmule is then capable of developing into a cell similar to that from which it was detached. But it can only develop when it finds itself in a position in the new organism similar to the position of its parent cell in the old organisation; and until it finds this position it may be passed on from generation to generation in an undeveloped state. But it will always be capable of development whenever it finds the necessary conditions.

This hypothesis was conceived, chiefly, to explain not only the phenomena of heredity, but also that of atavism, that is the reappearance of characters which have remained latent through one or more generations. And it was only proposed as a provisional working hypothesis.

In 1870 Professor Ewald Hering gave his celebrated address on Memory.[21] According to the author, memory is the faculty of reproducing ideas; but sometimes these memories come involuntarily. To account for this we must suppose that some

[21]English translation published in the "Religion of Science Library." Open Court Publishing Company, Chicago.

material vestiges remain in the nervous system, by which the nervous substance is enabled to reproduce such physical processes as are connected with the psychical processes, or sensations and perceptions. Repetition increases the power of reproducing the sensations. But, after all, memory is chiefly a faculty of unconscious life. Memories only emerge occasionally into conscious life; and it is this unconscious memory which produces unity in our actions and prevents each conscious action from being isolated and independent. Habitual performance of an action makes it easy to do; and this is only possible by the central nervous system being capable of reproducing the former states of irritation. It remembers, after practice, what it did before. The unconscious memory of the sympathetic system is as strong as that of the brain. In the same way muscles grow stronger from use, and so do all the other systems. They also can perform their functions better after repeated practice.

Now the nervous system is a coherent unity, probably connected with every cell, [and it might have been added that all the cells of a plant are connected by threads of protoplasm.] Any irritation effected in one part is re-echoed by the others; and this re-echo would probably be stronger in the reproductive cells than elsewhere. The reappearance of the parent in the full-grown offspring can only be due to the reproduction of such processes as the germ had previously taken part in, while still in the reproductive organs. The offspring remembers those processes, so soon as the same or similar irritation is offered. If the germ cells of the parent organism are affected, however feebly, by the habits of the body, then the offspring, as it grows, will reproduce the experience it underwent as a smaller part of the body. Therefore it accurately repeats what its ancestors have repeated through innumerable generations. When the first germ divided, it bequeathed its properties to its descendants: the immediate descendants added new properties, and every new germ reproduced to a great extent the *modos operandi* of its ancestors. For acquired characters, he says, can be inherited. Each generation endows its germ with some small property which has been acquired during life, and this is added to the total legacy of the race. Thus every organised being of the present day is the product of the unconscious memory of organised matter.

The same idea of heredity being due to unconscious memory was advocated by Mr. Samuel Butler in his "Life and Habit" (1878).

Mr. Francis Galton's paper on heredity was published in the Journal of the Anthropological Institute for 1875 (Vol. v., p. 329). There are, he says, two groups of facts to be accounted for. (1) Congenital peculiarities, and (2) peculiarities acquired for the first time by one or more individuals during their life-time. The sum total of the germs—or organic units—in the fertilised ovum, he calls the Stirp; and he supposes that a struggle for existence, and a process of natural selection, goes on among the organic units, which constitute the Stirp, by means of which some organic units are developed in the young animal while others lie dormant. The Stirp contains numerous dormant organic units, which may become potent in any generation.

Professor E. Haeckel's hypothesis of "The perigenesis of the Plastidule"[22] is as follows. He says that he seeks to explain heredity by the well known principle of transmitted motion. He assumes that in the process of reproduction not only is the special chemical composition of the plasma transmitted from parent to offspring, but also a special form of molecular motion, which belongs to its physico-chemical nature. The plasma is supposed to be composed of plastidules, each of which is probably surrounded by water. Heredity is the transmission of plastidule motion; whereas adaptation is change of plastidule motion. This motion, he says, may, in its general aspects, be conceived of as a ramified wave-action.

In 1880 Dr. W. Roux proposed to explain variation by a process of intercellular natural selection. He supposed that, owing to pathological or other conditions, a group of cells would not be so well nourished as their neighbours, which would, therefore, take a new lead in the development of the organ. This has been called Intra-selection, or the selection of organs.

Professor A. Weismann published, in 1883, his well known hypothesis that heredity is due to the continuity of the germ-plasm.[23] Protoplasm is

[22]Schopfungsgeschichte, 1876, p. 200; also "Nature," vol. xiv, p. 235.

[23]"Essays on Heredity." English translation published by the Clarendon Press.

known to be a very complicated substance, especially that composing the nucleus, which contains a number of elongated chromosomes, which split lengthways when the cell divides. Professor Weisman supposes that the chromosomes alone bear the hereditary characters, and that they are made up of minute particles called biophores, which combine into determinants; these are grouped into ids and the ids into idants. There is a determinant for each part of the body; and, as the germ develops, one half goes to the new germ cell, the other grows into the body of the organism. That portion which passes from the germ cell of one generation directly to the germ cell of the next generation he calls germ-plasm. That portion which goes to build up the body he calls somato-plasm.

At first he thought that acquired variations could not be transmitted, and that all variations were brought about by amphimixis. But, being convinced that this was a mistake, and being impressed with the importance of definite variation, he proposed, in 1895, the hypothesis of Germinal Selection[24] to account for it and for degeneration. This hypothesis is that in the inevitable fluctuation of the nutrient supply, some determinants in each cell will obtain more nourishment than others, and will develop into more strongly marked characters. If the individual bearing one or more of these characters is selected, this would favour the more powerful determinants of those characters, and if this selec-

[24]English translation in the "Religion of Science Library," Chicago.

tion was continued, a tendency must arise for the determinants to vary still more strongly, "not solely because the zero-point has been pushed farther upwards, but because they themselves now oppose a relatively more powerful front to their neighbours; that is, actively absorb more nourishment, and upon the whole increase in vigour and produce more robust descendants." In this way, he thinks, several modifications could be guided simultaneously by the selection of the individuals exhibiting them.

In 1884 C. von Nägeli also advocated definite variation.[25] He says that the idioplasm (nuclear-plasm) of each cell becomes differentiated by the "dynamic influence of the groups of micellæ upon their own growth; so that the body of idioplasm merely takes on a continually increasing complexity of configuration by the action of internal forces." This constitutes the automatic perfecting process, or progression of the idioplasm and entropy of organic matter.

As this principle of perfection necessarily implies progress, he has to supplement it with abiogenesis. He thinks that "primordial plasma" originates wherever and whenever the necessary conditions combine; so that the animal and vegetable kingdoms are not made up by branchings from an original idioplasm, as is generally supposed, but each race or group may have its own specific idioplasm.

In 1888 Professor Eimer, thinking that organic

[25]A Mechanico-Physiological theory of Organic Evolution. English translation in the "Religion of Science Library," Chicago.

evolution is definitely directed, proposed the hypothesis of "Organic growth."[26] He says that the constitution of the organism determines the direction of its development, and only a few directions are possible, so that indiscriminate modification is prevented. However, through the agency of external influences, the constitution of the organism must be gradually changed. The outward as well as the inward agencies do not act directly, but only by being causes of growth; and the external agencies can only act through long persistence of the same conditions.

Mr. F. W. Hedley, in his "Problems of Evolution" (1900), advocates fission as the primary cause of variation. It is inevitable, he says (p. 33), that fission must at times be imperfect and that the two cells formed by the division of the nucleus will remain adhering to one another and so develop into multicellular organisms. When a cell divides, the two parts appear to be equal. But it is impossible that they can always be exactly equal in size or exactly alike in character. Hence fission must be a source of variation.

Criticisms and Suggestions.—Such are the hypotheses. I have put them as clearly as I could, and have tried to do full justice to each. I will now examine them and see which offers the best explanation of the phenomena.

Lamarck made no attempt to explain heredity. He took that for granted, and endeavoured to shew

[26] English translation in the "Religion of Science Library," Chicago.

how variations arose. His opinions were wonderfully shrewd, considering the time at which he worked; and probably all three are correct, so far as they go. But they do not really explain how variations arise. For an organ must be in existence before it can be used; and no connection is shewn between the direct action of physical agencies on plants and the various forms which they have assumed. Also a very large number of facts are left without any explanation at all. For form does not always change with habit; as in the fruit-eating bats, the honey-eating bears, and in the carrion crow. While very many changes of form cannot be connected with change of habits.

The hypothesis of "Organic Polarity" of Spencer; Nägeli's "Principle of Perfection"; and Eimer's Orthogenesis are metaphysical conceptions and not scientific. Also they all suppose a necessary progressive principle in the development of protoplasm, which is disposed of by the fact that some low forms of life remained almost unchanged through several geological periods. Nägeli explains this by the supposition of spontaneous generation, which cannot be allowed at the present day. I will give one reason only. There are certain Radiolarians of the Cambrian period whose skeleton is so like that of some now living that all have to be placed into the same genus. Now, although the Radiolarians belong to the Protozoa, they have a very complicated skeleton of very various patterns, and it is impossible to suppose that two quite independent organisms could each originate a highly complex skeleton so similar that the two would be included in the same genus. It follows, therefore, that the modern forms are not of independent origin, but are connected with the ancient ones, and have hardly varied at all since the Cambrian period.

These three hypotheses may be at once ruled out of court as vague and meaningless.

Professor Haeckel's hypothesis cannot, in my opinion, be admitted in a scientific discussion, for it does not explain anything. It is like saying that locomotives move in different directions because each has a special mode of motion of its own. If this is not a metaphysical conception, it comes very near it.

The pangenesis of Darwin is an attempt to explain heredity and atavism; but it fails to give an adequate account of variation. Neither does it attempt to shew how new cells arise, and why gemmules should behave as they are supposed to do. Also it is altogether opposed to what we know about cell division. It also must be dismissed.

Neither Mr. Galton's stirps, made up of organic units, nor Professor Weismann's determinants, made up of biophores, explain why these units or biophores should always grow into the same ultimate shape in the adult. They are described as store-houses of energy, and then left there. The chromosomes may be the sole depositories of the hereditary elements, and no doubt their structure is very complicated; but the more complicated it is, the less chance is there of guessing right what that structure is.

The continuity of the germ-plasm has been shewn to be a fact in some animals; but, as we have seen, it breaks down in Nitella. For here the somato-plasm of the leaf gives rise to the reproductive cells. And if the supposed essential difference between somato-plasm and germ-plasm does not exist in plants, continuity of the germ-plasm cannot have in animals the importance attributed to it by Professor Weismann.

There is no evidence to show, nor reason for supposing with Galton, that a struggle for existence takes place among the organic units; but Weismann's hypothesis of germinal selection may indicate a possible mode of the accumulation of a variation after it has been selected. That is, it may give rise to definite variation; but it does not explain the origination of a new one; for the determinants must be there before one of them can be better nourished than the others. Neither is there any connection between being better nourished and being selected.

Dr. Roux's hypothesis of intra-selection does not touch the question of heredity. It is an attempt to explain Goethe's "law of compensation and economy of growth," which has also been advocated by Mr. Herbert Spencer. The hypothesis supposes that one organ is starved and dwindles, so that another, which is more useful to the animal or plant, may be better developed. Mr. Spencer says[27] "It is a general law of nutrition, that when there is a deficiency of food, the non-essential organs suffer more than the essential ones; and the unlikeness

[27] "Principles of Biology," 2nd ed., vol. 1, p. 328.

of proportion hence arising constitutes unlikeness of structure.'' But I have been unable to find in his book any attempt to establish this general law of nutrition, further than by a misleading analogy between a human society and a living organism, the labour and capital of the one being supposed to represent the food-supply of the other. Nor do I know of any experiments made to test the accuracy of this so-called law; and unless it can be supported by experimental or observational evidence, the "law" must be looked upon as an assumption only. Mr. Spencer forgets that money-making is a mental operation; and if the analogy is of any value, it means that assimilation is a mental operation also. But then he would have to shew why useful organs should always have a better mental endowment than useless ones; and that would bring him to the same position from whence he started.

Professor Cope has given, as an illustration of this law, the change of the skull in the early races of man. He says that the orthognathism of the later races was due to the increased use of the brain enlarging and expanding its bony case, probably at the expense of the lime-salts which would otherwise have gone to the jaws; and so the latter dwindled. In other words he gives the use of the brain as a reason for prognathous jaws disappearing with an increasing forehead. But we know now that the forehead increased most rapidly in the latter half of the pleistocene period, long before prognathous jaws disappeared; so that his illustration will not stand. The diminishing of the lower jaw is simply a case of retrograde development from disuse.

The principle has also been applied to explain the reduction of parts of flowers, but without any attempt to shew why the reduced part should have been the one to suffer. Plants furnish their growing tissues with nutrient material in a perfectly impartial manner, and if one part does not absorb its proper quantity, it cannot be because it is of less use than other parts which absorb more than their share. It is the same with animals; in a case of dearth of food all parts suffer together, and when there is abundance all rejoice. Dr. Roux's hypothesis is a pathological one; healthy parts outgrow unhealthy ones. It may account for sports or for monstrosities, but it gives no explanation of ordinary variations.

Professor Hering's hypothesis is very simple and supplies an explanation, both of heredity and of variation. It is, in brief, that growth and cell division are constantly taking place through assimilation, and that the direction of growth is guided by unconscious memory.

It may be objected that Hering is not warranted is assuming that, because the brain receives impressions from the peripheral nerve-endings, therefore the germ-cells may do the same. But I think he is right. We infer that impressions are made on the brain, because the sensations, or ideas, can be recalled at will; and we see in memory a proof that the brain has been affected. But we also see the germ-cell, as it develops, recalling all the operations that its parents went through. If this is not due to memory, then we have no word to express the process and no hypothesis to explain it. The only difference between the two cases is that we can experiment with the brain and get quick results, while with the germ we are restricted to a series of slow observations. But this makes no real difference in the argument; and the proof for the germ being affected is as good as that for the brain. An illustration will make this clearer. Suppose I wished to know what a friend saw at a certain place. I ask him, and he recalls the circumstance and tells me. This we call memory. Now suppose I wish to know what the flower is like of a plant of which I only possess the seed. I sow the seed, and it produces the flowers. Is not that done by memory also?

Another objection may be taken, that it is impossible to suppose that the small ovum, or still smaller spermatozoid, could contain all the memories necessary for building up the adult organism. This is an objection which applies to all hypotheses except epigenesis, and it is one which it is difficult to meet. However, the capacity of the germ-cells for storing up memories is not unlimited. It is only very few indeed of the impressions stored in the brain that are also registered in the germ-cells; and this, I think, is favourable evidence.

The weak point in Professor Hering's essay is the absence of any attempt to verify his hypothesis by an appeal to observation, especially on two points. (1) the transmission of habits, and (2) the presence of mind in every cell. I will try to do something towards supplying this omission.

Ten years previously to Hering's essay, when Darwin was discussing phenomena illustrating the problem of instinct, he had no difficulty in shewing that a large number of them were due to natural selection; for useful habits are selected as freely as useful structures. But, by a most remarkable oversight, he thought that by doing so he had destroyed the Lamarckian theory that instincts are inherited habits, whereas he really explained that theory. For new habits are due to mental variations, and natural selection could have nothing to do with them unless they were transmissible. Natural selection can develop habits into instincts, provided they can be transmitted, but it can no more originate a habit than it can originate a morphological variation. For habits arise from ideas or sensations acting on the brain and causing molecular rearrangements, which, by means of the nerves and muscles, are transmuted into movements. The next generation can only have the same habit either by transmission or by imitation. The elimination of the possibility of imitation is the only difficulty in proving the physical transmission of habits.

I will select a few cases in which imitation is impossible. When a new born baby breathes, cries, and sucks, these actions cannot be due to imitation. They are instincts which have been fostered by natural selection; but they originated as habits in the Jurassic period, or before it. Many insects die before their young are born, and yet the new generation follows exactly in the footsteps of its forefathers. The migratory instinct in the young salmon has prevented its being naturalised in New Zealand and Tasmania. Thousands of ova have been hatched, and the young fish have been seen at the mouths of the rivers before they went to sea; but none are known to have returned. They have wandered away in the direction that their parents were accustomed to take, and they have lost themselves. But plants also have instincts which cannot be due to imitation. Roots grow downwards and stems grow upwards by instinct. It is instinct which makes the ivy grow towards the shade and the clematis towards the light. These examples are quite sufficient to prove that habits are transmitted. Imitation may be a help in the early stages of a habit, but it is not necessary.

Next, as to the question of the existence of mind in each cell, it has been known for a long time that irritability is one of the qualities of living protoplasm. No one can watch the movements of infusorians, even for half-an-hour, without recognising mental action. Also an amoeba surrounding another organism and feeding upon it is as much a proof of mental action as a cat catching a mouse. The search for the ovum by the spermatozoid is also a mental action; even if it is led in its search by physical agents. A very remarkable example is those Rhizopods—like *Diffulgia* and *Saccammina*—which build up cases of grains of sand. They are born naked, and from the sand in which they are born they select particles of about equal size, and build them up into a protective shell. Some select small grains, some larger ones; but, whichever it may be, they are nearly uniform in size with themselves. This surely is a mental action.

In *Euglaena*, belonging to the Flagellata, we also see voluntary movements which are evidently mental in origin. But at certain intervals the animal ceases to move, surrounds itself with a cell-wall of cellulose, and becomes practically a plant. Now, if in its motile condition it had mind, we cannot refuse to believe that it contains mind in its resting condition also. Neither can we consistently deny mind to plants; for many of the lower forms have resting and motile stages. Indeed, several of the higher plants are generally allowed to possess sense organs. And if the antherozoid seeks the oösphere by a mental act, so also must the growth of the pollen-tube be a mental act. That it may be deceived by a solution of sugar and water, imitating the secretion of the stigma, is no evidence at all that the action is due to chemical or physical agencies. Another good example of physiological processes being started by artificial physical stimuli is the fact that in the ova of some animals the centrosomes can be produced, and development commenced, by the action of re-agents, such as magnesium chloride. But here again the chemical re-agent cannot form the centrosomes. The materials must be there, and the stimulus merely starts them into action, whether it be the natural stimulus of fertilisation or an artificial one. The protoplasm of the ovum, on being stimulated, sets to work in the only way it knows; that is by preparing for the process of mitosis. This and the growth of the pollen-tube are merely cases of reflex-action. They shew that both processes are instinctive and due to memory, and not that physical can be changed into physiological energy. It may therefore, I think, be claimed as a fact that mind exists in every living cell; for, if it exists in unicellular organisms, it must exist in each cell of the higher organisms. And where there is mind there is memory. This is the basis of Professor Hering's theory.

Professor Lloyd Morgan calls Hering's theory an analogy,[28] but that is a very incorrect word to apply to it. Physiologists recognise in all animals with a nervous system two kinds of life—tissue-life and somatic or general-life.—The latter is merely a combination of tissue-life and not a separate entity. The destruction of this combination we call death; but the tissues live for some time, until they die from want of nutrition. So also in mental phenomena we have tissue-mind and somatic or general-mind, which is a combination of tissue-mind. There is more than an analogy between the two, because they are identical. We must enlarge our ideas of mind and memory, and see in the growth of a cell the same mental processes that we recognise in an animal making its nest.

The idea that the development of an egg is due to the memories inherent in the embryo is new to most of us; but it does not seem so surprising if we

[28] "Animal Life and Intelligence," 2nd ed., p. 6. footnote.

call it instinct. If a spider makes its web by instinct, why should not the cells secrete the thread by instinct? If a gnat uses its wings by instinct as soon as it is born, why should it not burst its larval-skin by instinct? Why should it not have formed that skin by instinct? And why should not its whole development from the egg be due to the same cause? The gnat need not fly, he may die where he sits. It is conceivable that he need not have broken out of his larval-skin unless he wished to do so. But he could not help developing from the egg, for that is due to tissue-mind and is unconscious. The difference is that the animal has quite lost the power of control over the older instincts, owing to the number of times that they have been repeated. But there is no difference in kind between those actions and the exercise of conscious memory; and it is impossible to draw a line between heredity and instinctive action. Take for instance the origin of fission. This, as I have already said, is a sanitary provision, so that those pieces of protoplasm which divided would be preserved by natural selection, while those which did not do so would perish. But why should these pieces of protoplasm repeat the process? It is not compulsory, for some pieces do not divide. The only explanation is that the protoplasm remembered what it had done before, and did the same again. And in time it got into the habit of dividing. It is an instinct when the two pieces are separate; it is heredity when they remain attached.

Again, the fact that new variations are not always transmitted, but that after they have been transmitted several times they become constant, is strongly in favour of Professor Hering's hypothesis; for this improvement by repetition is characteristic of a mental operation. Physical forces act with as much certainty the first time as afterwards; repetition makes no difference to them. But in order that instincts may work regularly, it is necessary that they be constantly repeated; that the stimulus which starts the movements should not be absent too long. If the stimulus does not come at the right time the cell cannot respond; and if the stimulus remains in abeyance for a very long period, the cell, or group of cells, may forget how to respond even when the stimulus does come. This gives rise to retrogression or degeneration. On the contrary, the more an organ is stimulated the more vivid will be the memory in the next generation. The organ will be better developed, and this will give rise to definite variation. This appears to me to be the true explanation of the Lamarckian doctrine, that use or disuse are the cause of change in organs, and the true reason why acquired characters in time became congenital.

So also, when the germ contains two different memories, derived from its two parents, these may clash and antagonise each other, and so allow an older and dormant memory to be stimulated into activity. This is atavism. Or degraded characters, which have suffered from disuse, can, on a renewal of the old stimulus, again be recalled; as we see in Proteus, which gets dark in colour when kept in the light.

Prepotency also can be explained on the supposition that the germ of one parent has stronger memories than that of the other. And the reproduction of lost parts may be due to the memory of the remaining portions trying to replace the lost portion. In the same way we see that mutilations could not produce degeneration, or the loss of the part, no matter for how many generations they may be carried on, because the part develops and the stimulus has been given before it is removed. Again, the fact that variations appear at an earlier stage in the offspring than in the parent is good evidence that they are due to an excited memory which anticipates events. However, I do not see how Professor Hering's theory can explain the infertility of hybrids. Conflicting memories might lead to inaction, but I cannot see why these conflicting memories should arise until the time had come to differentiate the embryo into the form of one or other of the parent species. This would give rise, not to sterility, but to abortion. That is, the fœtus would not be perfectly formed.

But, notwithstanding this, I think that Professor Hering's theory rests on far better evidence than any of the others, and it certainly gives a more complete explanation of the facts.

CHAPTER VII

CAUSES OF VARIATION

HAVING come to the conclusion that heredity is due to the unconscious memory of each cell, we next have to inquire how variations arise.

Amphimixis.—This is an undoubted cause of variation. It is well known that when new varieties of a plant are wanted, cuttings or buddings are not resorted to, but its seeds are sown; for the young plants differ much more from each other than do those raised by any method of asexual reproduction. Dr. Warren has also shewn that the same is true in the Aphides.[29] Here also there is a slightly greater fraternal resemblance between those born by parthenogenesis than between the offspring of sexual reproduction. But it does not appear that amphimixis is a very important agent in variation; and it cannot originate anything new.

Among the higher animals some of the young resemble one parent more than the other; but intermediate forms are common, as is seen in the case of hybrids or mongrels. In 1865 G. J. Mendel published an account of a number of experiments he had made in crossing varieties of the garden pea

[29] "Nature," April 3rd, 1902.

(Pisum sativum). He found that in crossing two varieties which differed in some one character, that character was generally reproduced pure, as it existed in one or other of the parents. Those characters which are most persistent he called dominant, while those which are seldom reproduced he called recessive. He concludes that the reproductive cells of mongrels are pure, whether they be dominant or recessive, "and that on the average there are equal numbers of each kind for each sex."[30] The so-called law of Mendel applies only to self-fertilised mongrels. It is that of the offspring of self-fertilised mongrels about one half will be intermediate, one quarter will be dominants, and one quarter recessives.

There is in New Zealand a very interesting example of amphimixis. In the south island there are two species of Fan-tail Fly-catcher—the Black (*Rhipidura fuliginosa*) and the Pied (*R. flabellifera*). These two commonly breed together, but no one has ever seen a bird with intermediate plumage. I have been told by Mr. Edgar Stead, who is an excellent and enthusiastic observer, that in union nests the young are sometimes all pied, or sometimes one or more black and the others pied. So that the pied seem to be the dominant species.

Fission.—Mr. Headley's suggestion that fission is the principal cause of variation seems at first sight very plausible; but a little consideration shews that he goes much too far. Similar irregularities

[30]See *Pro. Royal Soc.*, Report I., to Evolution Committee, by W. Bateson and Miss Saunders, 1902.

in fission could not recur in each generation; and if Mr. Headley was right, no animal could have remained so long unchanged as Lingula and other well-known persistent types have done. Indeed the most remarkable thing in fission is its extraordinary regularity. If it was so irregular as Mr. Headley supposes, or if it was an important cause of variation, organic nature would be out of joint in a few generations. It may be a cause of malformations or monstrosities, but hardly of ordinary variation.

Physiogenesis.—This may be due to the action of the climate on the individual; or to the chemical action of food taken into the interior. Competition with other organisms could not originate variations by physiogenesis.

The action of external causes on the organism is sometimes easily recognised. For instance, the growth of muscle by exercise, the thickening of the skin by friction, the influence of continued pressure on growth, and by climate preventing the proper development of plants. Other cases are much more doubtful, such as the growth of spines on plants in dry climates, the peculiar plumage of birds inhabiting deserts, or the thickening of fur in cold climates. We cannot explain why cold should cause more hair follicles to be developed, or why it should cause more rapid secretion of hair in the follicles already in existence. Experience seems to shew that such is the case, and the action is usually said to be indirect. But that is a phrase which has no distinct meaning. The association of two things does not always prove that one is the cause of the other. A dry climate could not have produced the water-pouches in the stomach of a camel; neither could feeding on nectar have produced the honey-bag of the bee. It would be absurd to suppose that a projection from a tube could be caused by sucking liquid through it.

Again, Professor Bumpus, of Wool's Holl, Mass., has noticed changes in the shells of the periwinkles and in the eggs of the sparrows which have been introduced from Europe, and he thinks that these changes are due to the new environment. But he does not suggest any reasons why sparrow's eggs should be smaller and rounder, and why the shells of periwinkles should be thinner and longer in America than in Europe. Here we must remember that as animals are frequently changing their environment, and at the same time are frequently varying, the two must often occur together; and we cannot say that the change in character is due to the change in environment, unless we can connect one with the other, either by explaining why one should affect the other, or by shewing experimentally that such is the case.

Darwin made an extensive examination of the facts, known up to his time, relating to the direct action of the environment on plants and animals; and came to the conclusion that the effect was slight. But in later years he, to some extent, altered his opinion. It is a well known fact that many species of animals and plants are almost cosmopolitan, living under very various conditions; and yet they shew no change; while variations often arise when the surrounding conditions are apparently quite uniform; as in bud variation in plants.

The most variable of domesticated birds in Europe are the pigeon, the fowl, and the duck. Of these the pigeon and the duck are natives of Europe, while the fowl is a native of India. On the other hand, the goose, the guinea-fowl, the turkey and the peacock have hardly varied at all in Europe; and yet the guinea-fowl comes from Africa, the turkey from America, and the peacock from India. Evidently change in external conditions is not a sufficient explanation of variation; and, as Darwin maintained, individual constitution is of importance. If varying the external conditions made plants and animals vary, it would make the work of horticulturists and breeders much more easy than it is. But they merely keep the animals or plants well nourished and await results. Mr. H. Spencer has however come to quite an opposite opinion from that of Mr. Darwin, and finds in the environment the principal cause of variation.

That variations are not altogether due to physiogenesis we see in the difference between brothers and sisters of the same litter, or beween the seeds from the same capsule. However, external conditions must have some effect on organisms. The birds and bees introduced into New Zealand from the northern hemisphere readily changed their times of breeding in accordance with the new seasons. Most plants have done the same; but some, which are reproduced by bulbs or offsets, take time to accommodate themselves to the change. *Gentiana* *acaulis* is especially conservative, and still often flowers in New Zealand in May at the same time that its relations are flowering in Europe, although it also flowers in the spring, that is in October.

Physiogenesis is no doubt a cause of variation; but the theory supplies no method of action, and a great many variations are included under this heading which do not really belong to it, for they are only indirectly due to changes in external conditions. Usually we cannot shew any connection between cause and effect, and this leaves a doubt in our mind. And if the external causes are as efficient as some suppose, surely we ought to be able to trace their effects without such difficulty. Prof. H. W. Conn says "We do not understand how environment can act upon the individual in such a way as to produce even acquired adaptive changes in it. Why a muscle grows with use or diminishes with disuse, why sensations become more acute when exercised, why changes in food or climate modify colours, why the shapes of leaves and the length in the beaks of birds change with climate, we have not the faintest notion."[31]

If it is difficult to trace the action of the environment on the organism at the present day, when we can observe their habits, how much more difficult must it be to estimate its action on extinct animals. And yet there are naturalists bold enough to say that the changes in Ammonites were due to the favourable nature of the physical surrounding in the Jurassic period.

[31] "The Method of Evolution," 1900, p. 303.

Psychogenesis.—It is, I think, quite evident that amphimixis, fission, and physiogenesis together do not give a complete explanation of the phenomena of variation. Something more is wanted; and, the closer the phenomena are studied, the stronger becomes the conviction that we must look to some other agent as the principal cause of variation. This agent can only be mind. We have already seen that mind exists in every living cell; and, whatever it may be, it is not a passive but an active agent, which must exert an important controlling influence over all the internal movements of the cell.

I will take as an illustration one of the earliest variations that took place in protoplasm, viz., the formation of the nucleus. A little consideration shews that it could not have been due to external conditions; for the first defenceless piece of protoplasm, floating on the sea, must have been less capable of resisting the action of external agencies than it afterwards became. And if these agencies were capable of producing this change in protoplasm, they must have produced it at once. Also, if some protoplasm could be thus influenced, all would have been influenced in the same manner; and some portions could not have withstood these agencies up to the present day while other portions succumbed. These considerations throw out all hypotheses which depend on external agencies; and the process, whatever it was, must have been an internal one. Germinal selection fails, because we cannot conceive that the formation of the nucleus was due to the special nourishment of certain biophores. For why should they congregate together? If we look to the larger operations of biological evolution for a clue to guide us, we see some resemblance between this clustering of certain biophores and the action of preferential selection in forming groups. But preferential selection is a mental operation, and so, possibly, may have been the formation of the nucleus. I suppose it to be the concentration of mind in the cell; that is the formation of a cell-brain. We see a further development of the same kind in the formation of the centrospheres and the differentiation of the nuclear plasm. These were the first steps in co-operation for mutual benefit, which led to the physiological division of labour, which Professor H. Milne-Edwards was the first to explain.

This hypothesis may seem fanciful, even wild; but the phenomena are very extraordinary, and the explanation, no doubt, will be extraordinary also. And I think that, after duly weighing the evidence that can be brought forward, the reader will find that the hypothesis is more reasonable than appears at first sight. Let us look at some of the evidence.

Take the contractile vacuole found in the ectosarc of the Protozoa. In Amoeba it is a simple cavity, which gradually increases in size, filling up with water, until it suddenly contracts and disappears. Then, after an interval, it again reappears in the same place, and slowly expands once more. This contractile vacuole is thought to be an excretory organ, as uric acid is said to have been detected in it. When the Amoeba undergoes fission the vacuole does not divide, but remains in one half of the animal, and a new one is developed in the other half.

Can we account for this by the action of physico-chemical forces? If we suppose that water containing uric and carbonic acids gradually collected in one place until it burst through the protoplasm and escaped, we could not expect that this action would be confined to one place, always in the ectosarc, and that it would be regular in its pulsations. No observer has supposed that this is the cause, and the very name *contractile* vacuole shews that the contraction is thought to be a movement of the protoplasm. The fact that the vacuole always remains in the same place proves that, even in Amoeba, there must be some special arrangement of the protoplasm surrounding it; and this arrangement could not have been brought about by the action of external agencies.

But suppose that the vacuole originated by the concentration of water containing excretary matters, and that, when it had increased to a certain size, the protoplasm was so irritated that it contracted and expelled the offensive matter. This would be a truly vital operation. Then, after fission, the formation of a new vacuole, always in the ectosarc, must also be a mental operation. These actions may be unconscious, or reflex, now; but that could not have been the case when the first performance took place. Both actions must at first have been subconscious, even intelligent; and the arrangement of the protoplasm, which necessitates the vacuole being always in the same place, must also have been due to mind.

Next take the movements of the protoplasm in Amoeba. Portions of the ectosarc are pushed out, apparently at the will of the animal, and then the granular endosarc flows into them and thus are formed the pseudopodia, by means of which the animal surrounds its food, or progresses slowly onwards, feeling its way through the obstacles it encounters. No one who has watched this process will say that the movements are mechanical. External agencies could not have caused directly the pushing out of pseudopodia. Evidently they are produced by mental action; and so we find that the first step in circulation was produced by mind.

Also the separation of the male and female sexual elements, sometimes into two approximated cells, cannot possibly be due to physiogenesis. The same may be said of the secretion of substances like cellulose, silica, and carbonate of lime; some by one cell some by another. And neither could the formation of special gland-cells be due to physiogenesis.

Let us take the formation of the eye and examine it a little more closely. Physiogenesis cannot possibly account for the differentiation of a nerve-cell from a muscle-cell, nor for the further separation of the special senses. How could the vibrations of light be concentrated so as to produce eyes in certain places only? If it is said that the skin became more sensitive to light in some places than in others, that is acknowledging internal action. Why should the vibrations of light and of sound have formed sensitive spots, while heat vibrations did not do so? We know what light is, and we can judge of its action, but we cannot imagine how it could have originated the optic nerve nor the eye. How could vibrations of the æther build up the lens, the retina, and all the other parts of the eye? Eyes have originated independently in the Arthropoda, the Mollusca, and in the Vertebrata; and in all three they are situated as near the brain as possible. This look as if the brain had something to do with it. The brain must have taken advantage of the vibrations and built up an organ capable of recognising their different lengths. This was a mental operation, and looks as if it were the result of intelligence. For how else could three different branches of the animal kingdom have found out that images could be produced by a convex lens?

Also, could the action of water, either directly or indirectly, originate or increase air-spaces in the stems and leaves of water-plants? Could electricity originate electric organs in animals? Or could the absence of light originate phosphorescent organs in the deep-sea fishes?

In alpine countries the plants often have small, thick concave leaves, either closely pressed round the stem, or with the margins recurved; and these are unquestionably adaptations to the climate. But can we say that they were produced by the climate? In the same alpine regions the rocks stand out in high bare pinnacles, due to the wind and rain removing all debris. But we do not say that the rocks are adapted to the conditions; because by the word adapted we mean that the plants have been made suitable to withstand the climate, while the rocks are not protected in any way. Now, how could the physical agents have brought about this adaptation? Could wind, or rain, or cold, have thickened the leaves or curled up their margins? Certainly not. Their action has been indirect only. They have caused the protoplasm to do these things. It is the real agent, and not the physical forces. We might as well say that a house was built by the rain and wind, or that snow formed a great coat, as that these leaves were produced by physiogenesis. In fact physical energies cannot act indirectly. It is the response of the protoplasm to these energies—that is, accommodation or adaptation—which is meant, and this is identical with psychogenesis. Clearly all adaptations must be primarily due to psychogenesis, and only indirectly to the action of external agencies.

It would be easy to multiply examples almost *ad infinitum*, but no object would be gained by doing so. If it can be shewn that mental effort is not necessary in the cases I have produced, then all would fail. But if they are not due to physico-chemical causes, they must be due to mind directing the movements of the protoplasm. I therefore call the process psychogenesis. It includes all variations which are due to the initiative of the protoplasm.

Whatever mind may be, it is not passive. It is as energetic as the physical forces, and it must, in some way, originate changes in the protoplasm, which we can generally recognise as resembling the action of intelligence. In fact, we know from the phenomena of memory that it does originate changes in the brain. Mind is the "vital force" which so many physiologists now believe in. But the essence of mind is thought; and psychogenesis must be due to a form of thought—thought of the cell-mind.

There is one general argument that may be urged in favour of psychogenesis. It seems probable that the energy of inheritance must have been slight in the early organisms, and that it increased with repetition; for this is the teaching of a large number of experiments and observations on new varieties. But we learn from palæontology that variation was slow at first, and that it became more rapid as the world grew older, so that the cause of variation must have increased in intensity. Now the most reasonable hypothesis appears to be that the rate of variation increased as animals got more intelligent. So that the rate of variation depends largely on the intelligence of the animal or plant. This is indirect evidence of psychogenesis.

CHAPTER VIII

SELECTION

VARIATIONS arise by some of the methods just described; but if the individuals bearing these variations were exposed to free intercrossing with other individuals, the variations would be lost. How are they preserved?

In the first place, they must be transmitted to the next generation; and we know from the experience of breeders that at first this transmission is very uncertain; but becomes more and more certain according to the number of generations through which they have passed. In time every new race breeds true. Characters which have been acquired through physiogenesis, and which are called acquired characters, do not seem capable of transmission; but there is much diversity of opinion on this subject among biologists.

Lamarck assumed that variations arising through physiogenesis, or from use and disuse, would be transmitted to future generations. Several authors have produced much evidence to substantiate this view; but a large part of it has been shewn to be of no value; for the facts can be better explained by natural selection.[32] Nevertheless, we have seen that habits are often transmitted; and, if changes in brain structure can be handed down from parent to offspring, we cannot doubt but that other bodily structures are handed down also. But all habits are due to psychogenesis, and it seems probable that only those structures can be handed down which have been originated by a mental impulse. This would be quite in accordance with Hering's theory. The means by which it is done have also been explained by Professor Hering, as I have already stated. It is not a direct action, and it requires constant repetition to make an impression; but in time resistance is overcome and a permanent structure is developed. This is what Darwin was looking for when discussing the indirect effect of external agencies.

I have found it very hard indeed to discover any undeniable evidence of the transmission of acquired characters; for even among useless characters it is difficult to find any which are undoubtedly due to the action of physiogenesis. Perhaps the bright colours of alpine flowers is a good example, for they are thought to have been produced by special climatic conditions, and they are regularly transmitted in plants which have been removed to the plains. The brightly coloured birds and insects of tropical regions may also be admitted. For although there are many dull coloured species among them, these belong mostly to the primitive families,

[32]See Weismann on "Heredity," vol. i., Essay vii., p. 397.

and may not be able to vary so readily as the newer species.

I must once more point out that, if it is difficult to feel sure about any character in a living animal being due to physiogenesis, it must be far more difficult to form an opinion about fossil animals, of which we know nothing except their shells or skeletons. And yet there are several naturalists in the United States who find no difficulty at all, but write about the acquired characteristics of fossil animals with the greatest confidence.

Transmissible variations may be preserved either by selection or by isolation. The first of these modes accumulates variations as well as preserves them; but isolation is a mode of preservation only. And if the variations are to increase, it must be by definite variation acting as the accumulator.

Organic Selection.—In 1896 Professor H. F. Osborn,[33] Professor J. M. Baldwin,[34] and Principal Lloyd Morgan[35] independently pointed out that individual modifications, due to external conditions, would help to keep those individuals alive, and so preserve generation after generation until modification became transmissible and attained a selection value; after which it would be preserved by natural selection.

Professor Osborn thus explains his idea. "Onto-

[33] "A mode of Evolution requiring neither Natural Selection nor the inheritance of acquired characters." Trans. N. Y. Acad. Sciences, March and April, 1896.

[34] "A new factor in Evolution." *Am. Nat.* June and July, 1896.

[35] "Habit and Instinct," 1896, p. 312, ff.

genetic adaptation (=modification) is of a very profound character. It enables animals and plants to survive very critical changes in their environment. Thus all the individuals of a race are similarly modified over such long periods of time that, very gradually, congenital or phylogenetic variations, which happen to coincide with the ontogenetic adaptive variations, are selected and become phylogenetic. Thus there would result an apparent but not real transmission of acquired characters." He gives the following illustration. "If the human infant were brought up in the branches of a tree as an arboreal type, instead of a terrestrial, bi-pedal type, there is little doubt that some of the well-known early adaptations to arboreal habit (such as the turning of the soles of the feet and the grasping of the hands)[36] might be retained and cultivated; thus a profoundly different type of man would be produced."

Professor Baldwin gave this process the name of Organic Selection, and thus defines it. "The process of individual accommodation (=adaptation) considered as keeping single organisms alive, and so, by also securing the accumulation of variations, determining of evolution in subsequent generations." Prof. Poulton says "Organic selection is the power of the individual to play a certain part in the struggle for life, and may constantly give a definite trend and direction to evolution." Prof. H. W. Conn says, "The essence of the theory of organic selection is

[36]These are vestigial characters and not modifications. F. W. H.

that these acquired variations will keep the individuals in harmony with their environment, and preserve them under new conditions, until some congenital variation happens to appear of a proper adaptive character."[37]

We thus see that it is claimed for organic selection that it gives an explanation of definite variation. Prof. Osborn says "Heredity slowly adapts itself to the needs of a race in a new environment along lines anticipated by individual adaptation, and therefore along definite and determinate lines." This may be true, but these definite lines must be useful ones, and must be initiated by the action of external conditions. Organic selection merely preserves incipient useful variations, however they may arise. It is merely a form of natural selection, and, like it, has nothing to do with the origin of variations. It is quite incapable of explaining the origin or preservation of useless characters, and it is these which especially require the action of definite variation for their preservation.

Natural Selection.—This preserves beneficial variations by eliminating the inferior individuals. It has only one motive or agent through which the variations are preserved, and this is utility. So that all characters which are not useful, either to the bearer or to some ancestor of the bearer, have not been preserved by natural selection.

Three objections have been made to natural selec-

[37]This, and the preceding quotations, are taken from Prof. Baldwin's "Development and Evolution," 1902. I have not seen the originals.

tion which require notice here. The first is that a large number of individuals are destroyed by accidental circumstances, not in any way due to non-inheritance of a beneficial character. The usual example given is the destruction of the eggs of fishes before they are hatched. This, however, is part of the competition between the mothers and not between the young. Those mothers which produce the fewest ova will not be represented in the future, and so the species will tend to become more and more prolific. Also the destruction of the eggs does no harm to the next generation, for those that are left will be an average of the whole, and will, when hatched, commence to compete with each other. The destruction of large numbers by hap-hazard causes may delay the operation of natural selection, but it does not prevent it.

The second objection is that physicists have shewn that the earth has not existed long enough to allow of the process of development by the Darwinian theory, as that process was necessarily a very slow one. This also is a misconception of Darwinism. The objection is a mild form of the very venerable one which Cuvier brought against the theory of Lamarck in the beginning of the century, and which is mentioned in the first of these lectures. The answer is that if organic development has been slow during the last three or four thousand years, so also has been the geological development. As the earth has, as a matter of fact, existed long enough for the geological evolution to work out, so also must it have existed long enough for the organic evolution; for all through the earth's history the two have gone together. From the Radiolarians and sponges of the Huronian, through the Trilobites and Brachiopods of the older Palæozoic, the fishes and land-plants of the newer Palæozoic, the reptiles and Gymnosperms of the Mesoic, the birds, mammals and angiosperms of the Cainozoic, the geologic and biologic evolutions have marched on hand in hand; and, as there has been time for one, there must have been time for the other. The rate of evolution does not affect Darwinism, which has nothing to do with the origin of varieties. If the varieties came quickly, natural selection would act quickly; and *vice versa.* No doubt, if the physicists are right, variation must have gone on quicker than it does now; but Professor Poulton has shown that the data on which physicists have calculated the short history of the earth are untrustworthy, and not entitled to so much weight as the facts brought forward by geologists.[38]

The third objection has been brought forward by Mr. Herbert Spencer, who says that selection could not bring about the simultaneous development of several organs towards the fulfilment of the self-same object; as, for instance, those necessary for leaping. This is, I think, a misconception of the action of natural selection; for Mr. Spencer seems to suppose that only very few animals are preserved, all of which have one important character more developed than others; while in reality a large number are preserved—as many in fact as the

[38]British Association Report for 1896, p. 808.

district will hold—and they are those in which all necessary characters are combined. If leaping was important, those animals would have the advantage in which the combination of characters favourable for leaping was most pronounced. A single defect of any kind would be fatal.

Natural selection has no particular tendency to preserve individuals with one beneficial character only; but selects those which possess the best collective qualities for success in the struggle for existence. The struggle is generally continuous, and not intermittent, as is so often supposed. Droughts and famines may occur occasionally, but their effects are soon obliterated by a succession of good seasons. It is the ordinary, not the exceptional, season which determines the action of natural selection.

Nevertheless, the occurrence of the right variations at the right places, at the right times, and in many succeeding generations, is certainly very remarkable, and seems to require definite variation to explain it. This explanation was attempted by Weismann in his hypothesis of germinal-selection. But that only shews why a character once selected would be likely to reappear in a still more modified form in succeeding generations; it does not touch the question of the simultaneous origin of several variations. A better explanation is found in Professor Hering's theory; for any organ which was specially useful would be much used, and this would be re-echoed by the germ, and in the next generation all the useful organs would be better developed.

Thus use, although it cannot originate, is a cause of definite variation, and Hering's theory explains the opinion held by Lamarck and his followers, that use causes organs to be developed.

To judge of the importance of the principle of use-inheritance we must resort to observation; and here we find considerable difficulty in distinguishing its action from that of natural selection; for both develop and preserve useful characters only. The great characteristic of natural selection is the diversity of its action; the same end being obtained by various means. Whereas, in use-inheritance the same cause ought to produce the same effect, unless it be hindered by the internal forces of heredity.

For instance, it is thought by Professor Henslow that the irritation produced by insects when they visit flowers is largely a cause why ordinary actinomorphic flowers have become zygomorphic, or bilateral. But bilateral symmetry is often useful, by forcing the insect to assume a certain position when abstracting the nectar from the flower, and so may have been produced by natural selection; while it is difficult to see how the hap-hazard visits of insects to actinomorphic flowers could have originated zygomorphism, for they would alight quite irregularly. The long legs of some dipterous insects could not possibly be due to use, for they are developed in the pupa stage, before they have been used, and do not alter in any way after the perfect insect is produced. Also in many cases we find that the constant use of an organ does not develop it. The short wings of the penguin are constantly in movement when the bird is in the water, while the long wings of the albatross are held motionless during the greater part of the day. Here natural selection has over-ridden use-inheritance. Or compare the cartilaginous skeleton of the rapidly swimming shark with the bony skeleton of the sluggish eel. In this case also it is difficult to think that use-inheritance has been the cause of the better development in the eel.

It is, as I have just said, in the various contrivances for bringing about the same end that we recognise the action of natural selection most readily. For example, the means adopted by the land-snails for breathing air are different in the two groups. In the Pulmonifera the lung, which is lined with blood-vessels, is a cavity formed by a folding of the mantle on the right side. While in the Cyclostomatidæ it is a reticulated organ, situated in a cavity in the body on the back of the neck, and in front of the mantle. So also in the land-crabs the orifice for the air is formed in a different manner in each of the families. One more illustration will suffice. No two birds exhibit a greater contrast than a penguin and an albatross. The one incapable of flight, but the most expert diver among birds; the other incapable of diving, but the queen of flyers. And yet anatomists tell us that the penguins have their nearest relatives in the petrels. These two different forms, each so thoroughly adapted for getting its living on the ocean, have been produced from the same parent stock by the action of natural selection.

But natural selection cannot act unless favourable variations arise, and this is not always the case. For example, fish are very scarce at Campbell Island, and, according to Dr. H. Filhol, who lived there for four months, the Campbell Island cormorant feeds on the mollusks that live on the brown seaweed or kelp. So great a change in habits would seem to demand some modification of the bill, which cannot be the best possible instrument for detaching shell-fish from seaweed, seeing that it was intended for catching fish. Probably also some modification of the feet would be useful, for the birds have no longer to swim fast, but to crawl about among the seaweed. However, no such modifications have occurred, although the birds have probably been living on the island for a very long time.

This is by no means an isolated fact. Penguins obtain their food entirely by diving, and they have been in existence since the Oligocene period; yet they have not developed any modification to assist them in remaining under water; while the webbed feet of the Upland-goose of Patagonia prove that natural selection cannot always correct imperfect adaptations. These, and similar cases, go to shew that natural selection is not such an all-searching power as the Neo-Darwinians suppose, and that it cannot bring about close adaptation in every case.

A point generally overlooked is that by means of natural selection a genus may sometimes be formed after the species contained in it. In times of changing conditions individuals of several species may be preserved owing to their all possessing a better development of some useful organ, and this in time would become a generic character. Occasionally members of more widely separated groups are linked together in the same way; as parrots and woodpeckers by the feet, or hawks and owls by the beak. But these similar adaptations are always combined with other characters, which shew that the animals are not really related. With genera, however, it is different, for the species are closely related, but have been combined into genera after the species were formed. This explains why genera are often more difficult to discriminate than the species.

Retrograde Development.—Some cases of retrograde development are undoubtedly due to natural selection. A good example is the loss of the teeth in the upper jaw of the Sperm-whale. This cannot be accounted for by disuse, for its ancestors must have used the teeth of both jaws equally. But we have an explanation in natural selection. These whales feed largely on floating animals which they catch by swimming on the surface of the sea with the mouth open and the lower jaw hanging down. In this position the teeth of the upper jaw would be detrimental, for they would act like the cow-catcher of a railway engine and prevent animals from drifting into the whale's mouth; while the teeth in the lower jaw are useful for capturing the prey. On the other hand, there are many cases of retrograde development which cannot be accounted for by natural selection. The degeneration in the wings of the flightless duck of the Auckland Islands

(*Nesonetta*), and of the flightless cormorant of the Galapagos Islands ( ), are good examples. For flight could not have been disadvantageous to water-birds, as it might be to land-birds on small islands. The dwindling away of internal parts, such as the pelvic-girdle in whales, sea-cows and snakes; the shoulder-girdle in some Moas, and the optic nerve in blind animals, cannot be due to natural selection. In the petrels the hind toe is reduced to a claw, which is quite functionless, and it is difficult to see what disadvantage a hind toe could have been to these birds. But the petrels are an old group. Bones have been found in beds of miocene age, which shew that stormy-petrels, shearwaters, and albatrosses all lived at that time; and, as the hind toe is vestigial in all these groups, it probably became so before they were differentiated. And we cannot say what the habits of the birds may have been so long ago.

Attempts have been made to explain these cases of degeneration by the so-called "principle of economy of growth." I have, however, already shewn that this principle does not rest on any evidence; and it is very unlikely that useless organs should not receive sufficient nourishment to enable them to develop properly; for even in times of dearth of food all organs suffer equally. But we have in Hering's theory a simple explanation, viz., that disused parts are gradually lost through forgetfulness. The organs, or cells, no longer remember how to reproduce the long disused parts: the stimulus dies away and they remain undeveloped.

Take, for example, the absence of colour on the lower surface of the flat-fish, which is evidently a case of degeneration. The stimulus of light being absent for many generations, retrogression has taken place, and now the old characters can with difficulty be recalled.

This is different from atavism, in which a latent character takes the place of a newer one. In degeneration the character dwindles, nothing replaces it, and it is finally lost. So long as an organ is stimulated, although perhaps the stimulus may be different from the original one, the organ may remain; as the web in the foot of the Upland-goose of Patagonia. But when quite unstimulated the organ disappears altogether.

The incompleteness of Natural Selection.—We may now proceed to examine the difficulties in the way of considering natural selection as the sole agent in evolution. The first difficulty is the existence of numerous characters, either of colour or of form, which are called non-utilitarian, because they are not of any use to their possessors. Darwin always saw this difficulty; but at first he thought that it could be overcome. In the first edition of the "Origin of Species" he attempts to explain these useless characters as being principally due to the inheritance of characters, which were useful to ancestors of the present possessors, but partly as the results of correlation of growth. That is, he thought that they might be necessarily connected with other characters which are of use. No doubt the first explanation will account for the presence of useless degenerate organs or vestiges, but they are comparatively few; and still fewer are the characters which we may suppose to be due to correlation of growth. The great majority remain unexplained. Ten or twelve years later Darwin recognised the force of this objection; and, in the "Descent of Man," he says: "In the earlier editions of my 'Origin of Species' I perhaps attributed too much to the action of natural selection or survival of the fittest. I have altered the fifth edition of the 'Origin' so as to confine my remarks to adaptive changes of structure; but I am convinced from the light gained during the last few years that very many structures which now appear to be useless will hereafter prove to be useful, and will therefore come within range of natural selection. Nevertheless, I did not formerly consider sufficiently the existence of structures which, so far as we can at present judge, are neither beneficial nor injurious, and this I believe to be one of the greatest oversights as yet detected in my work. It is, as I can now see, probable that all organic beings, including man, possess peculiarities of structure which neither are now, nor were formerly, of any service to them, and which therefore are of no physiological importance."[39]

Dr. Wallace, however, still argues that these characters are not really useless, but that we suppose them to be so because we are so very ignorant of the habits of animals. He thinks it is impossible to prove that any character is not, nor ever has been, useful to its possessor, or that it is not necessarily

[39] "The Descent of Man," 2nd edition, p. 61.

correlated with some useful character; and he has himself pointed out that many of these so-called useless characters are useful as recognition-marks; that is, marks by which the individuals of a species are enabled to recognise each other. This theory of recognition-marks is probably true with reference to some of the higher animals, but it is very improbable that either form or colour could be used as recognition-marks among the lower animals, and the theory obviously does not apply to blind animals and plants. Even among animals possessing eyes there are many characters which cannot be regarded as recognition-marks, for they cannot be seen: as, for example, the teeth on the tongues of snails, and the internal convolutions of the suture in the shells of ammonites. The neuration of the wings of moths and caddis-flies is obscured by scales or hairs, and yet it often furnishes good generic and sometimes specific characters. Some crabs are always covered with seaweeds growing on their shells, and the species to which they belong cannot be ascertained until these seaweeds have been removed. And generally, obscure characters cannot be explained as recognition-marks, when there are conspicuous characters to answer that purpose. These specific characters therefore are not recognition-marks; are they adaptations of any other kind? We can hardly suppose that the colours which distinguish the shells of some bivalves which live buried in sand have any adaptive value. Nor can we suppose that a spine more or less, or a different arrangement of the tubercles on the carapace of a crab can give one individual an advantage over another. Neither can it matter in the struggle for life whether the nervure in the wing of an insect branches once or twice. Again, can we suppose that slight differences in the number or shape of the teeth in snails have any adaptive value? Or take the shape of the spicules in sponges, or the small differences in the leaves of ferns and mosses, or the various patterns of ornamentation on the valves of diatoms: can all or any of these characters be explained by the law of utility? No one, I believe, is at present prepared to maintain that they can.

But it will be as well to give a few special illustrations. The Radiolarians are minute, microscopic animals, whose soft body is supported by an internal siliceous cage, or skeleton, of great variety of form. Now these different forms cannot be correlated with each other, for each species has its own; and they cannot be recognition-marks. The skeleton, of course, is useful to the animal as a support, and as a defence against enemies. But several of the forms which we find in living Radiolarians we also find in Radiolarians which lived near the commencement of the Palæozoic era. During almost the whole history of life on the earth these different forms of skeleton have been competing with each other. During this competition many other forms of skeleton came into existence; but they did not vanquish the old ones; all lived and multiplied alongside each other, without any one obtaining the victory. Obviously, the particular form of the skeleton cannot give any advantage, and cannot therefore be due to natural selection.

The Radiolarians are amongst the lowest of organisms. Now let us go to the highest class for an illustration. The different species of elephants, both living and extinct, are distinguished, among other characters, by the different ways in which the enamel and dentine of the molar teeth are folded into transverse ridges. This folding of the hard enamel, and the filling of the interstices with a softer cement, is a very useful structure; for, owing to the different hardness of the different parts, an uneven surface is constantly maintained, which enables the tooth to fulfil its function of grinding down leaves and shoots of trees, on which both the species of living elephants feed. In the African elephant the transverse ridges are thicker in the middle than at the ends; while in the Indian elephant they are equally thick all through, and the number of ridges in each tooth is nearly double the number in those of the African elephant. In the Mammoth this type of tooth was still more specialised than in the Indian elephant. Elephants of both types, now extinct, lived together in India during the pliocene period. In the pleistocene, the African elephant lived in South Europe, with other species, some of which belonged to the Indian type; and at the close of the pleistocene, the Mammoth, which had the most specialised teeth of any, became extinct. As these two forms were competing for so long a time without either of them gaining any advantage, we cannot suppose that the two living species of elephant owe their preservation to the superior pattern of their molar teeth.

The fact is that one pattern is as useful as the other, neither more nor less; and as no advantage is gained by having different patterns, they cannot have been developed by natural selection.

I am tempted to give one more illustration, taken from the class of birds.

There is a genus of small fruit-pigeons, called *Ptilonopus*, found in the Malay Archipelago and Polynesia. It contains twenty-three species, of which no fewer than thirteen are found, isolated from other species of the genus, each in its own island or small group of islands; the other ten living associated, two or more species together. Now it is highly improbable that the whole of the thirteen isolated species were developed on other islands from which they have migrated, and that their ancestors, who were left behind, have all become extinct in their former homes. Also, it is highly improbable that formerly two or more species of *Ptilonopus* existed on each of these thirteen islands, and that all have been destroyed except one species in each island. Either one or other of these cases might happen occasionally; but it is impossible that thirteen should occur simultaneously. Consequently, it appears certain that most of these species were developed singly, each on its own island. If this be the case, the colours which now distinguish the different species cannot be recognition-marks, because there is no other species in each island with which they could be confounded. The colours cannot be due to correlation, because they are the only characters which have changed. They cannot have been useful to ancestors, because they have only lately been developed. And we cannot suppose that they give any special advantage in each island, because all the islands have practically the same climate and the same flora and fauna. This exhausts the resources of the principle of utility; and we are driven to the conclusion that these specific characters have a non-utilitarian origin. And, if the colours have not had a utilitarian origin in these isolated species, it is quite probable that they may not have had a utilitarian origin in other cases, where two or more species of the genus are found together. Therefore it follows that recognition-marks and other specific characters do not necessarily arise through natural selection. To form these non-utilitarian characters something else must have been at work.

A second objection is sometimes made, that incipient variations, even if they are useful, cannot be of any importance in the struggle for existence, and that natural selection could not develop them until they had made a considerable advance. This is quite true; but it is only another form of the first difficulty; for until the variations have attained to what is called "Selection Value" they are merely useless characters.

The third difficulty is that natural selection, although a powerful cause of divergence between different species and genera, cannot by itself, initiate divergent evolution. This will come as a surprise to those who have learnt from the writings of Dr. Wallace that natural selection is the one great cause of divergence. Nevertheless it is true that natural selection cannot make one species divide into two, but actually prevents such a thing from coming about. Natural selection hinders variation except in that direction which is the one most profitable to the whole of the individuals; and, when the external conditions remain the same for a long time, it entirely destroys all new variations.

Darwin, when discussing the question of divergent evolution, says: "As has always been my practice, let us seek light on this head from our domestic productions." After stating that fanciers of pigeons choose different characters, he asks, "Can any analogous principle apply in nature?" and he answers, "I believe it can and does apply most efficiently, from the simple circumstance that the more diversified the descendants from any one species become in structure, constitution, and habits, by so much will they be the better enabled to seize on many diversified places in the polity of nature, and thus increase in numbers."[40]

But Mr. Darwin here forgets that the pigeon fancier not only selects his birds, but he isolates them from each other; while natural selection does not isolate a few individuals from others of the same group. In another place he truly says, "intercrossing plays a very important part in nature, by keeping individuals of the same species, or of the same variety, true and uniform in character;" and he evidently overlooked the fact that this will prevent a species branching off and occupying diversified

[40] "Origin of Species," 1st edition, p. 112.

places in the polity of nature, unless there is some means by which the different varieties become isolated from each other, and thus escape from the effects of intercrossing.

Mr. Darwin tacitly acknowledges the failure of natural selection to produce divergence in the case of insects inhabiting islands. After pointing out the dangers encountered by flying insects inhabiting small islands, he says: "When a new insect first arrived on the island, the tendency of natural selection to enlarge or to reduce the wings would depend on whether a greater number of individuals were saved by successfully battling with the winds, or by giving up the attempt and rarely or never flying."[41] Here he recognises that there would be no splitting-up into two varieties, but that only the commoner one would be preserved, although both were useful. Nevertheless this very case is given by Dr. Wallace as an example of divergence under the action of natural selection.[42]

Some years later Mr. Darwin saw this difficulty more clearly, for in a letter to Moritz Wagner, dated 13th October, 1876, he says: "I do not believe that one species will give birth to two or more new species so long as they are mingled together in the same district."[43] And on the 26th November, 1878, he thus wrote to Professor K. Semper: "There are two different classes of cases, as it appears to me, viz., those in which a species becomes slowly modi-

[41] "Origin of Species," 1st edition, p. 136.

[42] "Darwinism," 2nd edition, p. 105.

[43] "Life and Letters," vol. iii., p. 159.

fied in the same country, and those cases in which a species splits into two, or three, or more new species; and in the latter case I should think nearly perfect separation would greatly aid their 'Specification'—to coin a new word."[44]

Dr. Wallace, however, still thinks that natural selection can produce divergence; but all the illustrations he gives in his book on Darwinism either include isolation or they start with two or more different species, and so miss the point, which is that one species cannot give rise to two without the help of isolation. Also, when discussing the influence of natural selection on infertility he says that, "if two forms of a species freely intercross with each other and produce mongrel offspring which are quite fertile *inter se*, then the further differentiation of the forms into two distinct species will be retarded or perhaps entirely prevented."[45] So, to help him in his argument, he assumes that the mongrel offspring are not quite fertile *inter se*.

But if the two forms are thus liable to obliteration, how could they possibly have arisen? The partial sterility must have commenced before the two forms could have been produced, and therefore before there were any mongrels. In other words, certain individuals must have been more or less physiologically isolated from each other before the two forms could have come into existence. This supposed example of Dr. Wallace does not, therefore, explain the difficulty, which is the origination of

[44] "Life and Letters," vol. iii., p. 160.

[45] "Darwinism," 2nd edition, p. 174.

two forms from one, without the help of isolation.

As this is a very important point, it will be better to illustrate it further. Let us take the simple case of the first organisms, floating on the surface of the sea, and belonging to one species only. We must, however, suppose—what was not really the case—that they increased in numbers by conjugation and not by self-division; for, unless we make this supposition, we cannot reproduce the action of natural selection without the aid of isolation. There are reasons for thinking that the primeval ocean contained mineral hydro-carbons, which would slowly oxidise into carbo-hydrates, and thus furnish food for these first organisms.[46] But this supply of food was limited; and in time it would be necessary for some individuals to develop chlorophyll, so that they might obtain their supply of carbon from carbonic acid when the carbo-hydrates were consumed. Other individuals, however, would lead a more animal life and live upon their neighbours. But if free inter-crossing was maintained, these two types could not completely differentiate, for they would always be getting mixed up again, and the whole group of organisms would progress in that single direction which was, on the whole, the most advantageous for them. Evidently they could not become entirely animal, for they would then lose the power of obtaining food from the mineral substances around them; and they would not become entirely vegetable, because the power of digesting organic substances, either living or dead, would certainly

[46] See Chapter II., p. 27.

be advantageous, as also would be the power of moving about in quest of this food. So that, on the supposition that free inter-crossing took place, the original organisms could not have separated into plants and animals. Just as a river cannot branch on its way down its valley until the sea throws up a mud-bank at its mouth and forms a delta, so natural selection can only propel a species in one direction unless isolation steps in and divides it into smaller groups.

A fourth objection has been urged, that natural selection cannot explain the mutual sterility between individuals of different species. So far as our present experience goes, it seems that complete fertility between individuals of different species is rare, and that nearly all are absolutely infertile. No matter what the characters may be which distinguish the species—whether it be form or ornament, or mere colour—this infertility is almost always present; and of all the innumerable differences which separate species, it alone is constant, or nearly so.

Darwin has shown that sterility between species is not absolute, as had previously been supposed; and therefore it is not a fatal objection to the theory of the development of species. But, although he did this, he failed to give any satisfactory explanation of the facts; and he himself did not believe that infertility could have been caused directly by natural selection. He suggested that the changes in structure were necessarily followed by physiological changes; and, as neither the great structural changes which have taken place in domesticated animals, nor their exposure to greatly changed conditions of life—owing to man having taken them to different parts of the world—as neither of these things have produced infertility, Darwin had to add that, to bring it about, a very long time was required, together with exposure to uniform conditions. But these suggestions, which rest on no evidence, are quite insufficient to account for so important and so wide-spread a phenomenon; and they imply that all incipient species or varieties are quite fertile among themselves, a conclusion which Darwin himself says is not correct.

In the later editions of the "Origin of Species" he is still more explicit. He says: "After mature reflection it seems to me that this (sterility) could not have been effected through natural selection;" and, after giving some illustrations, he adds: "But it would be superfluous to discuss this question in detail; for with plants we have conclusive evidence that the sterility of crossed species must be due to some principle, quite independent of natural selection, and, from the laws governing the various grades of sterility being so uniform throughout the animal and vegetable kingdoms, we may infer that the cause, whatever it may be, is the same or nearly the same in all cases."[47]

Preferential Selection.—Under this name I include all those cases where selection is a voluntary act on the part of the selector. By its means

[47] "Origin of Species," 6th edition, p. 248. See also "Life and Letters," vol. iii., p. 80.

groups are formed by individual preference, due either to the mutual attraction or aversion felt by some individuals for others of the same species, or to several individuals adopting similar habits. Thus certain animals are selected to breed together without any detriment to the non-selected. Preferential selection is always for the good of the selector, but it may or may not be for the good of the selected. With animals it is confined to the choice of food or of mates, but with man it has a much more extended range; but I shall have more to say about this later on. This form of preferential selection is called personal selection by Prof. Mark Baldwin.

Mr. Darwin's division into natural and sexual selection has not given satisfaction, for a large part of what he included under sexual selection is truly natural selection; while many of his instances of natural selection do not answer to the definition. This has been the source of much confusion, and I hope that my new classification will help to make things clearer, and will distinguish between two actions which are quite different.

Preferential selection is not restricted to the single motive of utility, for we have now the love of pleasure, which we see in all the higher animals.

First as to utility. Recognition-marks are one of its results. Several objections have been made to this theory of Dr. Wallace, it being urged that all the individuals of a species recognise each other without any distinctive characters, and it is easy to carry the idea of recognition-marks too far. Indeed, if birds which pair for life—such as Pigeons, the

Carrion Crow, and the Australian Magpie—can find their mates without any marks recognisable by us, it is not easy to see why recognition-marks should exist at all. Still I believe that these marks exist, because we see them in the higher animals only. The lower animals and plants, in which intelligence is absent or of a very low order, have not the same variety of colour-patterns as we see in the higher animals.

Change in habit is largely due to preference for a certain food. After the choice is made, natural selection comes into play. For instance :—a certain flower secretes more nectar than usual, and a bee prefers it to other flowers, and frequently returns, guided by colour, shape, or scent. Natural selection now begins; for as the visits of the bee are beneficial to both animal and plant, both get more and more adapted to each other. But it is evident that the first steps of a beneficial variation may be fostered and accumulated by preferential selection until the variation is of sufficient importance to be exploited by natural selection.

The structural growths which in many flowers necessitate the visits of special kinds of insects or birds to fertilise them, are also probably due to preferential selection, for it is very doubtful whether they are useful to the plants. No doubt the secretion of honey, the bright corolla, as well as all the devices by which plants prevent the visits of non-flying insects, or by which they entrap small flies, are due to the action of natural selection, for all of them are useful to the plant. But it cannot be of any importance to a plant that it should be visited only by a particular species of humble bee, or that it should be fertilised at night and not in the day; and we know that those plants which have the most elaborate apparatus for securing cross-fertilisation by certain insects are uniformly rare; and have not therefore been a success from their own point of view. Also, if it be good for a plant to have its flowers fertilised by pollen from some other plant, then it is evident that the grouping of flowers into heads or spikes must be injurious, because it almost insures that the flower shall be fertilised by pollen from other flowers of the same inflorescence; which Darwin says does little or no good; and yet capitate flowers are abundant.

Indeed, some of the variations which have taken place are decidedly injurious to the plant, such as the reduction of stigmatic surface in the Orchids, the abortion of one half of each anther in Salvia, and the asexual condition of the ray-florets in some of the *Compositæ*, and in the outer florets of the Guelder Rose. As a matter of fact, we find that in some cases these metamorphosed flowers are not sufficient to preserve the species from destruction, and they have been supplemented by others which have special means for self-fertilisation. If cross-fertilisation were all that is wanted, the simple device of dichogamy—that is the maturing of different parts of a flower at different times—would have answered every purpose.

But it is evident that capitate flowers are useful to the insects which visit them; for that arrangement enables the insects to collect a large quantity of honey, or pollen, with the least amount of trouble. And it is also evident that it is very advantageous to a humble bee to have a number of flowers in which the honey is so locked up that only she or her friends can extract it; and we may reasonably suppose that insects, finding honey sweet, began unconsciously to cultivate the plants. If a bee found that certain blue flowers always had more honey in them than yellow or white ones, she would certainly visit the blue flowers first. She would not know why there was more honey in the blue flowers. She would never think that it was due to the difficulty other insects found in extracting it, but she would always visit them and expect a feast. We may readily suppose that each particular bee had her favourite plants which grew in the neighbourhood, and, as she would constantly visit them in preference to others, it is easy to see how they might become isolated. In this way humble bees have caused long nectaries to grow and the lips of the snap-dragon to shut; while moths have caused some flowers to keep closed all day and so reserve their honey; and others, to give out scent only at night.

The great number and abundance of plants whose inconspicuous gamopetalous flowers show that they were formerly visited by insects, although now fertilised by other means, is a sufficient proof that they have suffered no harm by the cessation of insect visits. They are the abandoned ones, thrown on one side when a better class of goods offered; but they have not died out, nor even suffered any loss. Many botanists think that these flowers have retrograded since they were abandoned by insects; but there seems no reason why they should retrograde, and it is at least possible that some of them remain as they were, and simply mark the stages through which the more advanced flowers have passed.

By these means the most complicated flowers can be explained; for every modification which is useful to the plant is due to natural selection, and every modification which is useful to the insect visitors is due to preferential selection.

In fact, plants suffer from the preferential selection of animals, and they are defended by natural selection. In some cases plants have thus turned defeat into victory, and by means of the attacking animals have secured the dispersal of their seeds, or the fertilisation of their flowers, or have gone so far as to kill and eat their enemies. Indeed the two processes of preferential and natural selection, when the motive is utility, are generally intimately combined. But it is seldom difficult to distinguish one process from the other; for the first is marked by the exercise of choice and the unselected do not suffer.

Taking next the motive of pleasure, we see that it includes the greater part of Darwin's sexual selection. But in some cases it extends beyond the bodily appetites, and we find a real love of beauty developed, especially in birds. Indeed, so far has this preferential selection been carried, as sometimes to come in conflict with natural selection. For the long tail feathers and plumes of many birds must be detrimental to them and impede their movements. Here again we see that natural selection is not all-powerful. The song of birds, apart from their calls, is also due to the love of pleasure. Several of the forest birds of New Zealand sing softly to themselves, and it is necessary to be very near to hear them. This is, probably, the primitive style of bird melody, and the loud-throated thrush and sky-lark came later. All these songs are the result of pure enjoyment; there is nothing useful in them, so that they cannot be due to natural selection.

Preferential selection is entirely a mental action, and has been the cause of much modification. It may be that the absence of this motive in the vegetable kingdom is the reason why its genealogical tree is so much more simple than that of the animal kingdom.

CHAPTER IX

ISOLATION

Everyone is agreed that unless varieties are isolated they will be in great danger of perishing through free intercrossing with individuals which do not possess the variation. There may be cases in which the prepotency of an animal or plant secures for a time the transmission of a variation, but this must be exceptional. For it is very unlikely that prepotency and the occurrence of a favourable variation should often occur together.

Two processes are necessary for a variation to succeed; preservation and accumulation. Selection does both; but isolation, pure and simple, includes no cumulative principle. And yet there are many characters which we cannot explain by selection; and in all of these we must, for the present, assume that the cause of accumulation is definite variation.

Useless Characters.—These are characters which are thought to be of no particular use to their possessors, neither have they ever been of any use to ancestors of the present possesssors. Consequently they could not have been preserved by selection. It is highly probable that we call some characters useless through ignorance, and that a better acquaintance with the habits of the animals or plants would show us their uses. Still, making every allowance for this, we cannot suppose that many of the trivial characters which distinguish different species can be of any special use to them. Let anyone examine a series of species, belonging to one genus, of insects or of birds, or any other kind of animal, and let him note the minute differences which divide them—some by one character only, some by several—and he will, I think, be convinced that most of them cannot be called useful.

I have already, in the last chapter, given a good many examples of what appear to be useless characters; but as this is a very important subject, involving large issues, and is strongly contested, I make no apology for dilating a little more on it. I will take the group of petrels (*Tubinares*), and see what characters can be accounted for by selection. I choose this group, because the habits and surrounding conditions of sea-birds are so much more simple than those which live on the land, that we can speak more confidently about them. Evidently the long wings and webbed feet are adaptations; but we do not yet know the use of the tube into which the nostrils are produced; for the birds hunt by sight. The distinctive characters of the different families are the shape of the sternum and of the bones of the shoulder-girdle; the position and shape of the nasal-tubes; the absence or presence of lamellæ on the sides of the palate; and the relative lengths of the first and second feathers of the wing. We cannot, at present, suggest a use for any one of these characters except the lamellæ on the palate, which, no doubt, are useful by retaining in the mouth the small animals which they catch. The points which separate the genera are chiefly the relative lengths of the bones of the wing, leg, and toes; and the shape of the bill and nasal tubes. These may possibly be of some special use to the different animals, although we cannot explain them. The specific characters are, principally, size and the colours of the feathers, none of which have any particular use. Take the largest genus, *Œstrelata*. Here we find that four or five species are entirely dark brown, while the rest are white below and brown or grey above. Some have the head white, others dark. In some the upper tail-coverts, or the under-wing-coverts are dark, in others they are white; and there are still smaller differences. These colours cannot be specially useful to each species, for all hunt together for food on the ocean, and all have very similar habits. Neither can they be recognition marks; for the birds do not recognise each other at sea, but fly singly. Indeed, one of the characters which divide the species is the colour of the lower surface of the primary feathers of the wing, which cannot be seen unless the feathers are separated. At the breeding season each species retires to its nesting-place before courtship begins, and so recognition marks cannot be necessary.

There are also theoretical reasons for supposing that, if a variation arises in a small group of individuals isolated from the rest of their species, the variation is more likely to be preserved than if the number of the individuals was large. Even Dr. Wallace allows that under these circumstances characters which are neither advantageous nor disadvantageous will be retained. But he says that they will be variable and not available for specific distinctions. All specific distinction must be constant, and, he thinks, useful. If this is correct it would follow that no two species can have the same environment, for each has some character specially useful to that species only. If they live together, under the same physical conditions, they must, therefore, have different habits. And the characters by which the different species are distinguished must be related to their environment and be advantageous to each. Any change of a character possessed by one species into that possessed by another would be detrimental, unless it was accompanied by a change in the environment. Let us try to test this by an appeal to facts.

It is almost impossible for us to observe plants and animals so closely all through life, as to enable us to say with certainty that any particular character is of no use. But we can make inferences, and, certainly, we should not assume that because many characters are useful, therefore all are so.

For example, many insects have well-developed wings, yet they never use them; and there are also many others in which the wings are either rudimentary or absent. In these cases we do not hesitate to say that the useless wings were useful to former generations. Again, there are other organs which appear to have no use but show no degeneration. Of such are the pincers of ear-wigs, of which Dr. Sharp, whose knowledge of insects is unrivalled, says: "They are occasionally used by the insects as a means of completing the process of packing up the wings; but in many species it is not probable that they can be used for such purpose, because their great size and peculiarly distorted forms render them unsuitable for assisting in a delicate process of arrangement; they are, too, always present in the wingless form of the family."[48] Still we must presume that these pincers have some use, although we do not know what it is; for they are so well developed and never rudimentary. It is the same with the remarkable modifications in the antennæ of beetles and flies. We cannot help thinking that all the different forms have different uses, although we cannot detect them.

But the case is different with the insignificant characters which I have already mentioned, such as the folding of the enamel in the teeth of elephants. And we are confirmed in this opinion because no advantage has been gained by different foldings. Take now the case of the hairs on the eyes of some Diptera. Of the two common blue-bottle flies in New Zealand, one has the eyes hairy and the other has them naked. Both species frequent the same localities, both appear to have the same habits, and both are equally common. Now by the principle of natural selection these hairy eyes cannot be useful, or the species that has them would prepon-

[48]*Cambridge Nat. Hist. Insects*, Part I., p. 208.

derate over the other. Neither can they be disadvantageous, for their owners are very abundant. These hairs, therefore, must be indifferent, and could not have been developed by natural selection.

Now as to the variability of useless characters.

In the vertebrates it is often difficult to feel sure that apparently useless characters may not be recognition marks of ancestors. So I will take the venation of the wing in the Diptera as an example. Here we find in the numbers and branchings of the veins some of the characters which separate the families, genera, and sometimes even the species. These are excellent characters from the systematist's point of view, for they are remarkably constant; and yet we cannot explain them by the principle of utility. For one kind of branching does not seem to be more useful than another. In this respect the wings of the Diptera are quite different from those of birds, in which we easily recognise a connection between shape and use. We may find a character in a fly's wing which we think to be of some special use, such as the strengthening of the posterior margin in the Syrphidae, but we find that the house-fly manages equally well without it. Or if we point to the upward bend of the fourth longitudinal vein in the house-fly as strengthening the tip of the wing, we find that this is absent in the very common *Muscina*, which seems to fly quite as well as the others. Again, so constant and yet so varied is the venation that we can construct a tolerably accurate genealogical tree of the Diptera by its means. We can thus trace out an improvement from the primitive Psychodidæ to the more recent, but still very ancient, Tipulidæ and Bibionidæ. But after the Bibionidæ we seen no sign of improvement. No doubt the later forms, such as the Syrphidæ and the Muscidæ (restricted) are stronger flyers than the earlier Empidæ and Therevidæ, but this seems to depend more on the development of the muscles than on the branching of the veins. This branching looks like the result of accident or chance; but each change must have been caused by some agent, either external or internal.

If it is thought that even in the Diptera we must suppose the existence of recognition-marks, we will go to plants and thus eliminate all kinds of preferential selection. If the reader will take a descriptive flora of any country and select any moderately large genus, and then examine the characters which distinguish the species, I feel sure that he will come to the conclusion that a large proportion of these characters are not specially useful; that is, one is not more useful than another. And if this is so, these characters could not have been formed by natural selection. But these are the very characters relied upon by botanists for separating the species, and they have been chosen because they are the most constant that can be found.

Next, as to no two species having the same environment. The lower marine organisms, which float on the sea, such as the Radiolarians, and the Foraminifera, are known to be very variable. But the Medusæ, the Ctenophora, the Heteropoda, and the

Pteropoda, all floating forms with remarkably simple surroundings, are, I believe, as constant in their characters as other animals. But if examples from the higher animals are thought to be necessary, I would instance the Gannets, some of which are white, while others are brown, yet both live together in the same localities and have the same habits. It is the same with the Terns, Albatrosses, and other sea-birds. The colours here must be useless characters, and yet they are constant. The environment of land animals and plants is so much more complex than that of marine animals that we cannot feel sure that those which live together have the same habits; but if Dr. Wallace's statement breaks down with the marine animals, it is sufficient.

These so-called useless variations we suppose to have been accumulated by definite variation, and preserved by isolation, without any help from selection.

Definite positions of organic stability.—A question which is being much discussed at the present time is whether variations, after making a certain amount of progress, slowly or rapidly, do not then remain stationary. That is, is progress intermittent?

It seems probable that many of the variations which formerly took place are now stationary; but some are, certainly, still in progress. If the stationary characters are useful, it is easy to account for the stability by natural selection, because, if the external conditions remain constant, the useful characters will not change. Natural selection is not necessarily a progressive principle; it only forces organisms to become as perfectly adapted as possible to the conditions, and then keeps them there. The only difficulty is with the useless characters just mentioned. But here also the difficulty is not so formidable as it looks. Most of these changes are colour changes, and these necessarily have a limit. The change of a red corolla into a blue one need not take long, and the change ends. Useless changes in the size or shape of an organ are probably limited by natural selection, for they might easily become disadvantageous. Such is the case with the hind claw of the sky-lark, which has grown long and straight simply because the bird has given up perching on trees. The horns in male beetles are also limited from the same cause. The sculpture on the elytra of Coleoptera and Hemiptera seems to be a difficulty, for further elaborations would not be disadvantageous; and yet these characters are as constant as others. Many other difficulties could be cited, and I think that this is a question on which no definite opinion can as yet be given.

Physical Isolation.—Since the publication of Moritz Wagner's paper "On the Law of the Migration of Organisms,"[49] geographical isolation is so well known that it is quite unnecessary for me to explain it. I will, instead, illustrate it with examples from New Zealand.

The crow (*Glaucopis*) of the North Island has its wattles coloured blue, while those of the South

[49]English trans. published by E. Stanford, London, 1873.

Island are half blue and half orange. The southern tits (*Myiomoira*) have a yellow breast, and those in the North Island a white one. The thrushes (*Turnagra*) and robins (*Miro*) also differ in the two islands. We cannot suppose that these different species formerly inhabited different districts, when the two islands were united, that is, before Cook's Strait was formed; because part of the South Island lies to the north of part of the North Island, and if the two islands were again united the birds of Nelson and Wellington would certainly mix together. Some of these species must evidently have been formed since the islands were separated, and cannot be due to external conditions. If we turn our attention to the Chatham Islands we find that the bell-bird (*Anthornis*), the fern-bird (*Sphenæacus*), the warbler (*Pseudogerygone*), and the pigeon (*Hemiphaga*), all differ from their relations in New Zealand. It is unnecessary to discuss all these cases, but I will take the Chatham Island pigeon as an example. It differs from that of New Zealand in having the lower part of the back and the outer wing-coverts grey instead of purple. We have no reason to suppose that these colours are in any way related to the environment. We have no reason to suppose that the Chatham Island bird could not live equally well in New Zealand, or that the New Zealand pigeon would be under any disadvantage in the Chatham Islands. Consequently, we have no reason for thinking that these differences of plumage are of any special use to the birds, or that they could have been produced by natural selection; and the

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only explanation appears to be that physical isolation has preserved fortuitous variations which arose subsequently to the isolation.

Again, New Zealand and its neighbouring islands possess more cormorants than any other part of the world. The whole of America, north and south, has twelve species; there are seven in Asia; six in Africa; five in Australia; only three in Europe; and fifteen in New Zealand. Now the difference in the external conditions cannot be so great in the New Zealand seas as throughout America, from Canada to Tierra del Fuego; or as in Asia and Africa taken together. Consequently we cannot suppose that the specific characters have been induced by external conditions. This is emphasised by the fact that one species—P. Carbo—extends from Greenland through Asia-minor and India to Australia and New Zealand. The Australian birds of this species never have so many white feathers on the head and neck as have the birds in Europe, and they probably represent an earlier form; but no change has been made by the external conditions.

The real cause of the great number of species in New Zealand and its islands is that these islands lie at considerable distances from each other, and were formed long ago, in the Pliocene period; so that they are older than most of the islands surrounding the continents. Thus the New Zealand cormorants have been isolated for a very long period and have had time to vary.

We can divide them into two groups; one having the legs and feet black, the other having them pale pink or orange. Of the first group three species—P. carbo, P. sulcirostris, and P. melanoleucus—are also found in Australia; and the fourth—P. varius—is closely allied to an Australian species. The fifth—P. sulcirostris—has been developed in New Zealand. The second group consists of ten species, all of which are confined to New Zealand and its islands, but have relations in Antarctic countries.

P. brevirostris is a very variable species, incapable at present of breeding truly; while P. melanoleucus, from which it has been derived, is not variable. P. brevirostris is acquiring a black breast and abdomen; but, although the young are black, the adults often get white on the abdomen, like P. melanoleucus. Evidently this change to black is not a recognition mark, for the birds often lose it when they approach the breeding age. Neither can the black abdomen be taken to be a useful character. Cormorants have no enemies in New Zealand, so it cannot be defensive, and black cannot be better than white for fishing, for most of the cormorants have white abdomens. That the young should be black and not the adult is perhaps due to reversion to P. pygmæus, of the Mediterranean and Central Asia, from which P. melanoleucus is probably derived.

Of the second group, two—P. punctatus and P. featherstoni—have orange legs and a double crest. One inhabits New Zealand, the other the Chatham Islands. The remaining eight species have pale pink legs, and the crest is either single or absent. They may be divided into a carunculated section—containing P. carunculatus in New Zealand, P. onslowi in the Chatham Islands, and P. traversi in Macquarie Island—and a section in which the skin between the eyes and the mouth is smooth. This section contains P. chalconotus from New Zealand and Stewart Island, P. campbelli from Campbell and Auckland Island, P. colensoi from Auckland Islands, and P. ranfurlyi from the Bounties.

In P. caruncalatus the naked skin of the lores is at first smooth and then becomes caruncalated, from which we may infer that the caruncalated section is descended from the non-caruncalated. Again, several of the species have a white bar on the wing-coverts and another across the lower back, which do not appear until the birds are mature; consequently we may assume that the species with these white bars are descended from those without them. All the caruncalated species have these white bars, which is confirmatory evidence of their having descended from the non-caruncalated section.

Of the non-caruncalated species, P. stewarti is the only one in which both white bars are present, so that we can look upon it as the connecting link between the two sections. P. ranfurlyi has an alar bar, but shews only vestiges of the dorsal bar, so that it must also be a descendant of the P. stewarti. P. chalconotus is only a black variety of P. stewarti, and sometimes has white feathers on its breast and abdomen. In P. colensoi and P. campbelli there is an alar bar but no dorsal one, and the alar bar is very narrow in P. campbelli. In P. campbelli, also, the throat only is white and the neck is dark; while in the adult P. colensoi both the throat and the fore part of the neck are white. Finally the young of P. colensoi have the neck dark as in P. campbelli. So that we arrive at the conclusion that P. campbelli is the progenitor of P. colensoi.

Here we see one species changing its white abdomen for a black one; another changing a black abdomen into white. One species acquires a white bar on its neck, another loses it. P. carunculatus has lost the crest on its head which its ancestors certainly wore; while several have changed the colours of the skin between the eyes and the mouth. These changes cannot be due to the action of external conditions, and we cannot suppose that they are due to utility, for the conditions under which the birds live are remarkably similar.

In the Auckland Islands we see the evolution of a new species going on. The parent form, P. campbelli, is rare, and confined, I believe, to the south part of the island; while P. colensoi is extremely abundant. There seems to be no need for recognition marks either with P. colensoi or P. brevirostris. In both cases the new variation is simply swamping the older form.

Some of the specific characters, such as the crests, the bright colours of the skin on the face, and possibly the colouring of the feet, are decorative, and probably due to preferential selection; while other marks, or loss of marks, are due to reversion. However, the idea of preferential selection does not altogether satisfy me; for why should a preference for the same character be shewn by successive generations? There seems to be nothing to make individual choice continue in the same direction, and without this the new variation would not progress. Definite variation seems to be the only solution of the difficulty. New characters certainly arise in some way, and they are preserved by isolation.

There are other interesting facts about these cormorants which ought not to be passed over. All of them are well adapted for catching fish with their long hooked bill, and they swim and dive by means of their broadly webbed feet, never opening their wings under water. But when we come to examine the differences which divide the sub-genera, it is difficult to suggest any utilitarian origin for them. For example, most of the cormorants have twelve feathers in their tail, and it might be thought that so constant a character must, in some way, be useful and due to natural selection. But a few have constantly fourteen feathers in the tail, and so the idea of twelve being of special importance breaks down. The bills also are much stouter in some than in others, and this character cannot be correlated with any difference in food.

I need not press the subject any further. It must, I think, be allowed that a large number of characters are not useful, and cannot have been preserved by natural selection.

Physiological Isolation.—This is when certain individuals of a species are prevented from intercrossing with other individuals by physiological causes, although they freely mix together during the breeding season. The simplest form of it is found in the lowest plants and animals which have no sex, but increase their numbers by self-division. This insures that each individual is isolated from all others, and consequently any variation that may arise will be preserved, unless it is harmful to the individual or is counteracted by reversion. To this, no doubt, we owe the original separation of plants from animals; as the variations which gave rise to this separation were useful, they would be taken in hand by natural selection, and so would become progressive. We may also find in asexual reproduction the cause of the immense variety seen among Diatoms, Fungi, Radiolarians, and Foraminifera. These variations, some of which are the very earliest recorded in the rocks, were non-utilitarian and never progressed far, probably because further progress in any direction would have been harmful.

Self-fertilisation is nearly as efficient a cause, but a cross may occasionally occur. Ferns, and many other plants, as well as some animals, are thus isolated and are able to preserve indifferent variations. A few years ago Count Berg Sagnitz made a large number of observations, with the express purpose of testing the truth of this deduction; and he found that self-fertilised plants really have more constant varieties than species which are cross-fertilised.

The prepotency of some pollen grains over others in the fertilisation of flowers is another cause of physiological isolation. And in animals, when an individual of either sex shews great power in transmitting its special characters, it also is said to be prepotent, although the two cases are not quite alike. This prepotency in domesticated animals is usually due to inter-breeding, but sometimes a new variation may be prepotent over the old type from which it has but recently arisen. This may account for the two new species of cormorants, which I have just mentioned, swamping the older forms.

But the most important cause of physiological isolation is change in the time of the maturation of the reproductive cells. These are sometimes accelerated, sometimes retarded, so that all the individual members of a species cannot breed at the same time. This I believe to be a very common cause of isolation in both plants and animals; and I think that it has been the chief cause of species splitting up into two or more. Its action is evident, so I will give an example of a mixed case, in which physiological isolation has led to physical isolation.

In the southern seas no two species of Albatross breed in the same locality. Even when two different kinds are found on the same island—as D. exulans and D. regia on Adams Island, one of the Auckland group—they occupy widely separated sites; and they all breed at different times. So far as I know, D. cauta, of the Bounty Islands, is the first to commence to breed, at the end of August. D. melanophrys, at Campbell Island, comes next, in the middle of September. D. regia, at Campbell Island, commences in the middle of November. D. chionoptera, at Kerguelen, at the middle or end of December. D. exulans the first week in January at Adam's Island, and the middle of January at Antipodes Island. And last comes D. culminatus, on the Snares, at the end of January. So that there is no less than five months difference between first and last.

As these birds all live on the same kind of food, and all have the same simple habits when they are at sea, we cannot suppose that their distinctive specific characters are due to natural selection: for that which would favour one would favour all. Neither can we suppose that they are due to the action of external conditions, because what would affect one would affect all. Neither can we suppose them to be recognition-marks, for when the breeding time is drawing near each bird goes separately to its old nest before courtship begins. It cannot, therefore, be that the species of southern Albatrosses were formed by competition on the ocean, and subsequently chose separate breeding grounds. We must believe that isolation preceded the development of the specific characters. Now it is not difficult to imagine that those birds in which the breeding impulse came on first would retire to their breeding ground and there mate. Those in which the impulse was delayed might find the old breeding ground fully occupied and would have to choose another. Thus owing to physiological difference, physical isolation would be brought about.

It is evident that in an equable climate, where the exact time of breeding is not important, many variations could thus be preserved; while in more rigorous climates, where the breeding season must be short, this kind of physiological isolation could not take place. And we may perhaps in this way account for the great number of species in tropical countries, especially on islands, where the climatic conditions are equable, as contrasted with the enormous numbers of individuals, belonging to very few species, in temperate regions with continental climates.

CHAPTER X

SUMMARY OF CHAPTERS VI TO IX

We have seen how regular and automatic are the ordinary processes of growth and reproduction. This regular sequence we call heredity, and, to the best of my judgment, Professor Hering's theory of unconscious memory is the only one which offers us an adequate explanation. It is not a complete explanation, because we do not know what mind is, and how it works; but it is a great simplification of the phenomena, and perhaps represents the limits of possible knowledge in that direction.

There is evidence that mind exists in every living cell, not only in animals but even in plants; and where there is mind we presume that there must be the capacity for memory. We have evidence that habits, which are due to unconscious memory, can be transmitted from one generation to another, and so become instincts; and we cannot draw a line between recognised instincts and development. We must, it seems to me, allow that every cell has a store-house of memories, and that it moves by instinct.[50]

[50]Prof. H. W. Conn says in his "Method of Evolution." "Consciousness thus becomes an indirect factor in evolution. Indeed the attempt is sometimes made to extend this

Fission and amphimixis may both be true causes of variation, but they are of minor importance. They may ring changes on the old characters but they cannot introduce anything new. Use and physiogenesis are also true causes, and their action on the germ-cells is explained by Hering's theory; but they are far from being sufficient to account for all variations, and we must call in the aid of psychogenesis to explain a very large number of facts. The organic units, biophores, plastidules—whatever we may call them—are drafted off by mental action, and, when they grow, they develop as memory compels them to do. Variations directly produced by outside physical agencies are rarely transmitted; it is chiefly the so-called indirectly-acquired variations which are transmitted. But indirect variation is only another name for adaptation. These cannot be due directly to the environment. They are helped forward by natural selection, but they are initiated by psychogenesis.

The variations that arise are partly definite and partly indefinite. The indefinite variations may be due to fission, amphimixis, or to physiogenesis, when the action is irregular. Definite variation is caused by use, by psychogenesis, or by physiogenesis, when the action is regular and long continued; and per-

principle of consciousness to all organic life, and to find even among the lower plants something which corresponds to it. Such an expansion of consciousness to all organic life is, however, too crude and unintelligible to take its place in our general conception of nature." He does not, however, explain why this view is crude or even unintelligible.

haps by germinal selection. These variations are generally small and continuous, but occasionally they take sudden leaps, and then appear to remain fixed. To what this is due we do not know in every case, but the difficulty is not an important one. Variations are preserved by selection or by isolation, and are accumulated either by selection or by definite variation.

It is natural selection, working with other forms of isolation, which has brought about the main progress of life. It gives a directive or determinate impulse to living organisms, and by its means life has advanced from the lowest Protozoa up to man. But, together with the progressive, or determinate evolution, a large amount of indeterminate or indefinite evolution has been going on, and this has been the result of isolation working alone. We may liken the progress of organic evolution to the march of an army, which is continually throwing off numerous scouting parties, who penetrate into every nook and cranny and leave nothing unexplored. The few which find roads lead off part of the army after them; while the majority who fail to do so perish on their tracks and are heard of no more. Natural selection preserves and intensifies adaptations, or utilitarian characters only; isolation preserves both utilitarian and non-utilitarian characters. Progress is due to the former, variety to the latter.

Now we rarely see a useful character which is not shared by many species, and consequently is of generic or even of higher value; while a very large number of specific characters are non-utilitarian.

If we examine any large order of animals—that is one containing many species—we shall find that the ordinal characters, and those of the families into which it is divided, are of utilitarian value. But when we come to the smaller groups the case will be different. A large proportion of the genera and almost all the species will be distinguished by characters which, so far as we can see, are non-utilitarian, and could not therefore have been developed by natural selection. So it appears after all, that natural selection is not so much a theory of the origin of species from varieties as one of the origin of genera and the higher groups from species. Natural selection picks, as it were, here and there one species out of many and makes it the founder of a family. The rest—the vast majority—"have their day and cease to be." They vanish altogether from the board, without leaving any descendants behind them, although some linger longer than others.

It is then to natural selection that we owe progress, and it is chiefly to isolation that we owe variety. Without isolation all organic beings would have been nearly uniform, and all would have belonged to a single type, which would be the one best fitted for getting food and for propagating its race: a half-animal, half-vegetable, and a ruthless cannibal. This unhappy result was prevented by the first organisms being sexless, so that there was no inter-crossing, but each could develop independently. It is useful to contemplate what might have been, for we can then realise what the principle of isolation has saved us from, and we can the more readily recognise what an important part it has played in nature.

I have tried to shew that, while the characters developed by natural selection are utilitarian only—that is, they are of use to the creature possessing them—those due to isolation are for the most part non-utilitarian. Now we may at once grant that these latter characters are not, and never have been, of any use to their possessors. But are they of no use at all in the scheme of nature? Would man have been the same now, if these non-utilitarian characters had never existed? Certainly not. It is the variety in nature that has excited man's curiosity, urged on his thirst for knowledge, and so induced him to study natural phenomena; while contemplation of the beauty seen in nature has stimulated his sluggish soul, and has developed his æsthetic and religious faculties.

Natural selection has, no doubt, developed that part of man's intellect which makes him cunning in devising means to ensnare his prey, and to get the better of his fellow man. But this, after all, is the form of intellect which man shares with beasts; while the intellectual and spiritual qualities, which specially distinguish him, have not been called forth by natural selection. These are largely the result of contemplating the variety and beauty in nature; and, if natural selection has played an important part in gradually developing the body and mind of man, isolation has indirectly played a no less important part in developing his higher intellectual and spiritual faculties, and in teaching him to reverence and adore the Almighty Designer and Creator of all we see around us.

We are quite accustomed now to the idea that every structure in a plant or in an animal has a special object; else it would not be there. But it is generally supposed that that object must be a useful one to its possessor, for that is the teaching of natural selection. Now, why should we limit ourselves to so narrow a view? We know that many structures exist which are not, and never have been, of use to their owner. Is it therefore necessary to believe that they are of no use at all? If we allow that the ultimate object of organic evolution is the development of man, not only physically, but also mentally and morally, I do not see how we can escape from the conclusion that all these so-called useless structures, all that give us beauty and variety, have been specially designed for his education.

Three hundred years ago geologists argued that fossils could not have been either simple freaks of nature, or the outcome of fermentation in the rocks —as had been previously supposed—because that would imply that the Creator had laid traps for man's intelligence and had caused him to use his intellect for the purpose of leading him astray. Thirty years ago the same line of argument was used by zoologists, with reference to degenerate organs, and to the singular vagaries seen during the development of animals. It was urged that there must be some reason for these things, and that that reason could not have been to deceive man. In both cases the argument has been allowed; and why should it be disallowed in the present case? If beauty and variety *have* been a fruitful cause in the development of the special human characteristics: if they *have* been largely instrumental in making him a being "of wise discourse, looking before and after," and if —so far as we know—they have been of no other use, why should we refuse to believe that that was the primary object for which they were designed? The only alternative is that man's higher development has been due to a lucky chance, and evolution has no meaning. This is a question to which I shall return presently.

CHAPTER XI

PSYCHOLOGICAL EVOLUTION

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.[51]

However, I cannot convince myself that this is a true picture of the improving savage. It seems to me more probable that the moral sense was originated and developed by a primitive method of tabu. The priest, who was at first a magician or medicine-man, enforced restraint on others by punishment. The first offences against the tribe were probably cowardice and treachery. Then came murder, theft, and adultery. Others followed, and a constant enforcement of restraint gradually led up to a habit of self-restraint. Professor Rolleston has objected to this view that the priest could possibly have distinguished right from wrong. He says: "How could the old men praise or condemn, except by reference to some pre-existing standard of right and wrong.[52] However, I cannot see the force of this

[51]"Descent of Man," 2nd edition, p. 112.

[52]Quoted in Mivart's "Lessons from Nature," p. 101. from "The Academy" of November 15th, 1870.

objection, for it seems to me that the idea which would move his actions is: What is good for the medicine-man must be good, or must be thought to be good, for everyone else.

We see among the Polynesians and Melanesians the institution of tabu gone rather mad. But yet the morals of these races, at the time of Captain Cook's visit, must have been due to tabu; for they had no religion that was of any practical importance. But, however this may be, the fact that the code of morals differs somewhat in different nations shews that these codes are of human origin.

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 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 are 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 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.

The growth of Natural Philisophy.—Next, as to the intellectual development of man. 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 out-distanced 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 more to be 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. And we know that, probably in the latter half of the palæolithic period, and certainly in the neolithic, men were buried with their weapons, evidently as a provision for a future existence.

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 Müller 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 re-action 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 forward 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, 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 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.

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 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 ingenious but unsatisfactory speculations of Mr. Arthur J. Balfour.

CHAPTER XII

MENTAL PROCESSES

If the lowest plants and animals possess mind, and if psychogenesis is a fact, then psychological and biological evolution must have commenced together. And unquestionably they are closely connected. Nevertheless there is a distinction. Biological evolution is the action of mind on protoplasm, psychological evolution is the action of mind on itself. And although the latter has its roots in animal life, still it plays so much more important a part in human affairs than in biology that it has always been kept distinct.

Psychology, like every other branch of science, may be divided into two parts: principles and history. The latter is an enormous subject which no one man could undertake, even if he gave his whole life to it. But the principles are more compact, and, as the facts on which they rest are familiar to all, they can be put into a small compass. These principles, so far as they relate to the evolution of mind, are very similar to those which relate to the evolution of protoplasm, and it is necessary to have a clear conception of the latter before proceeding to the more difficult subject of mind.

The mental development of animals has been ably treated by various authors, both biologists and psychologists, and the principal points involved are well known. But these writers have generally ignored the ancient problem of free-will, although it is of the greatest importance to us in forming our opinion on natural philosophy. To discuss this question satisfactorily it is necessary to review, in however cursory a manner, the main features of mental development. And this is the only excuse I can give for my temerity in touching a subject on which I feel my ignorance. But I trust that I may be able to throw, from the biological side, a little light on this very confused heap of opinion.

The origin of mental variations.—Every man is endowed at birth with a set of mental characteristics, or instincts, which we call his personality. As he gets older his personality gradually alters, through the influence of the new ideas which he acquires. The simple ideas which arise from sensations derived from the outside, are the chief cause of these changes. The sensations, or perceptions, excite the mind through the medium of motives, or feelings, and thus different mental states, or emotions, are brought about. The principal motives are: (1) Self-preservation; which consists of the two feelings hunger and fear. The former gives rise to industry and pugnacity; the latter to prudence and deceitfulness. (2) Pleasure; which divides into two branches: Sensuality, or the gratification of the bodily appetites; and amusement, by which we try to appease the activity of the brain without giving ourselves too much trouble. (3) Sympathy; from which spring affection, generosity, benevolence, and the greater part of our duty to man. (4) Admiration; or love of the beautiful; from which come reverence and religion. We admire a thing and try to imitate it, or to express the delight it gives us; and this gave rise to poetry and the fine arts. (5) Curiosity; the source of wonder. We wonder at a thing and try to understand it; and this is the foundation of our love of truth, which has developed into philosophy and pure science.

By means of the faculty of reason we co-ordinate these motives, control the emotions, and so prevent ourselves from taking one-sided or exaggerated views. Two or more simple ideas are compared, a compound idea arises, and a judgment or wish is formed. For this memory is necessary. These wishes lead to actions, the strongest motive prevailing. Actions are thus partly due to inherited instincts, and partly to the new ideas which have accumulated in the brain since birth. These mental processes are found both in animals and in man.

But man has the further power of forming abstract ideas, or concepts, for which it appears self-consciousness is necessary; and language is necessary to reduce them to order (as we must name the concepts before we can compare them). These processes have largely developed the imagination, that is, the faculty of bringing before the mind ideal pictures of different things. Imagination has given us two additional methods by which new ideas originate: (1) by intuition, that is, the formation of original ideas not due to experience; and (2) by forming new combinations of old ideas and experiences. Intuition, however, is rare and is denied by some psychologists.

By the power of imagination, also, we can stimulate any of the motives. By introspection, or examining our feelings on a subject, we can wish for a thing or wish to avoid it; and so we can throw the strength of the will on one side or the other. Thus again we form judgements of a still higher kind than the last, judgements into which our own intrinsic wishes or desires are taken into consideration. And thus we get free-will, by which man has the power of acting as he wishes, and does not move like an automaton. This, however, is disputed by a large number of scientific men, and I will discuss the subject more fully in the next chapter.

Now in mental evolution new ideas correspond to variations in biological evolution. They are mental variations; and just as bodily variations are due to two causes—physiogenesis and psychogenesis—so also are mental variations. But physiogenesis, or the reception of sensations from the outside, is the most important cause of mental variation, and special organs have been developed for the reception of these outside stimuli. Psychogenesis is also important, for without new combinations no progress could have been made. Indeed, the difference between the rapidly progressive nations of the Western world and the stagnation of the Eastern nations is due to the want of variation in the latter. No new ideas have come to them from studying the infinite variety of nature. They have preferred to turn their minds inwards, and to contemplate their own consciousness, with the result that they have fallen behind in the race.

The Transmission of Mental Variations.—Mental variations are transmitted from brain to brain in three ways. (1) By ordinary generation. We have already seen that some simple mental variations, when constantly repeated so as to become unconscious and habitual, may be recorded in the germ-cells and so passed on from parent to child. But physical transmission is by no means necessary for handing down mental variations from one generation to another. This can be done either (2) by imitation, or (3) by communication. The latter is almost entirely a human method of transmission, for it is done by language either spoken or written. But we see something very similar in bees and ants.

These variations, due to imitation or to communication, if they are simple and constantly repeated, may also become habits, and then they can be transmitted physically until they become instincts. Usually, however, ideas transmitted by imitation or communication go only to the brain, and are not registered in the germ-cells. This mental transmission, without the intervention of germ-cells, is quite different from the way morphological variations are propagated. And now, as this mode of transmission has been made easy through the invention of the printing-press, mental variations rapidly spread over the civilised world. Another difference between structural and mental variations is that the latter may occur in an individual at any period of life, and are not solely pre-natal. And these two things together make psychological evolution far quicker in action than biological evolution. This accounts for the rapid changes which sometimes startle mankind. A great man—that is a man of great originality—can bring millions of minds to his own way of thinking. In other words, he can make them all vary like himself; and this without their having seen him, or even long after he is dead.

Education is partly a means of propagating mental variations and partly a means of training the reasoning powers and the imagination. It is therefore an important controlling power on future mental variations. And, as habits may be transmitted physically, the constant inculcation of good habits by education must, in time, influence the character of future generations.

The Preservation of Mental Variations.—Mental variations are preserved and accumulated by selection. Desires come first, and then, by the fulfilment of these desires, a highly complicated set of actions and interactions are brought into play. Preferential selection holds a very important position in human affairs. We choose our clothes, our houses, our amusements, even our religious opinions; and these selections start a most complicated chain of causes, through which industries rise and fall. This chain of causes is largely influenced by natural selection, by which the best survive. But this is a part of the subject which I need not follow out.

Motives.—Of the motives which move human society, self-preservation and pleasure are lower than the others, and if allowed to get the upper hand would ruin the national character. But they are antagonised by sympathy and admiration; and these higher motives can be much strengthened by education. Sympathy was useful in drawing the members of a tribe together and causing united action. Religion has been useful in the same way; but its power is now much weakened, and science, the creation of curiosity, has largely supplanted it in supplying strength to a nation.

Curiosity and admiration were born and nurtured among the infinite variety of nature. With the motive of admiration we advance to the highest human ideals, and in art we find the expression of the highest faculties. Poetry came first. It was the founder of music and the inspirer of religion; and must been a most important motive in the early days of human development. We see this in the poems which form the religious books of various nations; and we also see it in the poetry of some peoples that we are accustomed to look upon as savages. To bear out this statement, which may seem far-fetched, I will give two short examples of Maori poetry, translated by the Rev. J. W. Stack.[53]

(1)

Here I sit while my throbbing heart
Mourns for my loved children.
Here, like Tane's offspring,
Drooping yonder in the inland forest,
I bend like the fronds of the tree-fern.
Over my lost children.

[53] *Report Aust. Ass. for Advan. of Science*, 1891, pp. 387 and 388.

Where art thou, O my son!
Thou whom thy people were wont to greet
With the welcome cry, Draw near! Draw near!
Thou art gone, alas!
Borne by the strong ebbing tide
That bears all men away.

(2)

The mists still hang on Pukehina.
Along its slopes my lover wends his way.
Turn, love, once more,
That I may pour forth my tears to thee.
I was not the first to speak of love.
You deceived me, your inferior;
And now my foolish heart
Is beside itself,
When my eyes rest, love, on thee.

There is much more, equally good, in Maori poetry. But it is very difficult to translate, as the poet uses unbounded licence with his language.

CHAPTER XIII

VOLITION AND FREE-WILL

THE question of the existence of free-will in man is so important that I feel obliged to examine it more fully than I could in the last chapter. The present position of the question, from the determinist side, has been admirably and lucidly stated by Mr. W. H. Mallock in the "Fortnightly Review" for February, 1902, and I will take his summary as a starting point.

According to Mr. Mallock the first argument of the determinists is a theological one. It is: If God knows everything—future and past—man cannot be free to act. On this I will only remark that it is directly opposed by the statement of the libertarian that: If man has no freedom of will he cannot be responsible for his actions; and consequently there can be no such things as morality and ethical evolution. I leave the reader to make his own choice. But as ethical evolution is a proved fact I have, myself, no hesitation in making up my mind about it.

The second argument is psychological, and is thus stated: Will is determined by the strongest motive, and motive is determined by the character and temperament with which each individual is endowed at his birth, and by the circumstances with which, after his birth, he is surrounded. Obviously, it is said, he has no voice in the settlement of these, and consequently no free-will. I would here remark that undoubtedly will is determined by the strongest motive, but the question is : Has man the power of altering the strength of the motive? It may be presumptuous in me, who am not a psychologist, to offer an opinion on this argument, and I do so with much hesitation. But it seems to me that the effect of the imagination on the will has not been taken into consideration. We can call up memories by will-power, and we can, by introspection, make any combination of these memories we like, and by means of the imagination we can lay more stress on some than on others. No doubt the imagination is part of a man's constitution with which he was born; in some it is strong, in others it is weak. But the origin of the imagination is irrelevant to the question, which is : Has man any control over it? This is a matter of personal conviction. For myself I feel quite certain that I can alter the strength of my motives; so that here again I have no difficulty in forming my opinion. Prediction in human affairs is impossible except in quite a general way.

The third argument is a scientific one, and it looks most formidable. It is : There is abundant evidence to prove the close connection between mental and physical processes. Our mental conditions are inseparable from their material equivalents, namely, the processes of the brain and body; and these equivalents take place in accordance with the unvarying laws which prevail elsewhere throughout the material universe. How then can the will claim any principle of freedom which is not possessed by their inseparable companions the latter?

The answer to this is that the physiological evidence on which the determinist here relies does not really bear on the question. All the experiments on which the argument depends were made on nervous tissues, which had been the slaves of memory for millions of years; and they were not made for the purpose of testing the existence of free-will, but to ascertain how the nervous system acted. To shew that this is the case, we have only to remember that nearly all the experiments have been made on animals which are not supposed to have free-will. The determinists have dragged these experiments into the controversy without understanding their meaning. However, before dismissing their argument as worthless, let us examine it.

In the first place, are the mental and physical processes equivalents? and are they such inseparable companions as the argument tries to make out? Certainly they are not. For in the absence of an external stimulus the mind can make a similar rearrangement of the tissue of the brain without any physical agent. A good description can bring an idea before the mind so vividly that an impression is made on the brain, similar to that which would have been made if the object had been seen by the eye. "Flower in the crannied wall." We read the letters and we form a mental picture in the brain, not of the letters but of the flower and the wall. It is an ideal flower and an ideal wall. If we tried to draw them, they would be unlike anything we had actually seen. So also with hallucinations. "Is this a dagger that I see before me?" is typical of a large number of facts. They are impressions made on the brain without any external stimulus. In somnambulism we have just the opposite; a stimulus without any mental impression being made. So it is with a person under anæsthetics; the eyes and ears are open, sensations pass in the brain, but no impression is made. With conceptions and hallucinations the physical processes are absent; in somnambulism the mental processes are absent. How then can they be called equivalents? In the second place, do the processes take place in accordance with unvarying laws which prevail throughout the material universe? It is the opinion of many people that reflex action is mechanical; and I have even seen it stated by a Professor of Biology that the stimulus is the cause of reflex action. But a very little consideration will shew that this is not exactly the case. The fact that habits are formed gradually as the result of experience shews that reflexes are not purely mechanical, however much they may resemble mechanical action. It is the same when the process is in the opposite direction, and an instinctive movement is gradually abandoned. For such is often the case. The soldier in his first action ducks his head when he hears a shell whistling through the air; but in time he becomes familiar with the sound and no longer goes through the instinctive but useless action. One of my granddaughters had a piece of her ear bitten out by a pony. For some time afterwards she put her hand to her ear when she saw the pony; but in six months this action ceased, and the instinct died away. There is nothing mechanical in this; either in the inception or in the gradual decline of the reflex action. Evidently a mental process is involved as well as a mechanical one. The mind receives the stimulus, examines it, and decides what is to be done. When constant repetition takes place, the examination is omitted, and a pseudo-mechanical action is the result. But the mind is there all the same, and if it finds that its directions have been wrong, it gradually recovers itself and alters them. In fact, reflex action is an acquired character, due to experience, and its action is not invariable. Consequently it cannot be compared to any of the physical forces. Intelligence, or mind, is always an intermediary between the physical processes. Reflex action is due to lapsed intelligence, which may be re-awakened when the stimulus is not followed by the usual effect. And the greater the intelligence of the animal the sooner can the effect of a stimulus be altered.

We thus see that these physiological experiments give no evidence either for or against the existence of free-will in man, and I have, I hope, cleared the way for a further consideration of the case.

There are, I think, three lines of evidence in favour of free-will. First, the existence of the moral sense. Anyone who admits that he has felt regret for any act that he has done, feels that he is free.

The determinists try to escape from this argument by saying that because men think themselves free, they ought to obey the moral law. But how can they do so if they are not free agents? And if a man is a determinist, how can he feel regret for doing an action which he thinks he was obliged to do?

Secondly.—If mind has no freedom of action, intelligence is useless to us. Why should the intellect of man have been so far developed that he can understand the process of evolution, unless he was intended to affect it in some way?

Thirdly.—There is the conviction, felt by everyone, that he is a free agent. The determinist allows the existence of this conviction, but says that it is an illusion. He says that it is impossible for anyone to have an exhaustive knowledge of his own motives, and therefore he cannot tell what has moved him. But this argument is an obvious fallacy, for we cannot be swayed by ideas which we have forgotten. The process is not mechanical but mental. It may be influenced by habits, but these also we know, and we often shew the freedom of our will by overcoming them.

I will now place before the reader an hypothesis which appears to reconcile the facts and to supply an explanation of free-will in man. But to make this clear it will be necessary to recall Professor Hering's theory of unconscious memory, which I have already explained. However, as it is always useful to look at a new idea in different ways, I will re-state the theory from rather a different point of view.

Everyone knows that a simple movement of the body may become automatic by constant repetition. We no longer require our attention to perform the action, for it has become habitual. The nerve-cells, which cause the muscles to contract, themselves remember the action and perform it unconsciously. It has become pseudo-mechanical. Some of these habits, when transmitted through many generations, become instincts; all of which are due to the unconscious memory of the nervous system. The brain must have some faint resemblance to a collection of Babylonian tablets. A sensation makes an inscription on some part of it, and the mind can read that inscription and again perform the operation to which the inscription relates.

But memory is not confined to the brain, as is proved by reflex action. Any collection of nerve-cells, or in the lower animals even a simple nerve-cell, will respond to a stimulus. All this is due to memory. But in animals like Hydra, nerve-cells pass into muscle-cells, and if nerve-cells possess memory, so also may the muscle-cells. And as all the cells forming an animal are derived from one cell—the ovum—each distinct cell may have its own separate storehouse of memories. This implies that each cell contains mind which acts unconsciously during the growth of the body; and we have independent evidence to shew that mind, even intelligent mind, exists in unicellular animals like the infusoria and amœba.[54]

[54]See "The Physic Life of Micro-organisms," by A. Binet. The Open Court Publishing Co., Chicago.

Mr. Herbert Spencer defines our conception of life as "the continuous adjustment of internal relations to external relations,"[55] and this has been generally accepted as the best definition yet given. Now adjustment, or adaptation, is not, as we have already seen, a mechanical process, but implies not only intelligence to understand what is being done, but freedom of movement to prevent threatened action. Indeed the idea of unconscious adaptation is absurd. This is agreed to both by Professor Cope and Professor Mark Baldwin. In time adaptation may become instinctive, but it must at first have been intelligent. And thus we see that mind must originally have been free to act, although it afterwards became subject to law. It is important to remember that to fall into a habit is to impose a law upon oneself. Instincts are laws which have been imposed on the present generations by their ancestors. And all reflex action is the same. From the studies of animal life made by Fabre and others, nothing comes out clearer than that instincts, however strong, are not immutable, and that some individuals are more intelligent than others. This holds true with birds and mammals as well as with insects.

These self-imposed laws are not like the physical laws of the universe, for they can be altered or annulled. Dead matter has been subjected by the Creator to fixed laws, as we call them; but living protoplasm is free to act. To it has been given the power of adaptation, or antagonism to the fixed laws

[55] "Principles of Biology," 2nd edition, vol. 1, p. 99.

of dead matter. A constant war has been waged between dead and living matter, and mind has overcome the physico-chemical laws. Chemical affinity has been taken advantage of by the protoplasm to protect itself from external enemies. It defends itself against internal enemies by dividing into small portions. Physical energy has been used to break down chemical affinity, and then protoplasm has been able to lay up a store of potential energy. This necessarily implies that mind is intelligent, and has been free to act from the first. But it has overcome the physico-chemical laws only by obeying them; and this has given rise to the illusion that it is not free, but subject to fixed law like dead matter. We cannot suppose that the physical energies, when they fall upon protoplasm, antagonise themselves by forming chemical combinations which prevent their further assault, because this is so different from what happens with inorganic materials. Compare, for example, the formation of a cell-wall with the weathering of a rock. There is no similarity. The formation of the protective covering must be due to the action of living protoplasm, for it occurs only with living protoplasm. And when we see that this defensive action is different with different animals—sometimes silica being employed, sometimes carbonate of lime, sometimes cellulose, sometimes horn:—when we see these things we cannot doubt but that intelligence has been used in the selection of the material and in the formation of a defence. And this intelligence implies volition, judgment, and the power to carry the judgment into execution. Habit may come later, but the process must at first have been intelligent and free.

We are now in a position to understand the solution of the free-will problem. At first mind was free, because it *must* have existed before it underwent any experience. Experience came, and constant repetition made mind an apparent slave to the physical forces, although attention was occasionally called into action by new external irritants. But this was followed by relapse. Concentration of nervous matter, however, went on until, in the brain-cortex, attention developed in self-consciousness, and in the large cerebrum of man mind has once more passed into its original free state. It is this form of volition that we call free-will.

We need not assume a pre-natal hyperphysical soul miraculously introduced into the human body, as the determinists would saddle us with. All is natural, there is nothing mysterious about it. The soul is free-will acting on the imagination; and we only suppose that it gradually develops as the mind becomes more and more free with age.

Our freedom, however, is only imperfect. We are still bound by unreasonable customs and by ancient superstitions. As time goes on the mind will become more and more free. Reason will be more and more employed in things of every day life; and custom will be broken down by imagining better things. Changes will be more rapid and conservatism will die out. But this state of things will only be temporary. When all actions are reasonable, conservatism will again assert itself and mind will be, once more, in danger of losing its freedom. But by that time, I think, ethical evolution will have advanced so far as to rescue man from his perilous position. His mind will be kept open by having to give his attention constantly to devising new, and again new, plans for alleviating the misery and distress which must get more and more severe as time goes on.

CHAPTER XIV

MONISM AND DUALISM

By dualism we mean the belief that mind and matter are distinct things, of which either could exist without the other. Monism, on the contrary, is the belief that there is only one principle in nature, from which all phenomena have been derived. The materialistic monist holds that either matter or energy has produced mind, while the idealistic monist holds that mind has produced matter. But since the middle of last century a new form of belief has sprung up among scientific men, and the "Scientific Monist" now says that mind and matter are identical—"two sides of the same substance;"[56] whatever that may mean.

If we wish to form definite ideas as to which of these hypotheses has the best claim to be considered true, we must commence with an examination of what is known about matter and mind on the earth, and then compare them.

Our knowledge of matter.—In the first place, then, what do we know about matter and energy? We define matter as the substance of which the universe

[56]Lloyd Morgan, "Animal Life and Intelligence," 2nd ed., p. 468.

is made, and energy as the power which moves matter. The two are always found in association; and, as Newton said, force is inherent in matter. Matter we divide into the imponderable æther which fills space, and ordinary matter which is subject to the law of gravitation. Of the æther we know nothing, because it evades our senses altogether; and we believe in its existence only because it is impossible to explain radiant energy, traversing inter-stellar space, without it. Ponderable matter is supposed to be made up either of minute, solid, hard bodies of different specific weights and with different affinities, called atoms; or else of vortex-rings of æther, that is of portions of æther in rapid circular or spiral movement.

The atomic hypothesis accounts for the indestructibility and impermeability of matter, as well as for inertia and chemical affinity. Its chief difficulty is that gases behave as if they were composed of spherical bodies which are perfectly elastic; while, if an atom was solid, hard and indivisible, its surface could not be indented by the impact of another atom, and there could be no rebound. Secchi proposed to get over this difficulty by the supposition that atoms were always combined into rotating groups. But it is very doubtful whether such rotating groups could retain their movements indefinitely among the incessant shocks to which they are exposed. Of late years many physicists have come to the conclusion that atoms are built up from numerous ions of two kinds, positive and negative. And probably, when we know the difference between these positive and negative ions, we may understand why the atoms appear to be elastic.

The vortex-ring hypothesis explains the elasticity of matter, but not its inertia. And the idea of motion in a continuous fluid is inadmissible, because there cannot be movement without something to be moved.

Matter is invisible, unless it is aggregated into large masses, with the atoms so closely approximated as to reflect light. But, however closely approximated the atoms may be, they are never in actual contact with each other. They are supposed to maintain a constant oscillatory movement, passing rapidly backwards and forwards through a small space, the extent of the oscillation depending on the temperature of the atoms. But on the atomic hypothesis matter is unchangeable. There are a fixed, but at present unknown, number of different kinds of atoms, which may combine with each other in different ways, but which cannot be changed the one into the other.

Energy we can divide into five different kinds. 1.—Vibrations of the æther, or radiant energy. This includes light, radiant heat, and radiant electricity.

2.—Vibrations of molecules. Sound, heat, and current electricity.

3.—Mechanical, or molar, motion. A progressive movement of molecules, generally united into a mass.

4.—Chemical affinity and static electricity.

5.—Gravitation, which is instantaneous in its action. It passes indifferently through all bodies, and it cannot be turned on one side.

These energies are correlated, inasmuch as any one of them can by degradation of itself, give rise, either directly or indirectly, to any of the others. However, although molecular movement may bring chemical affinity into play, and molar movements may do the same for gravitation, in neither case can a transformation of one into the other be said to take place. Consequently gravity and chemical affinity remain invariable in quantity and intensity, while vibrations and molar movement may vary.

Gravity and chemical affinity are not movements, but attractions or repulsions of other matter. Ætherial vibrations are inexhaustible; but, as the molecules of matter have inertia, work has to be done to move them, which entails loss of energy; these energies gradually decline in power and finally come to rest. In other words molecular movements are exhaustible.

Matter and energy are absolutely thoughtless, and implicitly obey the laws which have been impressed on them. Matter, when moving, goes straight on, unless its direction is altered by a new action of energy. From this it follows that when two energies meet, the action and reaction are equal and opposite. And, if we know the direction and amount of the energies, we can calculate the result.

It thus appears that gravity and chemical affinity are inherent in matter. We cannot think of one without the others. The physical energies, on the other hand, are products of gravity and chemical affinity, and we can imagine the Universe without them.

Our knowledge of Mind.—In the next place, what do we know about mind? We define it as the intellectual power or thought; that is, the power of recognising the relations between different phenomena or between cause and effect. The facts relating to it are the following.

1.—Mind has increased in quantity on the earth. It does not come to us, with radiant energy, from outside; and it is spread only by assimilation. And, although we are constantly losing it by death, yet it has largely increased in quantity since the day when the whole of the life on the earth was contained in a single cell. Mind also increases in quantity in each individual as it develops, and then suddenly disappears.

2.—Mind on the earth has improved in intensity. Take first the history of the mutual development of mind and tissue.

(a)—The first stage is protoplasmic irritability, or sensitiveness to physico-chemical agents; and its capability of performing adaptive movements to meet them.

(b)—The second stage is nervous sensation or feelings; where a nervous centre has been established, connected by nerves with peripheral receiving organs; and, later, with special nerves for the special senses.

(c)—The third stage is self-consciousness, or the capacity of thinking of ourselves, of knowing what we are doing. It is the general opinion of physiologists that for this a brain-cortex of grey matter is necessary.

(d)—The fourth and last stage is the establishment of free-will, which gives to man the power of altering the strength of motives, and so enabling him to make a choice between actions.

But mind can also be improved by exercise, without any further improvement in tissue. This we see commonly in education; the effect of which is especially well marked in the case of children belonging to uncultured peoples, such as the Maoris. The fact that a Maori has taken second class honours in political science at the New Zealand University is a proof that mind may be improved without any accompanying development of the brain.

3.—Mind moves the molecules of protoplasm. It first takes sun-light, and with it decomposes the carbonic acid of the air and builds up carbo-hydrates like starch and sugar. Then it adds nitrogen and so has the basis of protoplasm. Mind thus forms a store of potential chemical energy, which it uses to produce physical energy. To do this it must arrange the molecules and direct their movements. Also the phenomena of memory shew that mind can re-arrange the molecules of the brain. These latter arrangements are not permanent, but fade away, unless they are constantly repeated, when, in time, they may become almost fixed. Mind can arrange the molecules better the second time than the first, which seems to shew that its power of moving molecules is limited, and that it takes time to do it.

4.—Mind is inexhaustible, it does not get tired.

We relieve the fatigue, which comes on after thinking intensely, not by ceasing to think, but by changing the subject of thought. This shews that it is the brain which cannot continue working, not the mind. The energy in a certain portion of the brain gets exhausted, and it is necessary to wait for a new supply. Again, the object of sleep is to rest the brain, not the mind; for the latter goes on thinking when we are asleep. These thoughts, or psychoses, when we are asleep, produce but little physical changes, or neuroses, in the brain; for, when we try to recollect our dreams, they generally escape us. Often we know that we have been dreaming, but cannot remember even the subject. And usually dreams, however vivid, rapidly become indistinct, and we forget them altogether, unless they are written down at the time. The more we work the brain, the more liable we become to insomnia. We have to try to stop thinking in order that the brain may be rested, but the mind is inexhaustible.

5.—Mind, even in its lowest forms, is purposive, or intelligent. That is, it has, or seems to have, looked forward to results. All adaptations, such as the formation of healing-tissues to cover over wounds, must have a purposive origin. The fact that these adaptations are helped by natural selection does not prevent them being purposive; for the purposive action is in originating the variation, not in preserving it. Take the case of the origin of chlorophyll. Everything, at that time, depended on the reduction of the carbon-dioxide in the air. Without that process life must have come to an end;

and we cannot believe that the discovery of that process was altogether accidental.

6.—Mind is to some extent lawless, that is, it has the power of volition, even in the lowest living organisms. If it were not for this freedom of action it could not oppose the physico-chemical energies and would be destroyed. It has often imposed pseudo-laws on itself, to make its action easier; but these laws are not like natural laws, they can on occasion be disobeyed. This, indeed, is the distinguishing mark of mind. These pseudo-laws we call reflex action, which is proved by experiments on the tissues of animals which have been recently killed or rendered unconscious. So long as the tissues live, they respond to stimulus, although bodily life may have gone.

Scientific Monism.—When Copernicus published his opinion that the earth went round the sun, he saw clearly that he must substantiate it with the best evidence he could get; because the opinion was both novel and contrary to common sense. The scientific monists are now in the same position. Their doctrine is novel and opposed to common sense, and it behoves them to substantiate it. The burden of proof lies with them, and not with the dualists, who have been in possession of the field for so long. Let us see what the monists have done in this direction.

Professor Tyndall, in his presidential address to the British Association at Belfast in 1874, compared a grain of wheat to a crystal, and declared that he could see no fundamental difference between them. It is perhaps hardly necessary at the present day to refute this argument. But, as it is occasionally reproduced, it may be advisable to point out that there is truly a fundamental difference between a crystal and an organism, in that the molecules of the former are all fixed in position with their axes parallel. If this were not the case, the substance would not be crystalline. It is true that the starch and cellulose in the grain of wheat affect polarised light, in the same way as a doubly-refracting crystal; but the starch and cellulose are not the living part of the wheat. They are merely secretions, and the similar action on polarised light merely shews that in both crystal and starch grain the molecules are not spherical and are arranged with their longest axes parallel. So also starch and cellulose grow from the outside, like a crystal, and not from the inside, like protoplasm. This, again, is because starch and cellulose are not alive. The living protoplasm of the embryo in the grain of wheat is quite different in constitution from the starch grain.

An analogy has sometimes been drawn between the definite shapes assumed by crystals and by organisms respectively; but the analogy is a false one. When crystals develop irregularly, the new faces are always formed parallel to the regular faces, so that the fundamental shape does not change; there is no true variation. And there is nothing in organic variation which answers to the law of rationality of intercepts in crystals, and nothing but physical conditions limit the size of crystals. Even symmetry obeys quite different laws in crystals and in organisms. In crystals the symmetry depends entirely on internal causes, and is hindered by the action of external causes; while in plants and animals symmetry is due to adaptation to external conditions, and the interior is often asymmetrical when the exterior is symmetrical. I need not pursue this subject further.

Although Mr. Herbert Spencer is not himself a monist, his philosophy forms the basis of all scientific monistic speculation. However, it is only that portion which relates to the doctrine of abiogenesis that concerns us here.

Firstly, Mr. Spencer sees in the mineral colloids, or mineral jellies, a connecting link between the mineral crystalloids and the organic colloids. He quotes Professor Graham as saying that the mineral colloids are dynamical states of matter, inasmuch as they possess energy and are prone to change. But this energy, if it exists, can only be employed in one way, namely, in changing the colloid into a crystalloid, and this is simply due to the loss of water. It is a purely mechanical process, and does not in any way lead up to vital action. Take a concrete example: the common change of the colloid opal into the crystalloid quartz. We see at once that the movements are altogether unlike those of a living substance. All the similarities that have been pointed out are merely analogies and have no meaning. Possibly the mineral colloids have their molecules surrounded by films of water, like the micellae of organic substances, but here the resemblance ends.

Secondly, Mr. Spencer has stated the problem of abiogenesis with his usual clearness. He says[57] organic substance may, perhaps, originate now; but more probably it originated at the time when the heat of the surface of the earth was falling through the range of temperature at which the higher organic compounds are unstable. Organic matter, he thinks, was not produced at once, but was reached by steps. Inferior types of organic substance, by their mutual actions under fit conditions, evolved the superior types, ending in organisable protoplasm. "And to the mutual influence of its metamorphic forms under favouring conditions, we may ascribe the production of the still more composite, still more sensitive, still more variously-changeable portions of organic matter, which, in masses more minute and simpler than existing Protozoa, displayed actions verging little by little into those called vital; actions which protein itself exhibits in a certain degree, and which the lowest known living things exhibit only in a greater degree." (1. c. p. 700).

This idea of the gradual complexity in the growth of carbon compounds is a possible one, for we see the same thing in the process of assimilation by living protoplasm. But, as chemists have not yet been able to follow it, we must hold it as a speculation only. There can be no difficulty in reproducing in the laboratory all the conditions mentioned by Mr. Spencer, but, up to the present, albumen or protein have evaded the efforts of experimentalists. It must be remembered, not only that protoplasm is killed by a temperature far less than that at which the pro-

[57] "Principles of Biology," 2nd edition, vol. 1, p. 698.

teids are dissociated, but that external agencies are destructive to protoplasm. Assimilation only takes place in cells prepared by living protoplasm to resist the destructive action of the physico-chemical forces. These cells are specially prepared laboratories, and it is difficult to imagine how a similar process could be gone through by unprotected carbon compounds when floating in the sea. Mr. Spencer's supposition, therefore, although possible, is highly improbable.

But what right has Mr. Spencer to slip the words "still more sensitive" into his argument? Chemists have not manufactured any substance which is in the very least sensitive, and to do so is impossible. For, unless sensation is a principle of the dead matter which chemists use, no possible combination of that matter could give it existence. But Mr. Spencer goes on to say that these compounds would display "actions verging little by little into those called vital," and states that protein exhibits these actions in a certain degree. Now what evidence has he for saying that vital actions are exhibited by protein as well by protoplasm? He certainly should have given it. Mr. Spencer has here been led away by a verbal argument; and it is quite impossible to reconcile this conclusion with his other statements about life. For example, "Life in its essence cannot be conceived in physico-chemical terms" (1 c., p. 120), and "we find it impossible to think of life as imported into the unit of protoplasm from without; and yet we find it impossible to conceive it as emerging from the co-operation of the components." (1 c., 1, p. 122). In this I quite agree with Mr. Spencer; but it is not necessary to stop in his position. The idea of life emerging from the co-operation of the components of the protoplasm is not only inconceivable, but it appears to me to be absolutely impossible. And, although the importation of life into protoplasm from without is also inconceivable, it does not appear to be impossible; for as a matter of fact we find that it is there.

One of the leading scientific monists is Professor E. Haeckel, and he has published a book on the subject. He says "an unmaterial living spirit is just as unthinkable as a dead spiritless material; the two are inseparably combined in every atom."[58] But let us see whether Professor Haeckel can make his combination of mind and matter less unthinkable than their separate existence. He first mentions the laws of conservation of force and conservation of matter (1 c., p. 16 and 17), altogether ignoring the law of dissipation of energy. He then says that it is probable that there is only one kind of matter (pp. 25 and 26), and lastly, discusses the relation of matter to the æther (p. 30), on which he says "I believe that the solution of these fundamental questions still lies as yet beyond the limits of our knowledge of nature." And in note 11 he appears to give up the idea that æther and matter are identical, for in it he gives a provisional scheme of the relation between these two "fundamental constituents of the cosmos." It will thus be seen that he has no

[58] "Monism," A. and C. Black, 1895, p. 58.

good evidence to prove the unity of matter and æther, which is only a first step in monism.

When he comes to the relation between matter and mind, or consciousness, he starts with the assumption that the two are one; an assumption for which there is no evidence. All he can say is (p. 47) "If we understood the nature of matter and energy, we should also understand how the substance underlying them can under certain conditions feel, desire, and think." And with regard to the origin of life he says (Note 2), "The solution of this transcendent riddle of the world . . . can only be reached by a critical analysis and unprejudiced comparison of matter, form, and energy in inorganic and organic nature." A weaker case has never before been presented to scientific men; and I am quite astonished at Professor Haeckel's statement (p. 60) that he is firmly convinced that at least nine-tenths of the men of science now living believe in it.

Professor Lloyd Morgan is another leader of the scientific monists, and in his book on "Animal Life and Intelligence" he discusses the question at considerable length. His argument is that, as both materialistic monism and idealistic monism are clearly wrong, therefore scientific monism must be right. Dualism is simply dismissed as the "commonplace view," and, therefore, I suppose, unworthy of consideration by a philosopher.

But dualism cannot be killed by sneers like this, nor by a cloud of empty words which carry no clear meaning. Evidence and reasons must be forthcoming before the "common-place view" will be abandoned by reasonable men. The position of the scientific monist is indeed incomprehensible, as a little consideration will shew. The molecular changes in the brain caused by sensations are called neuroses, and neurosis is the faculty of making them. Psychoses are the concomitant changes in consciousness, and the term psychosis may be applied to the faculty of reading or interpreting the neuroses. Now the scientific monist affirms that neurosis and psychosis are identical. That the printer of a book and its reader are one and the same person.

The opinions held by the scientific monists do not appear to have been arrived at by an analysis of the evidence, but have been assumed as a necessary truth. It was in the same way that Aristotle, in his proof of immutability and incorruptibility of the heavens, assumed that all celestial movements must be circular. This assumption has involved them in the following difficulties :

1.—They have to explain how two things apparently so different as mind and matter can be merely conditions of a single element.

2.—They have to explain the origin of life : why mind is only associated with protoplasm, and why dead protoplasm can never come to life again.

3.—They have to account for the moral sense in man. For logical monists must be determinists and fatalists.

These difficulties arise from the monists arbitrarily assuming that everything has been developed from a single element or principle. The dualist is freed from these difficulties. He knows that mind exists, and he thinks that there is sufficient evidence to shew that it is distinct from matter and energy. Certainly he cannot explain what mind is, but in this he is no worse off than the monist.

Dualism.—Let us now see what are the reasons for thinking that matter and mind are essentially different, and cannot have been derived the one from the other. As in the present phase of evolution all matter is in motion, we may consider the two as inseparable, and the problem resolves itself into the question, is mind, or life, a form of or a product of physical energy? I think that the following considerations will shew that this is not possible.

1.—Mind is not inherent in matter, not even in protoplasm, as is shewn by the first division of the egg-cell in many plants and animals. This division divides the protoplasm of the egg-cell into two portions, one of which is alive, the other dead.

2.—Mind directs and controls energy, and we cannot conceive it as derived from the energy it controls. The brain cannot originate. Matter can influence mind only after mind has arranged the matter, and even then the matter is inert. Evidently mind must be quite distinct from energy, as they are not interchangeable.

3.—Mind is inexhaustible. When we call upon the memory to repeat a previous thought, we strengthen it; and it is impossible that any form of energy could be increased by use. Mind is transformed into energy without any loss to itself.

4.—Mind does not follow the path of least resistance. It is always trying to do something new, unless it has fallen completely under the control of memory. The proof of this is the continual progress which distinguishes organic from inorganic evolution.

5.—In mental phenomena action and reaction are not equal and opposite. The same motive does not always produce the same action; and the strength of the will varies. Free-will is found not only in man, but to some extent in all living organisms. Mind therefore is lawless, or rather, it only obeys laws of its own making. This is quite incompatible with the idea that it is a form of physical energy, or that it is derived from physical energy.

Lastly, let us see what objections Professor Haeckel makes to dualism. On page 58 of his book he says "not a single empirical proof can be adduced to shew that either of these [energy and matter, or spirit and material] can exist, or become perceptible to us by itself alone." The latter is, of course, true, because we cannot perceive anything except through the mind. But that matter exists without mind is our ordinary experience. This is all he has to say on the subject; and he passes on to formulate two old objections to theism. The first of these is (p. 72) that nature is not perfect: that there is much misery and crime in the world. And the second (p. 73) is the waste in nature.

On these I will only remark that all the arguments against the goodness of God are based on the idea that man does not possess free-will. If free-will is allowed, the argument falls to the ground. With reference to waste in nature, we must remember that this so-called waste is the food supply for other organisms, without which they could not live.

Conclusion.—We see, then, that mind is not inherent in matter; and it cannot be a product of gravity nor of chemical affinity, nor of physical energy. How can the exhaustible give rise to the inexhaustible? How can the inevitable give rise to free movement? How can the unintelligent give rise to the intelligent? It is only necessary to put the question clearly to see how impossible it is that mind should be a product of energy.

I think that I have now given good reasons for believing in dualism from the scientific standpoint, and it explains the ancient enigma of free-will in man. This, again, solves any doubt that might be felt about the moral responsibility of man; explains why we feel regret or remorse for wrong action or thoughts; and casts its weight into the scale against the psychological argument of the determinists. The monist has to assume that matter and mind are identical. The dualist makes no assumption, but says that, as a matter of fact, they are different. And so long as the evidence on which he relies is not shewn to be erroneous, he is quite right in maintaining that position.

The prevalent belief in monism cannot be caused by the strength of the evidence in its favour. It seems to be chiefly due to the constant simplification of phenomena which went on during the last century. This has led many scientific men to think that ultimately everything will be resolved into a single principle. Still, there must be more than that, for few chemists go beyond what the evidence warrants, and believe that there is only one elementary substance. I think that, in order to explain the number of monists, we must, in addition to the simplification of phenomena, add the reaction against an age of credulity and superstition, an age when miracles were believed in. But the pendulum has now swung too far in the opposite direction.

For why should dualism be doubted? Is the independent existence of two primitive principles more miraculous than that of only one? Is the introduction of mind into protoplasm more extraordinary than the introduction of gravity into matter? I cannot see that it is. The determinist must be either right or wrong; no middle course is possible. If he is right, then the world and all that it contains is a machine working automatically. But if the libertarians are right, then organic evolution is the product of mind in protoplasm. It is impossible to believe that this progress is due to the action of unintelligent forces, and it is equally impossible to believe that terrestrial mind could have foreseen the results towards which it was working. So it seems to me that we are driven to the conclusion that terrestrial mind has worked under the guidance of extra-terrestrial mind; of the mind which originated the idea of evolution.

"The prophetic soul
Of the wide world, dreaming on things to come."[59]

To those whose opinions compel them to monism, in spite of the evidence, it is far more reasonable to suppose that mind made matter than the opposite.

[59]Shakespeare, Sonnet, 107.

As mind on the earth builds up and moves protoplasm, so the universal mind, which moves matter, may have made it also. It is mind and not matter that we must conceive as eternal. That terrestrial mind moves protoplasm is a fact. That the universal mind moves matter we postulate from inorganic evolution. For it seems to have caused inorganic evolution, just as terrestrial mind has caused organic evolution.

CHAPTER XV

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 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 for many millions of years, 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.[60]

We cannot believe that all these various and complicated adjustments were brought about by a fortui-

[60]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.

tous 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 been unfavourable. Or, if this also was suitable, there might not have been a due proportion of the various elementary substances to allow 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.

It is quite possible that in other parts of the Universe other substances than protoplasm may be alive. But we must remember that many of the elementary substances found on the earth are also found in the stars, and it is doubtful if there is any substance in the stars which is not found on the earth. If hydrogen exists in the sun and in the stars it must have the same properties and the same chemical affinities there as here, and so with the other elements.

Any substance which exhibits the phenomena of life must necessarily have a mobile constitution, for life exists by the constant rearrangement of molecules. Consequently it must contain water, for there is no other thing on the earth which could be substituted for water. And there are no elementary substances in the sun, or in the stars, which could make another substance which might replace water. Practically we know the possible combinations which might be formed in other worlds, if we assume, as we must, that the physical and chemical laws are the same throughout the universe.

Now water exists as a liquid only between certain narrow limits of temperature, so that no living substance, whatever might be its chemical composition, could shew the phenomena of life outside those limits of temperature. Also water will evaporate if the air surrounding it is dry, so that to prevent a living substance from drying up, it is necessary that the atmosphere should contain moisture. This moisture in the atmosphere can only be kept up by there being large reservoirs of water on the surface of the planet on which living organisms exist. Consequently living organisms, whether they consist of protoplasm or of some other substance, cannot exist on any heavenly body which is too hot, or too cold, or too dry, for water to remain in the liquid state.

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 for 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.

The great, but not insuperable, difficulty in accepting the theory of Theism is that of knowing where to draw the line between the designed and the undesigned. It is evident that we must consider all those objects as designed which have assisted to carry out the design, and without which the design would have failed. But it is not necessary to go further and insist that everything which exists has been designed. There is nothing unscientific about the theory of design; but Professor Meldola, in his notice of the first edition of this book,[61] laughs at it, and quotes authority against me, just as theologians laughed at Darwinism and quoted authority against him. And—in ridicule—he presents me with two new examples of design in nature.

The first is that sponges and other organisms of the Cretaceous seas were endowed with the power of accumulating silica so that, when man was evolved, he might find flints ready to hand for the purpose

[61] "Nature," vol. 66, p. 219.

of making his weapons. I cannot, however, use this illustration, because I have restricted the idea of design to those things which were necessary to produce the desired end, *i.e.*, civilised and moral man.[62] Now flint does not come under that category. No doubt it is an excellent stone for making weapons; but others can also be used, and, of course, they were so used in countries where flint is not found. It is only because flint is common in Europe that the idea has got about that palæolithic man used only flint for his weapons. The men who did this were not the originators of civilisation, neither were their descendants. Civilisation would have arisen if the flint-using men had never existed. So I cannot consider Professor Meldola's first illustration a happy one.

The second is still worse. It is that towns are providentially located, so as to be always on the bank of a river. This fails as an example, because, in the first place, a simpler explanation than that of superhuman design can be found. And, in the second place, because towns are built by men, who exercise free-will in the choice of the locality; and these local effects of human free-will could not have been part of the original plan.

[62]See 1st edition, p. 45.

CHAPTER XVI

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. For if the action of gravitation was suspended, all those whirling balls in the heavens would scatter into cosmic dust, and the re-imposition of gravitation would start a new evolutionary movement.

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. Professor T. H. Morgan says, "We can, however, state with some assurance that at present we cannot see how any known principle of chemistry or physics can explain the development of a definite form by the organism or by a piece of the organism. Indeed we may even go further, and claim that it appears to be a phenomenon entirely beyond the scope of legitimate explanation, just as are many physical and chemical phenomena themselves, even those of the simpler sort. To call this a vitalistic principle is, I think, misleading. We can do nothing more than claim to have discovered something that is present in living things, which we cannot explain, nay perhaps cannot even hope to explain, by known physical laws."[63] 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 in an impossibility. The processes of assimilation and fission, on which all progress depends, are quite distinct from anything

[63] "Regeneration," 1901, p. 255.

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. 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.

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. 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, if Professor Hering's theory is correct, mind is a necessary concomitant of life, so that the origin of the two is 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. Everyone, 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 I have given reasons for thinking that volition, which is the basis of free-will, is inherent in mind, so that the origin of this also is the same problem as the origin of life. But the origin of life certainly appears to be a break in continuity; 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 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.

CHAPTER XVII

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, Goethe, 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 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.[64]

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

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

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 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 been 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 freed 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.

CHAPTER XVIII

CONCLUSION

INORGANIC evolution is due to physical and chemical laws only. At its commencement energy was at its maximum, and the process has been one of degradation. Although inorganic matter is constantly changing its position, it does not get more and more complex as time goes on, after reduction of temperature has allowed chemical affinity to act. The rocks and minerals of the Palæozoic era are identical with those of the Cainozoic; the surface of the earth, also, was no doubt as diversified by plain and mountain, by land and water, in ancient times as it is now. The process is one of simplification. The tendency of gravitation is to draw all matter together, and the tendency of dissipation is to equalise energy.

Organic evolution, on the contrary, commenced at a minimum and the process is one of exaltation. Living substance tends to become more and more complicated; and this difference is due to the introduction of mind on to the earth. Inorganic matter is controlled by laws which are not intelligent, but which have been devised by intelligence. Living matter has intelligence of its own and can modify these laws. Life and intelligence are low and high forms of the same thing—Mind.

Natural selection, as originally conceived by Darwin and Wallace, had nothing to do with mind. Variations were supposed to arise spontaneously and were selected mechanically. It was only in the higher animals that mind came into action in the formation of new habits. But, if psychogenesis is a true cause, we must modify this conception. We must now suppose that the variations are not altogether fortuitous, but are partly due to mental operations. Selection preserves some useful variations only. Isolation preserves all that arise, unless they are detrimental, in which case they would be removed by natural selection. Selection has secured progress, isolation has given rise to variety.

But are the variations which have been preserved by isolation really useless in the operations of evolution. Or do they also play their part? It is evident that psychological evolution would not have taken place without them; they have largely assisted in the education of the emotions of man, and they even have helped religious evolution. For it is impossible to explain psychological evolution without taking into consideration the effect produced on the human mind by the marvellous variety of natural phenomena; by the immensity of the universe; the infinitesimal fineness of matter; and its innumerable different arrangements. Without these man would never have risen above the fighting and money-making stage; and it is doubtful if we should have had any natural science. This cannot be denied, whatever we may think about the cause of the connection.

They who, like myself, see design in organic evolution, will also see in psychogenesis the means by which this design has been carried out. How it has been done is quite beyond our understanding. Have the biophores free power to act? Or are they obliged to go through certain movements? Do we see the action of intelligent protoplasm scattered broadcast through nature? Or is all a marvellous machine? Each person must answer this question for himself. It is one on which the agnostic attitude may be justified.

Mr. L. T. Hobhouse, in his "Mind in Evolution," says "Organic development on the whole is purposive. We can conceive such a purpose in one of two forms. We may place it within the evolutionary process, attributing it to the beings taking part therein; or we may place it outside the process in a hypothetical Being who contrives the whole movement and shapes it towards the end defined. In the former alternative we are forced to characterise the purpose as an unconscious purpose, and this threatens to be a contradiction in terms. At most we can say that there is in the earlier stages elements of purpose and understanding, which are gradually blended and fused into coherence. The latter alternative would bring us to the conception of an unconditional creation of the world-order, which can never be accepted by the intelligence without stifling the moral sense. Is there any third possibility? (p. 403)." And two pages further on he says, "Nature is neither wholly blind nor wholly the creature of intelligent purpose. Origin and purpose are mutually dependent parts of one scheme." I hope that I have shown that we can accept the second of his propositions without stifling the moral sense, because mind is free from imposed natural laws.

That mind exists is a fact, and that it is an active force in nature is another fact; and we cannot resist the conclusion that it exists in all living cells. Wherever there is life there is mind, and wherever there is mind there is life. Mind is the vital-force of physiologists, and living matter is protoplasm in which the molecular movements are directed by mind. We must, therefore, enlarge our meaning of the words, mind and memory, so as to include the mental processes of the lowest organisms. Perhaps another example will make this point clearer.

When the oöspore of *Nitella* commences to germinate it divides into two portions, a large and a smaller. No difference, either chemical or physical, can be detected between the protoplasm of each cell, but that in the larger is dead, while that in the smaller is alive and will grow into a plant. It is the same with the eggs of many kinds of animals, including the hen. Here the white of the egg and the greater part of the yolk are as dead as the shell. A small portion only of the yolk, called the blastoderm, is alive. This blastoderm takes advantage of the heat-waves supplied from the outside and gradually arranges the yolk and the white into a young bird which fills the shell. This process of development appears to be intelligent, but we call it instinctive, because it is performed unconsciously. But when we examine the unconscious actions we find that they were always performed consciously at first, and only became unconscious after many repetitions. Consequently we are obliged to believe that the instinctive development of the egg originated in a number of intelligent actions. In other words, mind resides in the blastoderm of the egg, and gradually organises the whole of the contents, until a chicken is formed from unorganised dead material. For this reason, it is impossible to believe that the environment, by itself, could have been the cause of the development of protoplasm.

By Professor Hering's theory a structural variation is a new experience which requires repetition to impress it on the memory. Heredity is a kind of acting, in which each cell or organ goes over again former experiences, sometimes forgetting its part. Or we may compare biological evolution to the formation of a library of books, in which all experiences are recorded and a set supplied to each new individual. Death is the obliteration of the library. Mind then no longer knows how to prevent the attacks of outside enemies. For the physical forces are detrimental to protoplasm; they kill it and decompose it. It is only by the intervention of mind that these actions are averted and the protoplasm is adapted to resist environment. Mind takes these enemies in hand and converts them into friends. If this is not due to intelligence, I do not know any other word in the English language to apply to it.

We must, however, be on our guard against analogies. Their real use is to give us hints as to where new evidence may possibly be found, and they must not be taken as evidence themselves. Much harm has been done by comparing a living organism to a machine; forgetting that, as the living organism formed itself, the real resemblance is to a machine plus the men who designed it, made it, and kept it in order. Analogies are not proofs, and are only brought forward to prop up hypotheses for which no proofs can be found.

Thus we see that the prime mover in organic evolution is mind; which, whether under guidance or not, has shaped out the human body and made its headquarters the human brain. Mind is an active force, and it is this which makes the differences between the mineral, vegetable, and animal kingdoms. Minerals shew no activity because they have no mind. Vegetables shew slow movements only, because mind in the vegetable cell is cramped and isolated by the cell-wall; consequently it is of a very low order. Animals are active and intelligent; and this is due to the development of mind. The original mind must have had in it the rudiments of all the qualities we find in man. And we may suppose that intelligence, even in the earliest organisms, was constantly trying experiments, some of which were successful. The body of the animal or plant was built up by itself in the same way that we invent machinery, one improvement suggesting another. Then in time admiration and sympathy emerged; and at last came free-will and with it morality.

Nevertheless, organic evolution will in time be overtaken and destroyed by inorganic evolution. As the temperature of the earth falls, the tropical vegetation will die out, as also will the animals which depend upon it for food. Next will follow the temperate flora and fauna; and finally those of the arctic regions. The arctic flora and fauna will take possession of the former tropical regions; but only for a time. The last to succumb will be the lowest forms of life, which were also the first to appear. At last death will come to all, and mind will vanish from the earth. What will become of it? According to the materialistic monist it is utterly destroyed. But the dualist or the idealistic monist can believe that mental evolution may still go on, and that it is only its present protoplasmic surroundings which will disappear for ever.

Now how does life, or mind, or vital-force—whichever we choose to call it—act? How does it bring about movements? The first process is for a special kind of protoplasm, called chlorophyll-corpuscles—which we know so well as the green colouring matter in leaves—by means of the ætherial undulations of sunlight to decompose, at ordinary temperatures, the carbonic-acid in the air, and from the carbon thus obtained to build up hydro-carbons, like starch. This appears to be a purely chemical process, but it is as yet quite unknown to chemists. The starch is changed into sugar and dissolved in cell-sap. Some is reconverted into starch and stored for future use, while another portion combines with the nitrogen of the nitrates, brought in through the roots, and from this various proteids, and ultimately protoplasm, are formed. This is the process called assimilation. Thus plants lay up a store of potential energy in these carbon compounds, which they afterwards use for purposes of growth. Animals feed on these stores of potential energy, and they also use them for the performance of actions.

But how does mind move from the chlorophyll-corpuscles without which carbonic-acid cannot be decomposed at ordinary temperatures? And how do plants and animals make use of the store of potential energy? They must in some way move the molecules of protoplasm into new positions, so that chemical affinity may be brought into action. We say that mind orders the movements, but something must start them. If we suppose that molecules are always in movement, as in streaming protoplasm, and that mind only directs those movements so as to form new combinations, still energy is required to alter as well as to originate movement. So that mind must be capable of generating energy. This is not more mysterious than matter being able to generate energy through gravity and chemical affinity.

If mind can move the molecules of protoplasm in an ordinary cell, we may suppose that it can move them more rapidly in a nerve-cell, and with still greater ease in the grey matter which forms the cortex of the brain. It is this which may have given rise to what we usually call intelligence in the higher animals. But the healing of wounds and the formation of a cell-wall are purposive, and demand intelligence also, so that adaptation and consciousness are only low and high forms of the same thing.

Conclusion.—We have seen that mind is quite distinct from matter, and that one could not have produced the other. We see that on the earth mind has organised and built up protoplasm, and we cannot avoid the conclusion that the universe has also been organised by mind, which does not reside in matter, because the laws imposed upon it are unalterable.

Also 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 be only 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. 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 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.

APPENDIX I

WHAT IS LIFE?

A Paper contributed to the "Hibbert Journal," October, 1905.

In an article on Sir Oliver Lodge's criticism of Haeckel in the *Hibbert Journal* for July, 1905, the writer quotes Sir Oliver as saying that life is "something immaterial and itself fundamental, something which uses collocations of matter in order to display itself amid material surroundings, but is otherwise essentially independent of them;" and on this he remarks: "As far as all infra-human vitality is concerned, there is not a single fact to support this, and the negative evidence is imposing." As a biologist, I must join issue on this point with this writer, and I would ask leave to give my reasons for differing from him.

Roughly speaking, one half of the living matter on the earth is engaged in the process of assimilation—that is, in decomposing carbon dioxide by means of sunlight, and building up organic compounds. The other half is employed in changing the chemical energy thus accumulated into mechanical movements, to which, for the sake of brevity, the comprehensive name of "locomotion" may be given; for under this name I wish to include the internal movements of the cell-contents, as well as the external movements of the cells themselves.

The nutrition of animals is due to the absorption of the products of assimilation, and is therefore here included under locomotion. Reproduction is due to the movements of the contents of certain cells, and it also comes under the heading of locomotion. Sometimes the movements are sufficiently rapid for instant recognition; at other times they are very slow, as in the germination of seeds, and we have to wait for days or weeks before we know whether they are alive or dead. These two functions of assimilation and locomotion are performed by chlorophyll and protoplasm respectively; and one of these substances cannot perform the functions of the other. Assimilation is a chemical action, and is easily recognised by chemical tests. We cannot follow the reactions, neither do we know how the organic compounds of carbon, hydrogen, and oxygen are formed, but these processes may be explained any day by the chemist. However, chlorophyll is not universal in living matter. It is found chiefly in plants, but also in some groups of animals; while protoplasm never fails to be present wherever life is recognised. From this we must suppose that protoplasm is the fundamental living substance, and that chlorophyll grains are merely manufactories, set up by the protoplasm for the purpose of obtaining stores of physical energy. It is therefore to locomotion that we must turn, in order to study the fundamental characteristics of life.

Now, locomotion is recognised by the spontaneity of its movements; by which we mean that they take place, either independently of an external stimulus, or, if in obedience to an external stimulus, they do not respond to that stimulus uniformly. In other words, in vital movements, action and reaction are not equal and opposite. Of course, living beings *are* subject to certain physical laws, in which action and reaction are equal and opposite; but the distinctly vital movements are an addition to these, and it is just this addition which constitutes the difference between the facts of physics and the facts of physiology.

But when we say that locomotion is the characteristic of life, we must remember that the word "life" has two distinct meanings. When we have wrung the neck of a fowl we say that it is dead; but when we cut a rosebud off a tree we say that it is still alive, and will live for some hours or days, until the tissues dry up. But with the fowl we have merely stopped the action of the nervous system, and the tissues remain alive, as in the rose, for some time, until they die for want of nourishment. That higher life in the fowl is called somatic life. We find it in all the higher animals, and in a modified form in the lower animals and plants; and it is evidently quite different from the tissue or cellular life, although both are characterised by spontaneous movements. From the biological point of view the tissue life is the true life; while from the same point of view the somatic life is merely a co-ordination of the different organs, which in the higher animals is brought about by the nervous system. What it is more precisely is a question for the psychologist, possibly for the theologian; but that does not come within the scope of the present paper. These two different meanings of the word "life" have long been recognised by physiologists, although it has not been thought necessary to use different terms in describing them; but, without this explanation, these two distinct meanings of the word "life" might create confusion in the minds of some readers who are not biologists.

Although locomotion is characteristic of life, it is not life itself. That name must be applied to the cause of the movements, if it can be discovered. Now, with reference to the voluntary movements of our own bodies, we know them to be due to will, which directs muscular contractions; and, in the lower animals, down to unicellular forms, we see movements take place without any stimulus, which have every appearance of being voluntary also. But we know that a very large number of our movements are involuntary and uncontrollable by our will; and this is largely repeated all through animated nature. It is these that have given rise to the idea that many vital movements are mechanical and under the complete control of physical law; but this is a mistake. We have, is addition to conscious voluntary movements, conscious involuntary movements, for we pass gradually to unconscious involuntary movements, due (as we say) to reflex action of the nervous system. A conscious voluntary movement may by repetition become unconscious, and even involuntary; this we call "habit." A habit is unconscious action acquired by an individual. Instincts are inherited habits, brought nearly to perfection by natural selection. Thus all the vital processes of our bodies, such as breathing and the action of the heart, are instinctive. They are so regular that they give the idea of being mechanically performed; but the appearance is deceptive, and they differ fundamentally from all purely mechanical motion. Physical energy, when it acts for the first time, acts as efficiently and with as great certainty as if it had performed the action many times; there is no improvement. But with physiological actions the case is very different. The first movements are tentative; and it is only after constant repetition that they become decisive and prompt, like those due to physical energy. Even then they do not always remain constant; for, it is well known, instincts may sometimes be altered by a little dose of reason—that is, by the attention of the animal being called to them. It must therefore be allowed that these pseudo-mechanical movements, although now beyond the control of the will, originated in voluntary movements, and that, however rigidly they now act, they have been imposed on the organism by a long line of ancestors. We must also suppose that the apparently mechanical movements in the lower animals and plants also originated in actions of the will; for there is no other explanation left. It must further be noticed that, if these movements are spontaneous, the will directing them must be free, that is, free to act in opposition to physical energy; for it is by that alone that we distinguish locomotion from purely physical movements.

But there is another characteristic of living matter, which, although not so fundamental as locomotion, is equally widespread. That is the power which all living organisms have of improving their position by adapting themselves to external conditions. So universal is this, that Mr. Herbert Spencer defined life as "the continuous adjustment of internal to external relations." The word "adjustment" is, however, not a good one, as it would apply equally to a glass ball dancing in a fountain, or to other cases of equilibrium, which, of course, Mr. Spencer never intended to include. "Adaptation," which was used by Darwin, is a much better word, and it is the one now usually employed by naturalists. Now, the power of adaptation, which is so universal among all living organisms, and which has led to organic development, necessarily implies intelligence. For, suppose a useful incipient variation to arise in an organism, then, if the organism has no power of recognising that it is useful, it will not extend or repeat the movement, and the incipient variation will die out. If, however, the organism recognises that it is useful, it will attempt to increase or repeat the movement, until a variation has arisen, sufficiently important to come under the action of natural selection. It is incredible that unintelligent protoplasm could have originated chlorophyll. Yet not only has it done so on several different occasions, but in the red and brown seaweeds it has invented two other compounds, which have the same function as chlorophyll. No doubt protoplasm makes many mistakes; but these are eliminated automatically by natural selection. Thus it appears that intelligence is necessary for organic development; indeed, the only alternative is to suppose guidance from without. And it also follows that the two great characteristics of living matter, by which we distinguish it from dead matter, imply the presence of both will and intelligence—that is, of mind. Not only is it true that, wherever we see the action of mind, we also see life associated with it, but it is also true that, wherever we see life, we recognise the presence of mind. The two terms are, in fact, identical. A living organism is a mental organism; and the origin of life consisted in the introduction of mind into protoplasm, however that may have been accomplished.

In the absence of a nervous system, we find a difficulty in supposing that the movements in the lower animals and plants are conscious; and so the word "subconscious" has been used. In speaking about them both the terms may be useful; they are analogous to the "somatic life" and "tissue life" of the physiologist. I therefore maintain that Sir Oliver Lodge was perfectly justified in saying that life is "something immaterial, and itself fundamental, something which uses collocations of matter in order to display itself amid material surroundings, but is otherwise essentially independent of them.''

* * * * * * * *

As a postscript he also wrote: ''I think the proof that life is spirit and not physical energy is very important in theology, and it leads in fact to theism. It is also equally important in biology, where, if accepted, it will lead to considerable modifications in our ideas of heredity and variation. But I must leave these points to be worked out by others. I am quite satisfied if I have simplified matters by showing that mind and life are one.''

APPENDIX II

Extract from Art. LIX. of Vol. i. of Lord Kelvin's "MATHEMATICAL AND PHYSICAL PAPERS," *on a Universal Tendency in Nature to the Dissipation of Mechanical Energy.*[65]

THE object of the present communication is to call attention to the remarkable consequences which follow from Carnot's proposition, that there is an absolute waste of mechanical energy available to man when heat is allowed to pass from one body to another at a lower temperature, by any means not fulfilling his criterion of a "perfect thermo-dynamic engine," established, on a new foundation, in the dynamical theory of heat. As it is most certain that Creative Power alone can either call into existence or annihilate mechanical energy, the "waste" referred to cannot be annihilation, but must be some transformation of energy. To explain the nature of this transformation, it is convenient, in the first

[65]From the *Proceedings of the Royal Society of Edinburgh*, April 19th, 1852; also *Philosophical Magazine*, October, 1852.

place, to divide *stores* of mechanical energy into two classes—*static* and *kinetic*. A quantity of weights at a height, ready to descend and do work when wanted, an electrified body, a quantity of fuel, contain stores of mechanical energy of the static kind. Masses of matter in motion, a volume of space through which undulations of light or radiant heat are passing, a body having thermal motions among its particles (that is, not infinitely cold), contain stores of energy of the kinetic kind.

The following propositions are laid down regarding the *dissipation* of mechanical energy from a given store, and the *restoration* of it to its primitive condition. They are necessary consequences of the axiom, "*It is impossible by means of inanimate* "*material agency, to derive mechanical effect from* "*any portion of matter by cooling it below the* "*temperature of the coldest of the surrounding* "*objects.*" (Dynamical Theory of Heat [Art. XLVIII, Vol. i., "Collected Math. and Phys. Papers"] § 12).

I. When heat is created by a reversible process (so that the mechanical energy thus spent may be *restored* to its primitive condition), there is also a transference from a cold body to a hot body of a quantity of heat bearing, to the quantity created, a definite proportion depending on the temperatures of the two bodies.

II. When heat is created by any unreversible process (such as friction), there is a *dissipation* of mechanical energy, and a full *restoration* of it to its primitive condition is impossible.

III. When heat is diffused by *conduction*, there is a *dissipation* of mechanical energy, and perfect *restoration* is impossible.

IV. When radiant heat or light is absorbed, otherwise than in vegetation, or in chemical action, there is a *dissipation* of mechanical energy, and perfect *restoration* is impossible.

[Some mathematical work omitted here.]

The following general conclusions are drawn from the propositions stated above, and known facts with reference to the mechanics of animal and vegetable bodies :—

1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.

2. Any restoration of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organized matter, either endowed with vegetable life or subjected to the will of an animated creature.

3. Within a finite period of time past, the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be, performed, which are impossible under the laws to which the known operations going on at present in the material world are subject.

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