PERSPECTIVES IN EVOLUTION*

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"ALL useless science is an empty boast," Shakespeare is alleged to have said, but he lived before that pernicious cleavage had been made between pure science and economic science, which suggests, as Hinton once said, that the latter is a gold-digger while the former excavates only knowledge. And while we are strongly in favour of those lines of scientific endeavour which make their first purpose an attack upon the evils that man and his possessions fall heir to in the course of Nature, and which aim at easing the human struggle for existence, there are questions of no immediate practical moment to which the inquiring spirit of humanity demands an answer. I do not think Shakespeare would have called these recurrent problems "useless science", for the mind of man requires satisfaction as well as his material need.

THE SECRET OF LIFE

Much that was mysterious about life has disappeared or is disappearing before the persistent inquiries of the physicist and chemist. Life processes of the physiological order are ruled and guided by the self-same laws which regulate action in the non-living world.

But it is just as obvious that none of these interpretations reaches the secret spring of life itself. The physical explanation of the architecture of animals must assume the power of the living thing to react and mould itself to the forces that play upon it. The Donnan equilibrium, which interprets a condition of thermodynamical balance, meets the case of a living cell only when the cell activity is at its lowest, and the more active, that is the more alive, a cell is, the less does the Donnan theory become applicable. Enzymes may be necessary for the complete activity of a cell, but, though it may hasten a chemical reaction, no catalyst can set a reaction in motion; in the case of the cell that appears to be the prerogative of 'life'.

Let us turn, then, from the minute analysis of the unit of life which in recent years has done so much to reduce the mystery of life, without, however, reaching the kernel of the mystery, to see what suggestion may arise from another point of view, a perspective of evolutionary processes.

The occurrence of certain organic aggregates on land and in the ocean, and the increase in orderly arrangement of matter revealed in the evolution of life from more simple to more complex, leads to the conclusion that in practice the second law of thermodynamics, so well established for physical happenings, cannot be satisfactorily applied to living processes; and that while no one would deny that living things in the long run and in a universal sense are subject to its demands, and indeed that in their workings they are probably controlled by it, nevertheless organisms *appear* to be able temporarily to hold up or withstand the physical course of degradation of matter, if they do not actually reverse it.

From this point of view, then, the secret of the living organism, that is its essential difference from non-living matter, is its power of trading with its environment in such a way that it can build up its body stores of high potential energy from materials of lower potential.

Phenomena of life elude treatment by the laws of thermodynamics, not necessarily because living matter does not obey these laws, but because the unknown conditioning of working organisms is too complex to yield to analysis applicable to inorganic states. Nor does it seem likely, since livingness exists within a very limited range of temperature and is readily extinguished by interferences, that it can ever be subjected to the sort of analysis which has led to the interpretation of the constitution of physical matter. It seems logical, therefore, to take as axiomatic the existence of life, not as a vital force which animates something different, namely matter, but as the activity of an atomic combination the very activity of which renders it unanalysable by the standard methods of the physicist and chemist. Thus, as one of the greatest of living physicists, Niels Bohr, has pointed out, the biologist would accept for the living world a position analogous to that accepted by the physicist for the non-living. "The existence of life must be considered as an elementary fact that cannot be explained, but must be taken as a starting-point in biology, as in a similar way the quantum of action, which appears as an irrational element from the point of view of mechanical physics, taken together with the existence of the elementary particles, forms the foundation of atomic physics."

The biologist, admitting 'life', may build up a whole body of biological theory, as distinctive and peculiarly his own, and as logical in the logic of probability which Professor Darwin advocates, as are the theories of the physicist or the chemist in their own limited fields.

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LENGTHENING OF LIFE PERSPECTIVE

There is another notable development of this century which must affect evolutionary thought, the expanding idea of the time during which the earth and life upon the earth have been in existence.

From the earlier discussions it would appear that a psychological element entered into the final estimates, as if the calculators drew back aghast at the possibility of the enormous age of the earth at which their estimates hinted. Thus almost all tended in their final summing towards the minimum of their scales, and little is heard of the other extreme—Lord Kelvin's independent maxima, reached by different methods, of 1,000, 400 and 500 million years, or Geikie's 400 million years—although these came much nearer to the modern estimate.

Now, a consensus of opinion admits credibility to estimates based upon the break-up of radioactive minerals in the rocks. We may say that life has existed upon the earth for perhaps 1,200 millions of years ; and then to complete the picture that the birth of the earth and, as the new cosmology seems to indicate, perhaps also at the same time the stupendous birth of sun and stars, took place about 2,000 million years ago.

STABILITY OF ORGANISM AND SLOWNESS OF EVOLUTION

This amazing extension of the time concept of life emphasizes anew some of the striking features of evolution. We are accustomed to lay stress on the variation of living things, upon which evolution depends, but surely more remarkable is the stability of living organisms, which retain their own characters in spite of changes in the environment, and whose germ cells pass these characters unaltered through countless generations. The edible mussel (*Cardium edule*) has retained its specific characters for two million years or more ; its genus, in a wide sense, lived 160 million years ago in the Trias. The Crinoid genus Antedon which flourishes in our own seas antedated that old bird Archæopteryx in the Jurassic Period, 140 million years ago. It is surprising enough to realize that genera of foraminifera, like Nodosaria (Silurian) and Saccammina (Ordovician), still abundant in our oceans, have retained their generic characters for about 300 million years. But they are relatively simple organisms ; it is still more astonishing to think that contemporaneous with them or before them lived modern genera (again in the wide sense) of more highly organized brachipods, like Lingula (Ordovician) and Crania (Ordovician), and that these have experienced the geological upheavals and secular changes since Palæozoic times without turning a hair, or, in the revised version, without the shift of a gene upon a chromosome.

It is in agreement with that stability of organisms that we must conceive of evolution as a process of extreme slowness, as if living things are loth to change, and ultimately change only under the direct compulsion of circumstances. Of that slow progress in its minor phases the new chronology gives us a measure.

If this time-factor is a necessary element in the evolution of species in Nature, doubt is thrown upon the validity of arguments concerning evolution based upon laboratory experiments, in which intensification of means produces rapid change. There is no reason why the reaction of an organism under such exaggerated stimuli should be the same as that produced by minimal influences of the same nature over an exceedingly long time. Even in inorganic Nature the reaction of inanimate environment may differ according to the time element. The sensitive organism delicately adjusted to a particular environment is less likely than inorganic environment to give a 'natural' answer under concentrated compulsion.

ADVENT OF MAN AND EVOLUTION

The lengthening of the time perspective of life upon the earth adds new insignificance to the span of man's tenancy of the world and new impressiveness to the part he has played as an agent in evolutionary processes. Man of our own genus, beginning in the early Pleistocene Period, has probably less than a million years behind him, but the species of man now dominant in the world (*Homo sapiens*) appeared only at the close of the Würm Glacial stage, no longer than 25,000 to 40,000 years ago. Yet even this relatively short space of time exceeds man's span as an effective agent in world change, for in spite of the arts he developed in early post-glacial times he remained practically submerged in the fauna, having little more influence upon his environment than the beasts with which he shared it.

It was Neolithic man who set the ball a-rolling through his outstanding achievements in domesticating wild animals and in developing the cultivation of the soil and the growing of crops. For these achievements, apart from laying the foundation of a new era in the progress of civilization, started a series of changes which have profoundly influenced the distribution of life upon the earth. In one direction the safety of flocks and herds demanded the elimination of beasts and birds which threatened them, and in another the need of land for crops and pasturage played havoc with the wild environment and so with the fauna which it sustained and sheltered, although the crops themselves

encouraged the multiplication of certain elements in the fauna which became the pests of agriculture

The Neolithic Age, which originated these changes, reached Western Europe only some 8,000 years B.C., though in the East and in the lands of old culture it began several thousands of years earlier. But Neolithic man, although he initiated the most far-reaching changes in plant and animal life, was himself, with his implements of wood and stone and limited powers of offence, ineffective in his interference. Even in a limited area like Scotland, few animals died out during his rule and it would be difficult to bring home to him responsibility for their disappearance. For the effective introduction of man as an agent of evolutionary change we must look to a time more recent. And that time is determined by his increasing efficiency as a cultivator and destroyer, and particularly by the need for food and fire demanded by an increasing population. These influences began to make their mark about the tenth century of our era, when several of the interesting members of the primeval fauna of Great Britain had disappeared or were on the verge of extinction, but in the centuries following the sixteenth they commenced a period of pressure, which, increasing in intensity, has transformed the faunas of civilized lands.

It is not an accident that the emergence of man as a major factor in the evolution of faunas coincided with the increased power of destruction presented to him by the invention of gunpowder and guns, and with that extraordinary increase in population which in the last three hundred years has multiplied, almost five times over, the numbers of mankind upon the earth. For this burst of population was itself the accompaniment of intensified agriculture and stock-rearing, of the spread of industries and development of commerce, all of which have had profound repercussions upon aboriginal faunas and floras.

While modern man has existed upon the earth for some 30,000 years, his part as a distinctive agent in the evolution of faunas is limited to a thousand years, and within that span his great transformations are practically confined to the last three hundred years. That is a period infinitesimally short compared with the ages during which the aboriginal faunas into which he was launched had been differentiating, redistributing and establishing themselves in a natural balance. What transformations has he wrought in so short a time ?

I do not propose here to examine in detail the magnitude of this new world factor in the evolution of faunas and floras. That is best shown in a limited area which can be intensively studied, and I have elsewhere described with reasonable thoroughness the stages and sum-total of this process in Scotland, the recent geological history of which makes it particularly suited for such an analysis

I may, however, indicate the depth of penetration of this new faunistic factor by pointing out how superficial is the view that regards man merely or mainly as a destroyer. He has indeed deliberately reduced numbers or extirpated animals for his own protection or for that of his flocks and crops, for food and other necessities, for sport, and to satisfy the whims of luxury ; and without intention his cultivation of plains and marshes and destruction of primeval forest have destroyed feeding grounds and banished their former tenants. Yet his addition to numbers far outweighs his destruction. Intensive cultivation has added a stock of domestic animals far beyond the bearing capacity of wild country, besides increasing the numbers of wild creatures which also benefit from his crops. Deliberate protection of animals, for sport, for utility, for æsthetic reasons, and on account of popular superstition, has also multiplied numbers. Furthermore, apart from numerical changes within the aboriginal faunas, man has changed their qualitative composition by introducing foreign animals deliberately (here we must include domestic animals), and unintentionally through the ramifications of international commerce.

These are simple primary effects of man's interference ; secondary and remote consequences are even more impressive in their ultimate issues. In general it may be said that, wherever civilization has made itself felt, three main faunal changes are noticeable : the largest animals tend to be reduced in numbers and eventually to disappear ; smaller creatures, dependent upon cultivation and human habitations, multiply far beyond aboriginal numbers ; and the deliberate or accidental spread of 'foreign' creatures is creating a degree of cosmopolitanism throughout the world's faunas.

How do these changes brought about by man stand, viewed in the perspective of the long evolution of faunas upon the earth ? There are two types of change in progress in the natural assemblage of animals in any region. There is a constant ebb and flow within the fauna itself due to local and temporary influences, a swing of the pendulum about a mean, the 'balance of life' which is never quite struck. But there is also a faunal drift, revealed in the story of the rocks or in any long vista of faunal history, and this is due to great secular changes, to geological influences, to modifications of climate, to the insurgence of the forces of life.

Where man's interference is temporary and casual it may be compared to the internal faunal tide, which is of little moment in the long run ;

but where his interference is persistent in any direction it must be reckoned as sharing with the great secular forces of Nature in propelling a fauna upon a path along which there is no return.

Such is the remarkable conclusion to which the long view of man's place as a natural agent brings us—that he has set in motion forces which, in our era and mainly in the last three hundred years, have wrought faunal changes which can be compared only with the great secular changes of world evolution. When the ridiculously short span of his interference is contrasted with the slowness of natural processes, the probability forces itself upon us that in a few more thousand years of man's inheritance of the earth the old order of Nature will be superseded in the faunas of the world by a new order of mankind.

Man in Evolutionary Perspective

Having thus assigned to man dominance among the forces which determine faunal assemblages, let me now endeavour to put him in his place in the long perspective of life and evolution.

Many have speculated upon the new view of man's future. To some it has seemed likely that future progress will be along the lines of individual development, that brains and mind will become more perfect in their working until man is master of all Nature. Others look to a future in which not the individual as a unit, but society as an integration of individuals will become more closely knit and more perfect in its functioning.

Still others see in the modern developments and threats of warfare a warning finger of the doom of civilization. I would remind these doubters that evolution as we know it is built upon destruction; that the development of the whole animal kingdom rests upon the destruction of green plants, which biologically are formed of the same stuff as we are, and that within the animal kingdom the flesh-eaters have risen upon the bodies of their fellow-creatures. The drama of wars amongst mankind and the imminence of war seizes the imagination, and history-books bias the mind by emphasizing wars and ignoring the quiet but effective work of millions of unknown citizens through the ages. But in our perspective of hundreds of millions of years these are the merest incidents and, war or no war, the quiet progress of evolution flows through life carrying the world of living things steadily but unobtrusively from one step to a higher.

In his short past man has been moving towards a higher intellectual, spiritual and moral standard, and the biological view would be that in the immediate future (geologically speaking) that movement will continue, and that for human beings this future lies in the development and perfection of social life and in the spreading of the social idea to include peoples and nations as well as individuals, with all the correlated advances that these imply.

That is the short view of man's future, but what of the long view of mankind upon the earth? I notice that Sir James Jeans contemplates, at any rate fancifully, the existence and progress of humanity until the shadow of the extinction of life upon the earth falls upon the world, many millions of years hence. Does our vista of life support such a view? We must admit that any view of science about the future of humanity can be only a short-range forecast; of the long-range forecast it can say nothing. The reason is that science knows only the past and the present, so that it can read into the future only the glorification or degradation of what has already been expressed in mankind, let us say better brains, better social organization, less self-seeking. Yet the unfathomable characteristic of life is that it is always throwing up something new; evolution proceeds not only by permutations and combinations of the old, but by the emergence of new lines of development. The physicist can foretell with accuracy the movements of the planets, the return of eclipses and comets, but who, knowing only fishes, could have foretold the amphibia which arose from them, or, knowing only the reptiles, could have foretold their descendants the birds and the mammals? When we leave details in the world of living things we can be wise only after the event; we cannot be wise before the event. Therefore the long future of evolution upon the earth is unknowable, so far as science is concerned.

Nevertheless, bearing that warning in mind, we may gain some hint from our perspective of life upon the earth.

We look upon man, and rightly so, as the crowning glory of evolution: stage by stage, we say, the evolution of the past has led up to him; we can imagine nothing higher, evolution appears to have reached its goal.

But step back some 180 million years in our time-scale to the Triassic period when the great dinosaurs dominated the earth and nothing higher than reptiles had been evolved. To themselves and to the creatures which shared the world with them, they must have seemed (if they had any self-consciousness), and indeed they were, the crowning glory of creation; stage by stage the evolution of the past had led up to them; nothing higher could be imagined, evolution appeared to have reached its goal. That could be said by their contemporaries of the highest creatures at every stage in the course of 1,200 million years of evolution, just as it is said of man to-day. A hundred million years have rolled past since the

time of the dinosaurs, and they and all their immediate kin have disappeared for ever, and new and unforeseen trends of life have blossomed, as they have done over and over again, and have carried the story of evolution on to the present, when man is the dominant and highest.

Looking back over that 1,200-million-year vista of the steady climb of life upon the path of evolution, it seems presumptuous for us to suppose that man, the latest newcomer, is the last word or the final crowning glory amongst many, and that with his coming the great steps in evolution have come to an end. Looking forward to the future of life upon the earth, it seems even more presumptuous for us to suppose that for the next 1,000 million years life, so surprisingly inventive in the past, should be tied for all time to come to trifling changes like increase of brain power or better social organization for mankind.

The truth is that we, bound by the past, can imagine nothing more, but if the long vista of evolution is any clue to the future, we cannot regard mankind, the crowning glory of the present, to be more than a stage in life's progress and a milestone upon the path of evolution towards a greater future. To think otherwise is to imagine that with the coming of man, so insignificant in time, the advance and inventiveness of evolution, steadily carried on through an unimaginable vista of years in which no trace of slackening can be perceived, has all but come to an end.

It may seem to you that our perspectives have carried us far afield into a future so remote that it is scarcely worthy of consideration. My excuse must be that we are so accustomed to think of man as the sole significant inhabitant of the world that it is worth while now and again to look upon him in his biological setting as but one, and yet so far the greatest, of the manifestations of life upon the earth.

THE FUTURE OF FLYING*

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EVER since man inhabited the earth, he has lived not by his physical powers, which are slight, but by the exercise of his wits. Every new invention he has made has had its warlike use as well as its peaceful purpose, and each has challenged his wits to ensure that good rather than harm shall result from the new discovery. To bend the newest invention of all, the conquest of the air, to the service of mankind is now his great task. In it, success is essential lest we presently find that it is the air that has conquered mankind rather than mankind the air. Before we can regard the conquest of the air as achieved, we must control the warlike menace.

I believe that the scientific advances of the present time, and their probable development in the near future, will help us to solve, and not to aggravate, our central problem—the task Lawrence of Arabia spoke of as "the biggest thing to do in the world to-day"—to bend the newest invention of all, the conquest of the air, to the true service of mankind.

Mechanical flight was achieved when Wilbur Wright flew in December 1903 in that odd-looking machine now so proudly housed in the Science Museum at South Kensington. It certainly does look a queer machine to modern eyes. Although the engine weighed 180 lb., it gave but 12 h.p.! Of course it was natural that this, like all the other early aeroplanes, should be built with two pairs of wings. Engineers were well accustomed to carrying bending moments by a form of girder construction having an upper and a lower boom, and in the biplane form of construction the loads could be carried in this familiar way. Such early trials as were made of the monoplane type merely seemed to confirm the idea that a strong wing structure could not thus be found, and the biplane became the accepted type. Speeds in those days were low, and even long after the war of 1914–18 it was thought that the attainment of high speed would be mainly a matter of putting in more and more engine power. More and more power was accordingly put in. This led indeed to the achievement of higher speeds, but far-sighted designers saw that there was a limit to the extent of progress by this means. But, as a Spanish proverb has it: "When one door shuts another opens". The new door in this case proved to be the streamlining of the external form of the craft as a whole.

That the cleaning up of the aerodynamic structure could carry performance much further than had hitherto been realized, and do so without any increase of engine power, was first clearly

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