Fossils and Life.*

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II.

THE argument for orthogenesis based on a race-history that marches to inevitable destruction, heedless of environmental factors, has always seemed to me incontrovertible, and so long as my knowledge of palæontology was derived mainly from books I accepted this premise as well-founded. But more intensive study generally shows that characters at first regarded as indifferent or detrimental may have been adapted to some factor in the environment or some peculiar mode of life.

Prof. Duerden's studies of the ostrich lead him to the opinion that retrogressive changes in that bird are destined to continue, and "we may look forward," he says, "to the sad spectacle of a wingless, legless, and featherless ostrich if extinction does not supervene." Were this so, we might at least console ourselves with the thought that the process is a very slow one, for Dr. Andrews tells me that the feet and other known bones of a Pliocene ostrich are scarcely distinguishable from those of the present species. But, after careful examination of Prof. Duerden's arguments, I see no ground for supposing that the changes are other than adaptive. Similar changes occur in other birds of other stocks when subjected to the requisite conditions, as the flightless birds of diverse origin found on ocean islands, the flightless and running rails, geese, and other races of New Zealand, and the Pleistocene Genyornis of the dried Lake Callabonna, which, as desert conditions came on, began to show a reduction of the inner toe. Among mammals the legs and feet have been modified in the same way in at least three distinct orders or sub-orders during different periods and in widely separated regions. [The instances were given.]

In all these cases the correlation of foot-structure with mode of life (as also indicated by the teeth) is such that adaptation by selection has always been regarded as the sole effective cause.

My colleague, Dr. W. D. Lang, has recently published a most thoughtful paper on this subject. His profound studies on certain lineages of Cretaceous Polyzoa have led him to believe that the habit of secreting calcium carbonate, when once adopted, persists in an increasing degree. Thus in lineage after lineage the habit "has led to a brilliant, but comparatively brief, career of skeleton-building, and has doomed the organism finally to evolve but the architecture of its tomb." These creatures, like all others which secrete calcium carbonate, are simply suffering from a gouty diathesis, to which each race will eventually succumb. Meanwhile, the organism does its best to dispose of the secretion; if usefully, so much the better, but, at any rate, where it will be least in the way. Some primitive Polyzoa, we are told, often sealed themselves up; others escaped this self-immurement by turning the excess into spines, which in yet other forms fused into a front wall. But the most successful architects were overwhelmed at last by superabundance of building material.

While sympathetic to Dr. Lang's diagnosis of the disease, still I think he goes too far in postulating an "insistent tendency." He speaks of living matter as if it were the over-pumped inner tube of a bicycle tyre, "tense with potentiality, curbed by inhibitions" [of the cover], and "periodically breaking out as inhibitions are removed" [by broken glass]. A race acquires the lime habit or the drink habit, and, casting off all restraint, rushes with accelerated velocity down the easy slope to perdition.

A melancholy picture! But is it true? The facts in the case of the Cretaceous Polyzoa are not disputed, but they can be interpreted as a reaction of the organism to the continued abundance of lime-salts in the sea-water. If a race became choked off with lime, this perhaps was because it could not keep pace with its environment. Instead of "irresistible momentum" from within we may speak of irresistible pressure from without. Dr. Lang has told us "that in their evolution the individual characters in a lineage are largely independent of one another." It is this independence, manifested in differing trends and differing rates of change, that originates genera and species. Did the evolution follow some inner impulse, along lines "predetermined and limited by innate causes," one would expect greater similarity, if not identity, of pattern and of *tempo*.

Many are the races which, seeking only ornament, have (say our historians) perished like Tarpeia beneath the weight of a less welcome gift: oysters, ammonites, hippurites, crinoids, and corals. But I see no reason to suppose that these creatures were ill-adapted to their environment—until the situation changed. This is but a special case of increase in size. In creatures of the land probably, and in creatures of the water certainly, size depends on the amount of food, including all body- and skeleton-building constituents. When food is plentiful larger animals have an advantage over smaller. Thus by natural selection the race increases in size until a balance is reached. Then a fall in the food-supply handicaps the larger creatures, which may become extinct. So simple an explanation renders it quite unnecessary to regard size as in itself indicating the old age of the race.

Among the structures that have been most frequently assigned to some blind growth-force are spines or horns, and when they assume a grotesque form or disproportionate size they are dismissed as evidences of senility. Let us take the case of certain spiny trilobites. Strange though these little monsters may be, I cannot, in view of their considerable abundance, believe that their specialisation was of no use. Such spines have their first origin in the tubercles which form so common an ornament in Crustacea and other Arthropods, and which serve to stiffen the carapace. A very slight projection of any of these tubercles further acts as a protection against such soft-bodied enemies as jelly-fish. Longer outgrowths enlarge the body of the trilobite in such a way as to prevent it being easily swallowed. When, as is often the case, the spines stretch over such organs as the eyes, their protective function is obvious. This becomes still more clear when we consider the relation of these spines to the body when rolled up, for then they are seen to form an encircling or enveloping *chevaux-de-frise*. But, besides this, the spines in many cases serve as balancers; they throw the centre of gravity back from the weighty head, and thus enable the creature to rise into a swimming posture. Further, by their friction they help to keep the animal suspended in still water with a comparatively slight motion of its numerous oar-like limbs. Regarded in

* Opening address of the President of Section C (Geology), delivered at the Cardiff Meeting of the British Association on August 24. Greatly abridged. Only the larger excisions are indicated by asterisks. Continued from p. 164.

this light, even the most extravagant spines lose their mystery and appear as consequences of natural selection.

The fact that many extreme developments are followed by the extinction of the race is due to the difficulty that any specialised organism or machine finds in adapting itself to new conditions. A highly specialised creature is one adapted to quite peculiar circumstances; very slight external change may put it out of harmony, especially if the change be sudden. It is not necessary to imagine any decline of vital force or exhaustion of potentiality.

What, then, is the meaning of "momentum" in evolution? Simply this: that change, whatever its cause, must be a change of something that already exists. The changes in evolving lineages are, as a rule, orderly and continuous. Environment changes slowly and the response of the organism always lags behind it, taking small heed of ephemeral variations. Suppose a change from shallow to deep water—either by sinking of the sea-floor or by migration of the organism. Creatures already capable of becoming acclimatised will be the majority of survivors, and among them those which change most rapidly will soon dominate. Place your successive forms in order, and you will get the appearance of momentum; but the reality is inertia yielding with more or less rapidity to an outer force.

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But in all these apparent instances we should do well to realise that we are still incompletely informed about the daily life of these creatures and of their ancestors in all stages of growth, and we may remember that structures once adaptive often persist after the need has passed or has been replaced by one acting in a different direction.

The Study of Adaptive Form.

This leads us on to consider the influence of the mode of life on the shape of the creature, or, briefly, of function on form; and, conversely, the indications that form can give as to habits and habitat. For many a long year the relatively simple mechanics of the vertebrate skeleton have been studied by palæontologists and anatomists generally, and have been brought into discussions on the effect of use. These studies, however, have usually considered the structure of an animal as an isolated machine. We have to realise that an organism should be studied in relation to the whole of its environment, and here form comes in as distinct from structure. Similar adaptive forms are found in organisms of diverse structure, and produce those similarities which we know as "convergence." To take but one simple instance from the relations of organisms to gravity. A stalked Echinoderm naturally grows upright, like a flower, with radiate symmetry. But in the late Ordovician and in Silurian rocks are many in which the body has a curiously flattened leaf-like shape, in which the two faces are distinct but the two sides alike, and in which this effect is often enhanced by paired outgrowths corresponding in shape if not in structure. Expansion of this kind implies a position parallel to the earth's surface, *i.e.* at right angles to gravity. The leaf-like form and the balancers are adaptations to this unusual position. Recognition of this enables us to interpret the peculiar features of each genus, to separate the adaptive form from the modified structure, and to perceive that many genera outwardly similar are really of quite different origin.

Until we understand the principles governing these and other adaptations—irrespective of the systematic position of the creatures in which they appear—we cannot make adequate reconstructions of our fossils, we cannot draw correct inferences as to their mode of life, and we cannot distinguish the adaptive from the fundamental characters. No doubt many of us have long recognised the truth in a general way, and have attempted to describe our material—whether in stone or in alcohol—as living creatures; and not as isolated specimens, but as integral portions of a mobile world. It is, however, chiefly to Louis Dollo that we owe the suggestion and the example of approaching animals primarily from the side of the environment, and of studying adaptations as such. The analysis of adaptations in those cases where the stimulus can be recognised and correlated with its reaction (as in progression through different media or over different surfaces) affords sure ground for inferences concerning similar forms the life-conditions of which we are ignorant. But from such analyses there have been drawn wider conclusions pointing to further extension of the study. It was soon seen that adaptations did not come to perfection all at once, but that harmonisation was gradual, and that some species had progressed further than others. But it by no means follows that these represent chains of descent. The adaptations of all the organs must be considered and one seriation checked by another.

In applying these principles we are greatly helped by Dollo's thesis of the Irreversibility of Evolution. This is a simple statement of the facts as hitherto observed, and may be expressed thus:

(1) In the course of race-history an organism never returns exactly to its former state, even if placed in conditions of existence identical with those through which it has previously passed. Thus, if through adaptation to a new mode of life (as from walking to climbing) a race loses organs which were highly useful to it in the former state, then, if it ever reverts to that former mode of life (as from climbing to walking) those organs never return, but other organs are modified to take their place.

(2) But (continues the law), by virtue of the indestructibility of the past, the organism always preserves some trace of the intermediate stages. Thus, when a race reverts to its former state there remain the traces of those modifications which its organs underwent while it was pursuing another mode of existence.

The first statement imposes a veto on any speculations as to descent that involve the reappearance of a vanished structure. The second statement furnishes a guide to the mode of life of the immediate ancestors, and is applicable to living as well as to fossil forms. It is from such persistent adaptive characters that some have inferred the arboreal nature of our own ancestors, or even of the ancestors of all mammals.

The Study of Habitat.

The natural history of marine invertebrata is of particular interest to the geologist, but its study presents peculiar difficulties. The marine zoologist has long recognised that his early efforts with trawl and dredge threw little light on the depth in the sea frequented by his captures. The surface floaters, the swimmers of the middle and lower depths, and the crawlers on the bottom were confused in a single haul, and he has therefore devised means for exploring each region separately. The geologist, however, finds all these faunas mixed in a single deposit. He may even find with them the winged creatures of the air, as in the insect beds of Gurnet Bay, or the remains of estuarine and land animals.

The Upper Ordovician starfish bed of Girvan contains not only the crawling and wriggling creatures from which it takes its name, but also stalked echinoderms adapted to most varied modes of life, swimming and creeping trilobites, and, indeed, representatives of almost all marine levels.

In the study of such assemblages we have to distinguish between the places of birth, of life, of death, and of burial, since, though these may be all the same, they may also all be different. The echinoderms of the starfish bed further suggest that closer discrimination is needed between the diverse habitats of bottom forms. Some of these were, I believe, attached to seaweed; others grew up on stalks above the bottom; others clung to shells or stones; others lay on the top of the sea-floor; others were partly buried beneath its muddy sand; others may have grovelled beneath it, connected with the overlying water by passages. Here we shall be greatly helped by the investigations of C. G. J. Petersen and his fellow-workers of the Danish Biological Station. They have set an example of intensive study which needs to be followed elsewhere. By bringing up slabs of the actual bottom they have shown that, even in a small area, many diverse habitats, each with its peculiar fauna, may be found, one superimposed on the other. Thanks to Petersen and similar investigators, exact comparison can now take the place of ingenious speculation. And that this research is not merely fascinating in itself, but illuminatory of wider questions, follows from the consideration that analysis of faunas and their modes of life must be a necessary preliminary to the study of migrations and geographical distribution.

The Tempo of Evolution.

We have not yet done with the results that may flow from an analysis of adaptations. Among the many facts which, when considered from the side of animal structure alone, lead to transcendental theories with Greek names, there is the observation that the relative rate of evolution is very different in races living at the same time. Since their remains are found often side by side, it is assumed that they were subject to the same conditions, and that the differences of speed must be due to a difference of internal motive force. After what has just been said, you will at once detect the fallacy in this assumption. Prof. Abel has recently maintained that the varying *tempo* of evolution depends on the changes in outer conditions. He compares the evolution of whales, sirenians, and horses during the Tertiary epoch, and correlates it with the nature of the food.

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Whether such changes of food or of other habits of life are, in a sense, spontaneous, or whether they are forced on the creatures by changes of climate and other conditions, makes no difference to the facts that the changes of form are a reaction to the stimuli of the outer world, and that the rate of evolution depends on those outer changes.

Whether we have to deal with similar changes of form taking place at different times or in different places, or with diverse changes affecting the same or similar stocks at the same time and place, we can see the possibility that all are adaptations to a changing environment. There is, then, reason for thinking that ignorance alone leads us to assume some inexplicable force urging the races this way or that, to so-called advance or to apparent degeneration, to life or to death.

The Rhythm of Life.

The comparison of the life of a lineage to that of an individual is, up to a point, true and illuminating; but when a lineage first starts on its independent course (which really means that some individuals of a pre-existing stock enter a new field), then I see no reason to predict that it will necessarily pass through periods of youth, maturity, and old age, that it will increase to an acme of numbers, of variety, or of specialisation, and then decline through a second childhood to ultimate extinction. Still less can we say that, as the individuals of a species have their allotted span of time, long or short, so the species or the lineage has its predestined term. The exceptions to those assertions are indeed recognised by the supporters of such views, and they are explained in terms of rejuvenescence, rhythmic cycles, or a grand despairing outburst before death. This phraseology is delightful as metaphor, and the conceptions have had their value in promoting search for confirmatory or contradictory evidence. But do they lead to any broad and fructifying principle? When one analyses them one is perpetually brought up against some transcendental assumption, some unknown entelechy that starts and controls the machine, but must for ever evade the methods of our science.

The facts of recurrence, of rhythm, of rise and fall, of marvellous efflorescences, of gradual decline, or of sudden disappearances, all are incontestable. But if we accept the intimate relation of organism and environment, we shall surmise that on a planet with such a geological history as ours, with its recurrence of similar physical changes, the phenomena of life must reflect the great rhythmic waves that have uplifted the mountains and lowered the deeps, no less than every smaller wave and ripple that has from age to age diversified and enlivened the face of our restless mother.

To correlate the succession of living forms with all these changes is the task of the palæontologist. To attempt it he will need the aid of every kind of biologist, every kind of geologist. But this attempt is not in its nature impossible, and each advance to the ultimate goal will, in the future as in the past, provide both geologist and biologist with new light on their particular problems. When the correlation shall have been completed, our geological systems and epochs will no longer be defined by gaps in our knowledge, but will be the true expression of the actual rhythm of evolution. Lyell's great postulate of the uniform action of Nature is still our guide, but we have ceased to confound uniformity with monotony. We return, though with a difference, to the conceptions of Cuvier, to those numerous and relatively sudden revolutions of the surface of the globe which have produced the corresponding dynasties in its succession of inhabitants.

The Future.

The work of a systematic palæontologist, especially of one dealing with rare and obscure fossils, often seems remote from the thought and practice of modern science. I have tried to show that it is not really so. But still it may appear to some to have no contact with the urgent problems of the world outside. That also is an error. Whether the views I have criticised or those I have supported are the correct ones is a matter of practical importance. If we are to accept the principle of predetermination or of blind growth-force, we must accept also a check on our efforts to improve breeds, including those of man, by any other means than crossings and elimination of unfit strains. In spite of all that we may do in this way, there remain those decadent races, whether of ostriches or human beings, which "await alike the inevitable hour." If, on the other hand, we adopt the view that the life-history of races is a response to their environment, then it follows, no doubt, that the past history of living creatures will have been determined by conditions outside their control, it follows that the idea of human progress as a biological law ceases to be tenable; but since man has the power of altering his environment and of adapting racial characters through conscious selection, it also follows that progress will not of necessity be followed by decadence; rather that, by aiming at a high mark, by deepening our knowledge of ourselves and of our world, and by controlling our energy and guiding our efforts in the light of that knowledge, we may prolong and hasten our ascent to ages and to heights as yet beyond prophetic vision.

International Catalogue of Scientific Literature.

AN international conference of delegates from scientific academies to consider the future of the International Catalogue of Scientific Literature was held last week by invitation of the Royal Society of London. Sir J. J. Thomson, president of the Royal Society, took the chair. The conference was attended by delegates from Denmark (Prof. Martin Knudsen), France (Prof. A. Lacroix), Holland (Prof. G. van Rijnberk), India (Sir H. H. Hayden and Dr. S. W. Kemp), Japan (Prof. H. Nagaoka), New Zealand (Prof. A. Dendy), Norway (Dr. Rolf Laache), Queensland (Sir Edw. Parrott), South Africa (Sir T. Muir), Sweden (Baron Alströmer), Switzerland (Dr. H. Escher, Dr. Marcel Godet, and Dr. H. H. Field), United States of America (Prof. L. E. Dickson, Mr. L. C. Gunnell, Dr. S. I. Franz, and Dr. Robert M. Yerkes), Victoria (Prof. E. W. Skeats), and Western Australia (Mr. G. B. Rushton). The Royal Society was represented by three of its officers (Sir J. J. Thomson, Sir David Prain, and Mr. J. H. Jeans), together with Prof. Henry E. Armstrong, Dr. F. A. Bather, Dr. P. Chalmers Mitchell, and Sir Arthur Schuster. The Italian delegates, having been delayed in the railway journey, were unfortunately not in time to take part in the proceedings.

The conference was called to consider whether any modifications in the present Catalogue are advisable and how the difficulties created by the war can best be overcome. It is well known that the Royal Society, in its "Catalogue of Scientific Papers," has undertaken to make an index of all books and papers on scientific subjects published during the nineteenth century. Sixteen quarto volumes of this important catalogue have already appeared. Four more volumes will probably be sufficient to complete the Author Catalogue for the period 1800–1900. A corresponding Subject Catalogue is also being published.

In view of the ever-increasing number of scientific publications, the Royal Society realised that it could not continue to index the scientific literature of the whole world, but that such an undertaking should be carried out by a division of labour, each country indexing its own literature, the several catalogues so prepared being sent to a central bureau in London, where they should be combined and published in annual volumes. The "International Catalogue of Scientific Literature" was the outcome. It undertook to index scientific literature published after January 1, 1901.

More than thirty countries joined in the scheme, each agreeing to index its own scientific literature upon cards which should be sent to London for incorporation in the printed volumes. Fourteen annual issues, each of seventeen volumes, have now been published indexing the scientific literature of 1901–14. It was found that the sales and subscriptions to the volumes very nearly covered the cost of production.

It might have been predicted that a work of this kind, requiring harmony between workers of so many nationalities, could not be carried out without international jealousy and friction. Such has not proved to be the case. The greatest goodwill has existed between the various regional bureaux in the different countries and the central bureau in London.

The outbreak of war interrupted the work by restricting intercourse between the nations. The finances of the catalogue have also suffered from the loss of subscriptions from Austria, Germany, Hungary, and Russia. At the same time the cost of printing and publishing has more than doubled. It was in these circumstances that the Royal Society convened last week's conference.

The delegates, while agreeing that it is essential that scientific literature should be fully indexed in order that the results of researches in every country might be made known quickly to all, entered into a full discussion as to how this indexing should be done, and passed in review the different agencies now engaged in such work.

They came to the conclusion that, even though a change be made in the future in the method of indexing, it is imperative to continue the International Catalogue of Scientific Literature in its present form until the literature published up to the end of the year 1915, and possibly also that up to the end of the present year 1920, has been catalogued. In this way the important scientific work carried out during the war period will become available for reference at an early date and continuity in the work of indexing be maintained. This recommendation of the conference will come before the council of the Royal Society at their October meeting, and we are confident that the council will wish to give effect to the proposal if sufficient funds can be obtained.

A considerable sum of money will be required. It is estimated that the rise in salaries, wages, paper, and everything connected with printing and publishing is so great that an annual issue of the International Catalogue will now cost about 17,000*l*. In addition to the annual expenses, working capital of considerable amount will be required. The sum mentioned at the conference was, we believe, 34,000*l*., this being the cost of two annual issues.

There is here an opportunity for someone to make a generous donation in aid of science. The Royal Society cannot be expected to provide the large sums now required out of its own resources. The society has already spent much money in the preparation of the Catalogue of Scientific Papers, and has lent 7500*l*. to the International Catalogue and made a further donation of 1100*l*. from its funds. Contributions from European countries are invited, but may prove difficult to obtain owing to the adverse rates of exchange. It would be a great misfortune if a work of this importance came to an end through lack of funds. We have here a league of nations engaged in making the results of scientific inquiry widely known; every effort should be made to help this league to live through what is evidently the critical period of its existence.

The question as to the future of the Catalogue after the completion of the twentieth issue was referred to a committee of the delegates for further consideration. Amongst other questions this committee will examine how far the work of the International Catalogue can be brought into relation with the many existing agencies for the publication of abstracts of scientific papers.

In addition to the abstracts prepared by many of the scientific societies and to those published in periodical collections dealing with special subjects, there are card catalogues such as that under the