HOW LIFE BEGAN

A SPECULATIVE STUDY IN MODERN BIOLOGY

BY

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TO

GEORGE BUCKSTON BROWNE

PREFACE

UNTIL now biology has been mainly occupied in studying organised life as it is manifested in each of a multitude of species. Research in this direction has been carried into very fine detail, and a truly vast store of facts has been collected. Some of these have been used to establish important generalisations, especially in genetics; but with a great many of them their significance remains obscure. No one can read any of the big biological textbooks without becoming impressed on the one hand by the amount of investigation that has been done, and on the other by the large share of it that still waits to be interpreted and understood. Its very magnitude is bewildering, almost dismaying—seemingly a case of not being able to see the wood for the trees.

Can it be that the need is to turn for a while in the opposite direction, and try to find some broader and wider conceptions about biological life as a whole? Anyway, that is what I have attempted in this book. A good deal of it follows original lines, and on this account is unorthodox. It will be for others to judge its value.

If, as a medical man, I should be asked my title to go outside my proper study and write about another kind, I would offer this explanation. Since my student days, one of the most important changes that has come over medical science is its permeation by biological ideas. From being a necessarily narrow study of man alone, it has been steadily enlarged by modern biology, until now humans have been put into their relation to the rest of the animal world. This revolution—for it amounts to little else—I have watched with full sympathy, and for my own part have tried to keep in touch with every step of it. Indeed, I should say that at the present time a medical man cannot go about his work understandingly without being acquainted with biology.

On yet another ground—this a personal one—I might defend my authorship. Biology happens to have been my first love. Before my medical training, I possessed a fervent interest in natural history, and, better than any other way of spending my life, I should have liked to devote it in this direction. But like most others, I needed to earn my bread and butter, and in those days there were no openings in biology except a very few in the British Museum, none of which I could hope to obtain without having graduated at one of the older Universities. As the next best vocation, one that fulfilled the dire necessity, I became a doctor. But ever since, my heart has remembered its early attachment.

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CHAPTER I

ABOUT THE BIOLOGY OF MAN

OUR theme is the beginnings of primitive life, and like many other subjects it will be understood best if approached from a distance. On this account I propose starting at the other end, allotting the present chapter to the least simple form of being—man. Biological research has reflected a fresh light onto that particular organism which, in our conceit, we have labelled "Homo sapiens," different to any that could come from the medical sciences. It has portrayed him in his relations to other animals, a view which was impossible from the standpoint of human anatomy and physiology. My endeavour will be to give here what seems to be the main contribution that has been made in recent years to this more comprehensive interpretation of the human body, at the same time not excluding some ideas of my own, which, though novel so far as I know, seem to me worth putting on paper.

I

Nearly four centuries have passed since the

Renaissance, when Vesalius in his great work, *The Fabric of the Human Body*, placed anatomy on a scientific basis; more than three centuries ago William Harvey did the same for physiology. From that period, both these sciences have grown, and have become the foundation of present-day medicine. Human anatomy has been studied intensively, and an abundance of data collected. Every organ and every structure has been mapped to the last particular, so that little can remain undiscovered. Human physiology, too, has developed, slowly at first, but in recent times quickly, until now it has brought together a great deal of knowledge. Not that it has solved all its problems, and it still has fresh discoveries to make.

I recall that, as a student of medicine, I was required to assimilate a veritable mass of anatomical minutiæ and of physiological facts and theories. I was taught the action of this part of the body, and the function of that. I learned about the rôles of practically every bit of specialised structure—and these are many. But one thing I heard nothing about, never knew the question to be mentioned, still less discussed. It was this. With its many intricate structures and complicated activities, what is the human body as a whole intended for? What is it all about?

It seemed to me impossible to suppose that it did not have some underlying purpose. As an entity itself, it must serve some end, if only we could find it out. This problem I have often turned over in my mind. If we know what the body comes into existence for, we have identified its prime function ; and when we have discovered this, we can begin to understand how each of its parts makes its own contribution to the main scheme. I should like to give the conclusion I came to about it. I reached it by passing in review each anatomical system in turn, and particularising its chief special duty.

The alimentary system serves the rôle of nourishment and excretion. The respiratory is for oxygenation. The heart and blood-vessels for the circulation of the blood. The lymphatic system to antagonise infection by diseases. The nervous system for co-ordinating and integrating the activities of the body, and keeping it apprised of its surroundings. The endocrine glands (still in part enigmatic) to control bodily growth. The urinary system for excretion. The muscles and joints for movement, with the skin as a wrapper, connective-tissue as packing, and the skeleton to keep everything in shape.

This list shows that each set of organs specialises in some kind of work. Work to what end? If we take any one of these systems, we cannot imagine that the others have become specialised in the interests of that one. For instance, that all the rest of the body has developed in order to oblige, as it were, the heart and blood-vessels, and give them their individual job to do. We must suppose rather that whatever the kind of anatomical structure, it subserves some common aim which is outside the whole of them. In that case, the only item that has been omitted mention in our list, is the sex-gland—the gonad—in which lodge the germ-cells. Must we not infer that each of the bodily forms and functions is a specialisation on behalf of this germ? The conclusion seems irresistible to me. And this brings us back to our original question, what is the body for? Our answer must be—to house the sex-cell. All the complicated details of the human frame are united in the single purpose of serving this tiny particle within it. They contribute to its healthy existence, and without them it cannot mature, or even survive.

In this way we have reached what looks like a valuable generalisation. But it hardly accords with the present-day medical opinion. Hitherto in the medical sciences, the human body has been regarded as of chief consequence, with the generative cell a detail as unimportant as it is microscopic. This view has inevitably taken shape in the course of the centuries when human anatomy and physiology have filled the horizon. We need now to recognise that the germ is of the foremost significance, with the body merely as a kind of offshoot from it—and this in spite of the enormous disparity of size and apparent complexity between them.

II

Some medical scientists may feel sceptical about this notion of the primacy of the human germ, and the body being its ministrant. If so, the idea can be confirmed from the wider sphere of zoology. It was August Weismann who, towards the end of the last century, first separated the germ and the body (or soma). He claimed that the life of the former is transmitted from generation to generation, and that the latter dies. Today biologists generally agree that the one is immortal, the other mortal. This epochal discovery must surely hold true in the narrow field of human existence. Let us apply it here.

If the human germinal cell is immortal and the soma mortal, we must envisage a germ producing a succession of bodies—generations, as we know them. Each of these comes into being and dies, while the cell goes on. If we picture human descent being speeded up so that threescore years and ten pass in a day, we should see a germ producing a new soma every few hours. We could watch it, after uniting with a cell of the opposite sex, encasing itself in a fresh human frame. Then, when this new body had come to full growth, it would quit it, and again joining a germ as before, at once set about making yet another soma around itself. This is the biological process that lies behind human procreation.

We should also see that each of the bodies, not long after it had been cast off in this way, would perish, crumble, and return to the inorganic state. Its elements would be used—and probably used again and again—in fashioning other somas, human or animal, and plants. (A fact which, parenthetically, is pretty fatal to the religious belief in human resurrection.) We may be sure, too, that the material out of which we ourselves are made, has almost certainly gone, all down the geological ages, to construct many other living things.

The point I should like to make is that the germ-cell forms a body in order to assure its own vital continuity. In this sense it might be regarded as extruding the soma, or even secreting it. In due course it sheds this, but not until the cell has ripened. From this it might be inferred that a body's main function is to serve in maturing the sex-cell.

Perhaps we shall form a better idea of the succession of human generations, if we realise that the whole of it is very similar to what we are familiar with in garden annuals, only that it takes rather longer. In the case of a fox-glove, for example, a seed produces a stem, leaves and flowers, and the new ovule, when it has been fertilised, quits the plant. The latter dies and decays, but the seed provides itself next year with another plant as before. This is repeated annually, whereas man's cycle of generations is of course about 20 to 30 years.

We suppose, then, that the human soma is produced by the fertilised human germ as a set of organs which the cell needs, if it is to survive and multiply. Otherwise, it does in fact die; and this we know is the fate of the overwhelming majority of sperms and ova. Only those have a chance of living on and attaining Weismannian immortality which are able to provide themselves with somas. These latter, therefore, are essential to the sex-cells.

This need is only temporary while the young cell is ripening; and, some time after puberty, it leaves the gonad, as we have seen, and, uniting with another, throws out a new human body. This functions on behalf of the germ, once again in an immature state, as the older soma did previously. Note that the germ-cell is for ever alternating between what we call an immature and a mature condition. Each time it reaches the ripe stage and, joining another, starts growing a new soma, it is simultaneously reduced to its rudimental form. Why this should be is not easy to suggest. Perhaps it has to do with the fact that its requirements are now being supplied by the somatic organs around it.

Here again it must be stressed that the real significance of human organs and functions, will be understood only in their relation to the germ. Their raison d'être is to meet the cell's needs. Per contra, we may expect to learn about the nature of a germ-cell from what we already know of the body. To specify a fairly obvious example of this. What is there in a male gamete which makes it surround itself with that kind of soma which we speak of as "masculine," when the female gets along all right without producing, say, a hairy skin ? The difference between them must surely be in the sex-cells themselves.

III

This account I have given of human descent is, I believe, entirely accurate biologically, except in the one detail of speed. We may find it useful and even salutary to know about it on two grounds at any rate.

First, it makes known to us that we ourselves, with all our human vicissitudes large and petty, are only very temporary excrescences on a vastly long life-line of ancestors and descendants. This may help to reconcile us to our daily tribulations, by giving us the best possible perspective for viewing the past, the present and the future. Secondly, the bird's-eye view that it offers of human genealogy, indicates unambiguously what are, scientifically, the first things to be taken first. By impressing on us the fact that a human soma, notwithstanding its size, is essentially a product of a tiny seed, it shows us that, if we are to improve human beings, we must direct our efforts to the generative cell. Future researches must concentrate on the gametes.

Here is another conclusion not at all in harmony with the current medical ideas which place the body first and the sex-cell almost nowhere. Biologically, this is a topsy-turvy way of looking at things. It will hardly be superseded until medicine becomes further penetrated by the discoveries of its sister science. In eugenics alone is it being recognised that the germ-cell should and must come first, and that its study is the direct road to human improvement. As this becomes generally accepted, changes will follow in both medical practice and training. The latter has hitherto been mainly anthropocentric, but on a biological basis would take on a very different form.

It seems to me that the whole range of science can have no goal of greater moment than to understand the conditions favouring the human germ-cell. A good deal has been done in this connection, but it is only a beginning. More needs to be learned both about the surroundings, as they affect this germinal life, and about the cell itself. Here I need only instance the question what sex is. Since this is differentiated at least as early as the gametes, it is not later than in these that the problems of human sexuality must lie for their ultimate solution. In other words, love as manifested in social life, must be an elaborated function of the same primitive cells.

All this goes to emphasise again the pre-eminent importance of matters relating to human breeding. Yet this subject has still to find its apologists. So far, we can note the current interest of a very few in genetics, when this should be the concern of everyone who gives serious thought to the future of mankind.

IV

Arising out of this, I should like to venture a speculation about the nature of the two sex gametes. We know that in each of them is a quantity of physico-chemical energy—when they fuse, their metabolic activity is instantly quickened, even several thousandfold, as has been shown electrically and chemically. We know also that a new soma starts growing only after the germ-cells of opposite sexes have come together. This would suggest that the energy contained in them is of two sorts, which are complementary to each other; and that each needs to be supplemented by the other in order to usher in the intense excitement and vigour that leads to cell-division. If this is correct, sex would represent, fundamentally, two dissimilar kinds of force. It is hardly possible not to be reminded here of the only comparable duplicate form of energy in the physical world, namely, negative and positive charges of electricity. Can it be that sex is primarily a difference of this nature, and that male and female stand in the relation of negative and positive electricity? It is indubitable that sperm and ovum attract each other powerfully. Is this, then, a matter of electrical charges? In that case, the mutual fascination of the adult male and female would seem to be another instance of the same thing. We may even suppose that the lures and artifices in the love-life of men and women, give expression to electrical attraction.

This opens a vista of the whole range of love and sex. Love has always preoccupied the minds of our greatest characters—poets and painters, dramatists and novelists—and it has recently those of psychologists. And now it would seem to be in its ultimate analysis an affair between electrons and protons. Here, perhaps, is a pathway beginning in the arts and running through psychology and biology to chemistry and physics. Maybe by opening communication from one end to the other, it will afford a freer interchange of thought between these various subjects of human interest than has been possible hitherto.

I said just now that the sexuality which enters into social life must be derived from the germ-cells, and that within these is to be found the explanation of all adult sexuality. These rather cryptic statements will now have become elucidated, if it is with electrical charges that we are dealing, as I have suggested. Along this line of interpretation we also get our first glimpse of the way a soma may function on behalf of its germ, namely, that an adult male and female in their behaviour to each other, carry out the behests of the sperm and ovum within them.

Another idea might find its place here, helping perhaps to throw light on a remarkable biological fact which, so far as I know, has never been accounted for. Why among the higher animals are millions of small, active sperms emitted by the male in order to fertilise one large and passive ovum? These masculine elements can be watched under a microscope swarming vigorously all round a stationary female cell. Modern physics would seem to present us again with a suggestively similar picture in the structure of an atom—extremely light electrons revolving rapidly round a positively charged nucleus, into which is concentrated the mass of the atom. This atomic formation has, of course, already been compared by physicists to the solar system with the planets moving quickly round the central sun. Is biological life, then, akin to these two, and intermediate between them?

CHAPTER II

HEREDITY AND ENVIRONMENT
CAN THEY BE DISTINGUISHED?

Our goal is still the beginnings of life, but we cannot avoid something more by way of a preliminary approach to it. We have not altogether finished with Homo sapiens, though we shall now consider him side by side with the rest of the animal world. Every organism is held to be composed of two streams which intermingle—one which comes to it by inheritance, and the other from its environment. If we are to understand how primal germinal existence was set going, we must first be clear about these two. We should be able to trace them back step by step as they have played their parts in evolution, until we see them as they affected living matter when it started.

I

This subject of heredity and environment possesses everyday social applications of the highest significance, and yet it is one of those larger questions on which scientific opinion, both medical and biological, is not as yet united. This difference of views is so well known that I feel exonerated from citing evidence to prove it. Still in dispute are not only the exact rôles of nature and nurture, but also even the extent and limit of each sphere of influence. Not that the matter has gone undiscussed : on the contrary, it has been debated and debated again, these several decades. All this "interminable argument," as more than one writer styles it, seems to have left us not a great distance from where we were at the beginning, and perhaps rather more perplexed.

If, notwithstanding, I shall venture to revive this hoary topic, I shall ask indulgence on two grounds. First, it is not my intention to bring up any of the old arguments, for or against. I propose instead to approach the subject from a standpoint which is new, so far as I know, and provides some fresh considerations that should help to clarify our ideas. Secondly, my hope is to be able to account for the divergence of opinion hitherto, and to show that it has indeed been unavoidable. I believe I have succeeded in bridging the chasm between the hereditarians and the environmentalists, and in going most, if not all the way, towards reconciling their conflicting views.

II

Let us begin by defining the two biological conceptions that we are about to discuss. These terms, I find, are differently explained by authors, and for my present purpose I would give them the following meanings. Heredity I take to imply the transmission from one generation to another of structural and functional tendencies to develop organised life. By environment I understand the conditions around a living being.

What are the general relations between these two? It seems to be agreed medically and biologically that :—(1) heredity and environment both play indispensable parts in development, and (2) each operates separately from the other. If corroboration of these important conclusions should be required, I should like to refer to Dr. Julian Huxley's Galton Lecture before the Eugenics Society in 1936 where he says that nature and nurture "are both essential." Let me quote also as another recent and authoritative statement, Prof. L. T. Hogben's words in his *Principles of Animal Biology*. "Heredity and environment," he writes, "are different aspects of development; but they are independent of one another." (p. 115.)

These views would, I suppose, be accepted by almost everybody. At one time I assented to them, also ; and it was only on trying to apply them to what is now known about the conditions of biological life, that my doubts were raised. They did not seem to work. If, so it seemed to me, heredity and environment are indeed independent of each other, we should be able to trace the extent of their separate influences, and to delimit clearly the boundary between them. Their origins would presumably be different. Certainly their activities should be detectable apart from each other somewhere in the life process. In a word, we should be able to draw a dividing line between them.

As I will describe immediately, my attempt to do this has proved surprisingly difficult. I will set out the considerations which seem to show that, in most instances, it is impossible either to recognise the factors apart from each other, or to separate their effects. Let us see where we are led when we try to delimit them as different and independent aspects of development.

III

Opinions as to where inheritance leaves off and environment begins have by no means remained unchanged. They have been gradually remodelled to meet new facts. In themselves, the antithetical ideas have nothing very ancient about them, even on the side of their medical ancestry. They date back just a century, and it was Herbert Spencer who first discriminated between them, though Darwin and others soon made use of them. We need look back no further than the opening years of the present century, in order to learn how notably different the views were then from what they are today. At that time the term environmental was applied, by doctors at any rate, to all that occurred after birth ; and what happened before was called hereditary or congenital. The birth process was taken as the line of separation—a convenient one surely enough, though not very scientific as we see things now. But at that date practically nothing was known about the conditions of prenatal health and ill-health, and the very words prenatal and postnatal had not been coined, showing that the need for the distinction they express had not as yet been felt.

Birth seemed to initiate a period of luminosity which was accessible to scientific investigation, and to terminate another where most things were wrapped in what looked like impenetrable dark. It was not realised then, as it is now, that birth is only an incident in anyone's life, and not of the first importance either. Here our narrower medical notions have since been greatly widened by biological ones. Psycho-analysis, too, has familiarised us with the continuity of mental phenomena from adulthood through infancy to prenatal life. As a result, we have come to look on the birth process as being little more than traversing a very short tunnel in the course of a very long biological journey. In this manner, scientific curiosity has been turned upon prenatal problems, in a way that was impossible so long as our medical ideas were limited to an obstetric point of view.

Changes followed, therefore, in the current ideas about inheritance. Once it had been shown that a healthy child might become diseased even before its birth, as a result of unsound conditions existing in its mother, it was no longer possible to label all prenatal influences as hereditary. Clearly the maternal body (or soma), since it might injure the embryonic child within it, could only be counted a part of the environment. The term hereditary accordingly became restricted to the child, and rather hazily, to the uterus around it. Gradually the distinction was drawn more closely, until the embryo alone came to stand for the inherited element, with the maternal soma, together with the womb, as environmental.

Today the separation has been carried back further still. It is made no longer between an embryo—still less a fœtus—and its mother, but is applied to that very early stage just before the embryo has begun to form—that is to say, to the germ-cells themselves, whether sperm or ovum. The following seems to be the present position in both the medical and the biological sciences. All that is implied by heredity is to be found solely in the germ-cell and what it comprises at the moment the female is fertilised by the male. In contradistinction, all the influences outside this fertilised ovum (or zygote) which may affect it, are now brought under the heading of environment.

IV

The foregoing I take to be the existing state of the theory. I propose examining it in some detail, and to set forth the difficulties which appear to me to arise in trying to harmonise it with recent biological and medical advances. I shall give reasons for supposing that the factors of heredity and environment are not so readily separable as has been supposed. On the contrary, in nearly all instances when they are studied, the two prove to be so intermingled that there is no disentangling them. I shall suggest that we need some other way of representing and elucidating the biological developmental process. And, parenthetically, if, the rôles of inheritance and environment are in the main indistinguishable from each other, have we not here the explanation of the confusion and never-ending argument on the subject of the past? It would seem that both the hereditarians and the environmentalists have been right in what they claimed to be able to see, but both wrong inasmuch as they failed to recognise the other half of the picture.

Now to apply the current, accepted ideas to the actual facts of development, as they are known to us. Let us try to see what it is that is supposed to come to an organism by inheritance, and what from its surroundings. Consider first a newly fertilised ovum, human or mammalian. According to the contemporary view, all the hereditary elements are included within this zygote—if not in the genes and the chromosomes alone, at any rate in these and the germ-plasm—and are transmitted by it to the embryo. What constitutes the zygote's environment? This is threefold:—(1) the womb, (2) immediately beyond that the maternal soma, and (3) beyond that again the outside world.

Cell-division has begun in the zygote, and soon an embryo has formed, which later grows into a fœtus. Inside this immature being lies its sex-gland (or gonad), harbouring its rudimentary germ-cells. It is evident, therefore, that until the time of birth, the offspring's germ-cells are enveloped in two somas, its own and its parent's. Still to adopt the present view, we are to regard the embryo's soma as hereditarily derived, and the mother's as environmental. This indeed follows from making the separation between heredity and environment at the zygote stage.

Next let us consider the fertilised ovum again, but this time in order to trace its origin backwards to an earlier generation. It lies, as we have seen, within the maternal body, and it has been freshly made by the union of the two sex gametes. The female of these, we know, has laid in the mother since she was an embryo in the grand-maternal body. Similarly, the male gamete has come from a paternal soma in which it has remained since the father was an embryo in another grand-maternal body.

Let us trace the female line of ancestry first, and we need to attend rather carefully to what follows. Conformably to present theory, the maternal soma, when it was inside the grand-maternal, was hereditarily constituted, with the grand-maternal as its environment. But we saw just now that this maternal body, regarded in relation to the embryo within it, is environmental. If I have stated the position accurately—and I believe I have—it is difficult to resist the conclusion that the same (maternal) soma which, in an earlier generation, is the product of inherited factors exclusively, becomes later solely environmental. Equally, when we trace the inherited constitution of any embryo forward one generation, it becomes part of the environment. In other words, in both these cases, what is hereditarily determined at one period of descent becomes, when traced forward, environment in the next. We see the one changing into the other.

Yet again, when we follow the process back a single generation, we find environment in the form of a maternal soma, and heredity as expressed in an embryo, both becoming heritable. Here again the two are exchanging their distinctive complexions.

What has been said about the female line appears to hold of the male likewise. We have to label paternal somas inherited or environmental just as happens to fit in with the stage of their development.

All this seems surprising, and not a little perplexing. It would look as if we are up against something like a confusion in terminology, such as is not usually tolerated when we are trying to define a pair of influences which are supposed to contrast with each other. Must we not conclude that our present distinction between heredity and environment can serve at the best only in the case of a given generation? Applied over even a couple of successive steps in descent, it does not hold good. However many generations backwards or forwards this may be tested, a parental soma will always be found to be doubly constituted : first, as the environment of the germ-cell or embryo it encloses, and secondly, as the product of its own inheritance. A conception of heredity and environment which fails to recognise this, surely needs revising again and bringing up to date.

And yet, if I am asked what means we have of determining what comes to an organism from the one source, what from the other, I am at a loss. I cannot even imagine any way of doing this. The two spheres of influence are so mixed up as to be indistinguishable from each other.

V

To pass to another set of considerations. So far we have been examining our subject as it appears in successive generations—in longitudinal section, as it were. Now let us see what a transverse has to show—how far, that is, we can discriminate between heredity and environment in any one generation.

We noted earlier that outside the zygote lies the maternal soma—this we have dealt with—and beyond that the external world. What help has this last to give in the matter of differentiating between inheritance and surroundings? Few, I suppose, would be prepared to say that the outside world could be anything but environment. Since it comprises air, moisture, chemicals, nourishment, and the physical conditions of heat and light, it might seem to typify environment in contrast to heredity. In point of actual fact, have we not all been taught to regard it as the very pattern and model of everything appertaining to nurture?

But let us look a little closer, and we shall find that the material of this environment constitutes also the substance of every organism, even making up almost its entire bulk. When a zygote goes through the cell-division which leads to an embryo being formed, it increases in its size and mass; and its growth comes to be enormous. This implies that nutriment of every kind passes into it from the outer world, either through the intermediary of the maternal soma, as in mammals, or directly, as in simpler beings. An embryo, on that account, must be composed to a very considerable extent of the material which has been its environment all the way through. It would seem obvious, therefore, that all growing things must contain, in addition to their inherited derivatives, a substantial amount of the actual stuff which is commonly regarded as environmental. And, of course, by the time that adult maturity has been reached, this would apply in even greater measure.

We have to recognise that no animal or plant can be the pure product of inheritance, but that every one of them is inevitably a mixture containing environment as well. The outside world can hardly be regarded any longer as typically contrasting with the inside world of an organised being, since it enters so largely into the latter's composition.

An additional fact which perhaps best finds mention here, relates to any attempt to isolate the two factors of inheritence and environment, even as early as the germ-cells. These gametes are themselves, ex hypothesi, the very epitomes of heredity. But we have now to recognise that, as they grow and mature prior to fertilisation, they must incorporate within themselves the ingredients of their surroundings. They, too, are no pure product, but another compound of the same kind as before. Should they unite later, the zygote which they form can only be one more instance of the same admixture ; and this from the first moment of its existence. How, then, can we continue to suppose the contrary, namely, that it is constitutionally the outcome of inheritance only? Yet this is what everyone seems to accept without misgiving, when really by far the greater part of every zygote has no possible connection with any constitutional origin.

To carry the argument a final step further. What can be said of a germ-cell's chromosomes and genes —the ultimate conveyors of inheritance? Can we doubt that they too, as they grow, take in material from their surroundings; and that their composition is another mix-up? Any other explanation of their increase in size is difficult even to conceive.

We have seen, then, that what is environment at one period of life, becomes later an integral part of organised matter; and that this cannot accord with any existing theory that a living being contains only what is constitutional. On the contrary, every organism is part nature but mainly nurture, and this applies to all the stages of its growth. Not even in the case of a gene can we point to one of these factors apart from the other.

Is it ever possible to distinguish what has been transmitted by inheritance from what has been derived from the surroundings? Or are these two aspects of growth so amalgamated as to be beyond our powers of separating them and identifying each of them? If it is possible, it is beyond me to suggest how to do it. It seems to me that the very division into heredity and environment breaks down in its application. No one can say in the case of any kind of organised life from humans downwards, what is to be attributed to the one, what to the other. All that we can assume, so far, is that any clear distinction between them can be made only at a stated period of time; but over a sequence of time, and, still more, over a succession of generations, it cannot be drawn. If this is so, not a little of those practical aspects of the medical and biological sciences which have been and are being built up on the contrary belief, will need to be reconstructed.

VI

Support of the foregoing would seem to be at hand in the special field of human psychology. Here, too, contention is still lively about the relative values of heredity and environment as factors in mental health and ill-health. Formerly, inheritance was held to be all-important; but in recent years environmental conditions have come to be more generally recognised as affecting psychological development even deeply. Psycho-analysis has shown, in this connection, the signal importance of the earliest years of life, character being moulded for good or bad within the first five or six years. Throughout this period the decisive influence is held to rest with the parents ; and these are placed in the category of environment. Accordingly, many adult psychological illnesses which are now known to originate in childhood, are represented as environmental and not inherited. But no agreement has been reached about this, and many medical psychologists still stress the rôle of heredity.

But here again the question will repay closer study. Even when we have admitted not only that a child's personality is largely fashioned by its mother and father, but also that other contemporary factors are of small account, the matter needs to be carried a little further. How does the parental influence come to take its particular shape? Since character is formed in childhood, must not the parents' natures have been settled in their own early years, when their sensitive personalities were acted upon by the grandparents? Here we seem to bring to light an element of transmission and inheritance in a situation which looked, prima facie, a straightforward example of character being modelled by environment. This is confirmed when we find, on tracing the process backwards, that the psychological part played by the grandparents in the lives of the parents as children, was itself determined by the great-grandparents—and so back and back.

Must we not recognise in this an undoubted transmission of inherited psychological qualities? In that case the moulding of a child's nature by its parents is environmental only when its own generation is taken into account. From the wider view of successive generations it is hereditary. And the wide view is probably correct.

This should go a long way towards reconciling the contrary opinions which, as I have said, are still prevalent. Both views are accurate so far as they go, but neither expresses the whole truth. The conclusion would seem to be that the psychological environment counts for most in childhood, but is itself the product of inheritance.

I have no particular liking for coining new terms, but perhaps the present circumstances warrant it. An "inherited environment" describes precisely what I am speaking about. It may sound a contradiction in terms, and I can imagine it being looked at askance by the orthodox. All the same, I put it forward as both valid and necessary for describing the situation accurately. Maybe we have here yet another instance of the awkward position we land ourselves in, when we try to keep environment and heredity in separate compartments, and find it cannot be done. We are forced to invoke both of them together.

An inherited environment seems a novel idea: if only on that account I feel chary of casting it aside. It may come in useful in a later chapter, applied to a much larger field than the psychological. I have it in mind that we may have occasion to surmise something about inheritance in connection with the material, terrestrial environment that surrounds consecutive generations of living things. The same idea of an inherited environment may prove helpful again.

CHAPTER III

HEREDITY AND ENVIRONMENT

(CONCLUDED)

I

I BELIEVE I have been able to show in the previous chapter that it is impossible to say what has come to organisms through the strict line of inheritance, and what has been added to them from outside. We cannot do this even over so short a span as a couple of generations, and when long periods of descent are involved, the case is by so much the more hopeless. Nevertheless, so far as we have gone, it would seem still practicable to differentiate between the two, subject to one proviso—and that is, that we make a limit in the matter of time. If we imagine any living being at a given moment, we might suppose it to be the easiest thing to draw the line. All we have to do is to indicate that here is the creature representing its own heredity, and here all round it, is its environment. This would certainly be a necessary distinction to be able to make in experimental work, so much of which aims at tracing the different rôles of nature and nurture. This research appears to proceed on this very assumption that animals and plants are made up of what is exclusively heritable, and as such can be contrasted with what looks obviously to be pure environment. But how far is this reliable? Or does it mask something in the nature of a fallacy? Two important qualifications must be taken into account.

The first is that the time limit must be very narrow. Interchanges are always going on between an organism and its surroundings as part of the vital process itself, and these speedily produce alterations in both. Some of what is organised substance at one instant has become a constituent of the environment at the next, and the same applies the other way round. Any attempt, therefore, to demarcate the two could be strictly valid only for the moment; and must become more and more inexact with the flux of time.

The second qualification is more far-reaching. It is this. We have learned that living things are never the unadulterated product of heredity, but always include much that has come from outside. While it is possible, therefore, at any moment to point with certainty to their environment at that time, they themselves regularly have a mixed origin, and no one can know what has come from the one source, what from the other. This would seem to fatally dispose of any differentiation being made, however brief the period may be. Of the numerous biological and medical studies and investigations that have been carried out on the problem of heredity, most have assumed the contrary, namely, that the rôles of nature and of nurture can be traced separately ; and many of their conclusions must be weakened, if not vitiated, on this account.

In view of all this, are we not able to understand the widespread difference of opinion in the past between those who detected only inherited factors, and those who pointed exclusively to environmental influence ? As we see their positions now, each school was correct in what it saw, but incorrect in what it overlooked. They did not know, as we do, that all organised life draws from both sources.

II

The conclusion to which we have moved is that the antithesis "heredity—environment" breaks down in its practical application. The two concepts, instead of representing independent aspects of development, cannot be separated from each other. We need to replace them by some other kind of explanation of the growth of living things. Where are we to look for this? As I see it, it should be based on the very intimate connection which, as we know, exists between every organism and its surroundings. No plant or animal can exist without these external conditions. In this sense the environment suggests itself as an essential part of every organised being. Here is an idea which is both elementary and fundamental. Let us see where it will lead in revising our understanding of biological life.

Now that we are freed from thinking rigidly of development as presenting two different and independent aspects, we may approach with an enquiring mind another established belief. The phenomenon of life itself has always been regarded as being comprised within each living structure: it is the individual possession of every organism from amœba to man. The following question presents itself. In view of the fact that a living particle is very closely and intimately related to its environment, should we still stress the differences between them, and restrict the term life to what lies on the one side only of a dubious dividing line? Or recognising their similarities and affinities, should we begin to think of what we call life as being also a property of what surrounds an organism? The subject that we are broaching is not merely the old physiological difference between internal and external environments; it is much more than this, as I shall now hope to show.

III

When we regard any living creature, small or large, we perceive it, and are accustomed to think of it, as being in contrast with its immediate surroundings, and circumscribed by them. We look at a horse or a dog, for example, and see it as possessing a certain solid form with a hairy covering, and it stands out, maybe, against some grass and trees. Discerned in this way, an animal appears surrounded by space—the atmosphere—from which it seems to be differentiated both sharply and completely.

I suggest that herein lies the prime origin of the dual concept of organism and environment, together with a sense of contrast and opposition between them. I would date it from at least as long ago as ancient man, when his simple mentality was impressed in precisely this way. But let us examine the situation in detail, studying it, not as though our minds were still primeval, but in the light of the facts provided by modern science. For convenience solely, I will use the human animal as our paradigm, though any of the more complicated metazoa would be suitable.

Man's anatomical body, far from ever being made of too too solid flesh, is de facto so divided by hollow spaces as to be riddled by them. From mouth to vent passes one tube—the alimentary canal. By twists and turns it comes to measure some thirty feet over all; and its interior surface represents an area of a square yard or two—approximately that of the human skin. Another hollow passage—the respiratory—runs from the throat to the lungs. Here it divides into smaller and smaller tubes, until in the end it spreads out over an extent of about 120 square yards—60 times that of the skin. Yet again, the body is traversed by other hollow channels—the generative and the urinary—which begin deep inside it, and open on its surface.

Here, then, are anatomical data which lend small support to the idea that the human organism is differentiated from its environment either sharply or completely. On the contrary, they show that the apparently solid body is nothing of the sort, but is tunnelled and hollowed by canals and tubes and passages which reach to its furthest interior recesses. True, it is surrounded by space, but it is also permeated by space.

To carry the argument another stage. Along the alimentary canal flow nutritives, all of which come from the outside, and are a part of it. Similarly, the currents of air that pass up and down the respiratory channel to aërate the blood in the lungs, are derived from without. Both these main tubes together with their contents are, therefore, portions of the environment which are prolonged interiorly. Where, then, is the line of separation to be drawn between the body and its surroundings? At its surface, as is customarily done? Clearly not, since some of what envelops it, penetrates it also. The two overlap, spatially and structurally, to such an extent that the boundary between them must be almost inconceivably plicated and involved. Any idea of isolation and contrast between them can hardly be maintained.

A final proof that it is impossible to draw a dividing line is afforded by the microscopic details of the conditions where the two meet. Take the lungs, for example, with the oxygen from the air passing through the fine texture of the lung-cells into the blood, and carbon dioxide and water vapour going in the reverse direction. The transit of these gases is so gradual that no one can fix a moment when they have ceased to belong to the environment and have become a part of the organism; or vice versa, no one can say when they are no longer organised matter and again help to form the atmosphere. The same applies to the alimentary canal with nourishment and excreted matter moving through its lining: no exact demarcation between body and outer world can be made. It is quite impracticable to decide where one leaves off and the other begins.

We cannot escape the conclusion that functionally, as well as spatially and structurally, living beings and their environments merge and blend in such a manner and to such a degree that there is no separating them, or isolating them from each other. They constitute a unity. Must we not allow, then, that the phenomenon of life is the property, not of one part of this combination, but of all of it? Let us try and develop this idea.

IV

Any new conception of biological life should be based on this essential unity of an organism and its surroundings. As this is gradually realised, we begin to give up stressing the differences between them, and representing their activities as being opposed to each other. Still more, we are not content to depict living things as struggling for their existence in the conditions around them. All this appears to be only a partial interpretation of the facts, and is better replaced by another in which organised matter merges into its environment, the two being reciprocally dependent.

This relationship is paralleled by another which is generally recognised in physiology. Here the individual somatic cells are bathed by outside streams of blood and lymph, which physiologists regard as constituting their environment. It is precisely their outer world. The cells are living and, together with the liquid that surrounds them, they make up a live thing. Applying this on a bigger scale to an entire animated being with its surface bathed by what is beyond it, we need find no particular difficulty in recognising this outside world as part and parcel of it. Just as what lies around an individual cell is counted as sharing the organism's life, so the fluid that lies around an individual plant or animal should be reckoned a component of its vital process.

In this way the current idea of biological "life" is expanded. We conceive of it as the joint attribute of both an organism and its environment. Life now becomes a property not only of an organised structure but also of its outer world.

This enables us to take a further step. So far I have been speaking of a single living unit. The earth, however, teems with organised beings. To each of these myriads can be applied the considerations which have been set out above. That is to say, the life of each of them is a matter also of what immediately encompasses it. But these individual surrounding conditions, whether of water or air, are not isolated from each other, but are continuous, each merging into the next. Together they are uninterrupted over the world's surface. From this we get the idea of a continuum of life, in which all organised structures are connected by means of their environments, which are themselves joined together everywhere.

Living cells we know, living organisms also. Life in its most comprehensive form we now see as a property of the medium of water and air which is spread over the globe.

V

Here I should like to make the suggestion that the phenomenon of inheritance and transmission, which has hitherto been reckoned as distinctive of living things themselves, cannot be denied to their environments also. In the previous chapter, when speaking of the psychological influences in childhood, I referred to an "inherited environment" as properly describing the situation. I want now to extend this to the physical environment of every living creature.

Its surroundings are those of its parents and of its grandparents, and are transmitted down the generations as truly and literally as are the chromosomes and the genes. This seems to me self-evident.

If heredity cannot be represented as the peculiar mark of living matter only, but is common to both them and the medium in which they exist, it can hardly retain the same significance as a feature of biological descent that has been accorded to it. On the contrary, it must almost certainly lose much of its importance as the chief interpretation of the facts of development. Instead, we feel impelled to seek another explanation of the life process. In the case of environment, inheritance would seem to be something in the nature of a persistence of physico-chemical conditions. Perhaps what has been called inheritance in living matter is similarly an expression of some physico-chemical process which repeats itself in successive generations. At present we do not know anything about this, but will consider it more fully later, when the various speculative matters that have been broached in this chapter, will be discussed at length.

CHAPTER IV

HOW DID BIOLOGICAL LIFE BEGIN?

I

THE line of inquiry in the last chapter has led us to the idea that biological life is an universal phenomenon. It is a manifestation of the whole world's surface, rather than, as is generally held, a multitude of separate, isolated points of existence. The newer and wider view can be supported by a number of considerations. First, in connection with the earliest appearance of organised matter. We know that this began on the exterior of the globe—here and nowhere else. What are we to suppose were the conditions that made its development possible precisely in this one situation? Geology has shown that living things came into being only after the igneous rocks had been deposited as the earth cooled ; and that their primal forms were marine. More particularly, we can say that they originated not in rock, nor in the air, nor in pure (i.e. rain) water, but in water which had come to contain the dissolved elements of both rock and air. This constitutes a chemical mixture which we may suppose was a pre-requisite in the production of life. How entirely suitable this aqueous solution must be, is shown by the fact that even when it is thousands of fathoms deep as in many seas, organised existence has come to abound at every level.

Later in the world's history, when rock had been acted upon by rain and frost, and had been riven into boulders, stones and finally soil, terrestrial life began. But here again, only in the presence of water with dissolved air and salts. We can conclude, then, that this chemical solution was the first essential condition in forming living beings of every kind. Since it was as widespread as the oceans, the rivers and the lakes, and occurred also on much of the land, a vast extent of the globe's surface became capable of generating organisms, so far as this one necessity was concerned. A fluid medium of this nature is not to be found anywhere else in the world, or even, according to astronomy, in the stellar system, with the dubious exception of the planet Mars. We must suppose that it is unique.

A second peculiarity is to be noted in respect to that part of the earth where life began. It is in connection with the solar radiations. These rays traverse a very great distance on their journey to the world, but they undergo little or no change, even as they pass through our atmosphere, until they reach this very level. Here they strike the globe, and are checked. Some of them are absorbed, others reflected, with the evident effect of warming this layer. All this, too, seems to be an occurrence which is unmatched elsewhere in the universe.

These two, then, would appear to be the conditions that we were looking for. We must suppose that the action of the solar radiations on this chemical solution produced biological life. The process which led to the original formation of living matter was a physico-chemical one. It fitted in with the geological state at the time.

If further evidence is needed of the direct relation between sunrays and animal and vegetable existence, it can be found in the varying fecundity of different parts of the world, both as it exists today and at its geological past. At present, life teems most where the sun is tropical, and gradually ceases towards each pole where warmth and light are feeblest. In the temperate zones it multiplies or stagnates according to the seasonal movements of the sun; with the "return" of the sun, life "re-awakens." This fact is itself an annual proof of the sort. In the same way we have the geological testimony of ice ages alternating with torrid inter-glaciations. This sequence is the result of some parts of the earth's surface being exposed at one time to under-heating and at another to over-heating by the sun ; and where living matter has ceased during a glaciation, it has become tropically prolific at the next inter-glaciation.

II

There are other considerations that bear on the idea of the universality of life. They relate to the way living things are distributed. The remarks I should like to make in this connection are, I believe, novel. Long ago organisms had come to extend over most of the globe, both sea and land. Their dispersion at present has been studied by zoologists and botanists, who have mapped in detail the geographical areas where individual species are to be met with. Both Darwin and Russel Wallace are outstanding figures in this work and what they were able to observe about the existing range of animals and plants, is commonly regarded as their chief contribution to the theory of evolution.

At the same time, a curious omission makes itself apparent in the investigations which have been carried out so far—at any rate I have found no mention of what looks like an important relevant fact. It is this. While the spread and distribution of vegetable and animal life over the earth's surface have been examined pretty completely, its occurrence measured vertically seems to have escaped attention. And yet the significance of this is not likely to be small, or the inferences to be drawn from it of little value, as I shall now try to show.

From the centre of the globe to the outmost fringe of its atmosphere, organised beings are known to occur at one level only. Except for little more than inches into the soil, and a few feet into the air, life does not develop. Nowhere else between the sun and us is it found, only at this one plane. In fact a comprehensive idea of biological existence can hardly be formed until we have realised that it constitutes as it were a film spread over the world's surface. It is a covering with a superficies very much more extensive than its depth, and we recognise it, therefore, as being infinitely thin. It might be likened to a delicate skin or shell, or to a kind of gossamer wrapped round the earth. Another detail about it is that it tends to be discontinuous towards each pole, where the temperatures are low.

This layer alone is life-bearing. For it I suggest the name "sphere of life" or "life-sphere." Alternatively and perhaps better, we might follow the example of astronomers when they labelled the surface of the sun the "photosphere," and call this terrestrial envelope the "biosphere."

The stratum to which all living things are restricted, lies where water unites earth and air. We have already indicated this very layer as the site of the genesis of life, and supposed that it occurred under the stimulus of solar radiation. We recognised also that these were the physico-chemical conditions which were necessary for vital growth. It seems to me that we can now go further and say that, given these circumstances, organised matter became not only possible but inevitable. It came into existence necessarily as a stage in the earth's evolution, at that period when the geological state was suitable for it. It showed itself as it did and when it did because it was a physico-chemical phenomenon of the same kind that was going on in the world at that time.

Before leaving this subject, let me refer to an apparent exception to what was stated unqualified just now—that life develops only a few feet up or down. And yet I had already spoken of organised elements being present even in deep waters. In the Pacific Ocean, for example, they occur at all levels, even five miles down. There is no contradiction here, though it might look like one at first sight. In the case of a sea, no living things come into being either above its surface or beneath its bottom. As for the sea itself, it is a liquid solution and, no matter how far it goes down, it possesses everywhere essentially the same chemical and even physical properties ; less change in these respects is found in descending 1,000 fathoms, than in passing 6 inches from air into rock. Even allowing, therefore, for ocean depths, we can still maintain that life is restricted to the watery layer lying between the atmosphere and the earth, and we need not modify our comparison of the life-sphere to a very delicate film.

III

If, long ages ago, the sun's rays, acting on this terrestrial liquid, originated living things, must we not suppose that the same physico-chemical forces have been responsible for bringing into existence all the subsequent developments of organised matter? And that they are accountable today for producing it abundantly in the life-sphere? This mechanistic explanation leaves no occasion to invoke any supernatural power or other mysterious influence. Vitalism would seem to have no place here, now that life is seen to be confined to the biosphere, and that its occurrence can be reasonably traced to mechanical causes.

The vitalists' case has many weaknesses, and these

I have dealt with in another book. Their position suffers from a further illogicality which I have not seen set out before. Vitalism we all know about as the principle appealed to as lying behind the phenomenon of life. But no vitalist has felt constrained to put forward a doctrine of "mortalism," invoking an enigmatical power to account for death. In the matter of dissolution and decomposition they are satisfied with a chemical explanation. In other words, they accept katabolism, but boggle at anabolism. Whereas, there is no more mystery when the inorganic is built up to the organic, the inanimate to the animate, than when it subsequently breaks down. The change in either direction is equally understandable, and we can assent to both as being parts of the physico-chemical process which is life.

A further word on the subject of death. We know that cells die, and that organisms die. We may anticipate that the biosphere, too, will die. This last will become due at some not very distant geological future, and it will mean that the physical and chemical conditions will have passed beyond those which make the production of living matter possible. All life will then have completed its transient appearance as a small detail in the evolution of the cosmogony.

Perhaps this throws a ray of fresh insight on the two other kinds of death, cellular and organised. We can suppose that cells and organisms go on living just so long as the physico-chemical activity which is their life, takes to reach a certain stage; and then they die. Little is known about the longevity of individual cells, but a good deal of that of animals and plants, though little again why some are long-lived and others short. If we may conjecture that the same process is working itself out in all of them, the duration of life is the measure of the speed with which this is proceeding.

IV

The opinion has been expressed above that life is a phenomenon which became inevitable in view of the existing conditions. This permits us to find new answers to certain questions which have exercised many minds, and are still in debate. Did the vital process begin at one place and spread from there? Many—probably most—scientists seem to incline to the belief in a single living thing at the outset, which became the ancestor of all subsequent plants and animals. Or did it originate in a few localities simultaneously? This appears to be what some think. For myself, I am not inclined to agree with either view. On the contrary, it seems to me much more probable that organised matter started in a great many different parts, as the appropriate geological state came about.

I would go further and suggest that primitive living things did not arise at one period only, but are likely to have been formed at successive times. We may even surmise that brand-new life is still taking shape around us, wherever the natural circumstances necessary for it are realised. Indeed, these three inferences can hardly be resisted, once we admit that, given the foregoing state of things, germinal existence must develop.

This is not to say that the first stage of life is or has ever been as complicated as even a unicellular organism. Something much simpler is to be looked for, now that we know that the big molecules of proteins are related to the smaller ones of colloids, and these in their turn to the more elementary inorganic ones. The very beginnings would probably be in the nature of protoplasmic slime. Wherever in these pages I am concerned to trace processes either down to rudimentary living things, or up from them, I should like to be taken as including also any of these most primitive forms which are not cellular, as this term is understood today.

V

We reached a final understanding of life as being a property of the whole of the earth's surface. Regarded in this way, all plants and animals are related to each other, and each kind plays its part in this universal existence. They must be supposed to carry on activities which are interdependent ; and they function in the biosphere much as somatic cells do in an organism. Like cells again, they are separate and distinct in some respects, but in others are associated as components of the larger organisation. It is their isolated aspects which have received chief attention so far, especially the features that distinguish different species. But from the other point of view, the rôle of each of them in the more expanded scheme of existence has hardly begun to be investigated. And yet its importance is scarcely to be doubted. It would seem to comprise a study of various general considerations, including the circumstances affecting the growth and fecundity of individual species ; the influence on one another of the members of a species ; the relations between different species ; and ultimately, the laws governing the production of life throughout the biosphere. Among the more particular subjects for research might be instanced the effects of external physical and chemical changes on the interior structure and composition of organisms, on their size, and on their longevity; and the conditions leading to the numerical variation of a species by way of its excessive multiplication, its decrease, and its extinction. It is along these lines that ecology is proceeding.

The scientific goal must be to understand about the life-sphere, and just as human physiology has led to the wider subject of comparative physiology so this latter now needs to be expanded. The next stage is a physiology of the biosphere, which will investigate the functions performed in it by the different species of plants and animals, and explain them in terms of physics and chemistry. Anything beyond that would presumably mean fitting terrestrial existence into its place in the whole astronomical scheme—bringing the biospheric phenomenon into relation with the cosmogony.

VI

By recognising the inevitability of life on the globe we have been able to infer something about primal existence. We can apply this to other than elementary living things, and suppose that every kind of plant and animal has necessarily come into being when the special conditions appropriate for it have been established; and that so long as this state persists, the species must go on being reproduced. We may not unprofitably apply the same idea to the emergence of the most elaborated structure, man.

Since human beings first appeared, they have multiplied until now they number about 2,000 millions. These are spread very unevenly in the biosphere. They occur on land only; over a very few parts of it they are closely set, in a few others thinly, but over most of it they are not to be found at all. What are the local conditions which have aided their growth and increase? The minimal needs are a certain measure of warmth and light, fresh water, a soil which has already produced vegetable organisms, and some shelter against rain and storm. It is a further advantage if the plant life has been established long enough to have given rise to some kinds of animals.

Primitive humans must have come into existence, not on high-lying, barren areas, but on lower levels of fertile land alongside rivers or near springs. We must suppose that they, too, developed inevitably out of their geological forerunners, once the desiderata just mentioned were satisfied. They have since extended by propagation, but only over those restricted portions of the continents where their special needs are met ; elsewhere they have failed to appear. In this respect human beings are no different to, say, ferns or oak-trees or buffalos ; each of them is cast up by the soil where it is appropriate, and occurs nowhere else.

At the present time the human race is still multiplying, and most prolifically in those places where the local conditions are best fulfilled. Breeding is freest when people are closely herded, adequately supplied with water and food, and protected by some sort of housing to keep out wet and cold. From this arises the modern social problem of over-population. But even today very little of the land surface is overstocked, and most of it is almost or totally void of human life. How limited are the suitable areas can be judged from the recent calculation that 4/5ths of the world population clusters on 1/5th of the soil. And how sparsely the earth is still populated is evident from the fact that all the 2,000 millions could find standing-room on an area of less than 100 sq. miles—the size of the Isle of Wight. Human beings, as the last word along their own line in evolution, are produced only where the natural circumstances are quite exceptional; and their habitat is very restricted.

CHAPTER V

WHAT UNDERLIES THE EVOLUTIONARY PROCESS?

I

IN the previous chapter we reached the conclusion that at the remote geological age when the life-sphere first showed its peculiar property, its earliest products—unicellular, if not simpler still—were the result of the action of the solar rays on the waters covering the earth. I maintained that there was no reasonable objection to thinking that this beginning of the vital process was in the nature of a physico-chemical change—that and nothing more. We may now equally presume that all the subsequent events which have become apparent in the course of evolution are to be similarly accounted for.

In our first chapter on the biology of man, we saw that the specialisation of structure and function could be explained in the case of a human soma as a means of carrying out some underlying activity. If we now apply this more widely, it would seem that all through evolution from the simple structures upwards, developments of this kind have been an elaboration of already existing processes. In fact, it is difficult to suggest any other way by which new organs could have come into being. We may infer, therefore, that a one-celled organism contains latent in itself all the potentialities which have come to expression in the highest animals and plants. In other words, that the whole of the ensuing happenings which ultimately led to man being formed, is a chain of occurrences, the sum total of which was implicit in that first step.

Granted this, we can now carry the matter another stage. Once evolution was started, the rest of it had to follow. If, however, we attempt to satisfy ourselves as to the exact nature of the original change which produced life in its simplest form, the problem we must admit is obscure. This much we have to go on—as was pointed out earlier—that the conversion of the inorganic into the organic, of no-life into life, was inevitable because of the physico-chemical conditions at the time. Perhaps the question to be solved, like many others which will not yield to a frontal attack, can be more successfully approached circuitously. Anyway let us try.

The assumption is that the whole evolutionary process was implicit in its first stage. Here we discern a principle operating all the way through. Whatever led to the inorganic becoming organic, and the one-celled many-celled, is the same that later brought forth the myriad-celled higher plants and animals. Though we may be baffled in detecting the principle in the undifferentiated forms of elementary life, we may be more hopeful of recognising it when it has come to pretty full expression in the most specialised organisms. The question we wish to answer is, what goes with a multicellular state which is deficient in the unicellular? Or, perhaps better, how is the former an advancement on the latter?

To consider first creatures which are other than primitive, we know that a specialisation of structure always implies a specialisation of function ; and we can also say that both of these serve physical and chemical ends. Instances of this are exceedingly common. Ears and eyes, heart and blood-circulation, fins, limbs and wings, gills and lungs : these are only a few of the many that might be mentioned. It would seem that every kind of specialised structure fulfils in an elaborated style an activity which is already necessary to the other somatic cells. This duty, moreover, is one which in simpler organisms falls upon the cells themselves ; but as a result of a new specialisation, they are relieved from exercising it. This appears to me to be the chief consequence that follows on specialisation.

It emphasises that the principal purpose of the increasing complexity that goes with evolution, is to help to free the rest of the cells from the effort of discharging certain of their original functions. Specialisation means, therefore, less labour for them.

By way of illustration, let us take the blood circulation. This has been specialised in order to serve the twofold end of bringing oxygen and nourishment within reach of the somatic cells, and of carrying away their waste. With its help further stages in evolution have been brought about, by enabling great masses of cells to live together, although most of them are spatially shut off from oxygen and their other outside needs. So completely have they given over these functions that, should the circulation fail, the consequences are disastrous to the point of death. Contrast with it those more primitive organisms which lack any circulatory mechanism. Each of their cells is required to look after its own nutrition and excretion, and to do this must be placed pretty near the surface. This means that only a few cells can join up together, that evolution cannot go very far.

If we look for the broadest possible comparison between the simpler and the complex organisation, I suggest that the main difference is the following. In the former each of its few cells has to carry out all functions, and this means a waste of energy; in the latter, the energy of every one of a vast multitude of cells is economised when a specific blood-circulation is kept going by a comparatively small number of specialised muscle-cells composing the heart. This circulation brings both nutritive and excretory services to the very door, as it were, of every cell. Again we see specialism saving labour, and now we can add that it also increases efficiency.

II

Whatever other instances we may take of specialised structure and function, the outstanding feature of them all would seem to be that they save energy being spent by the rest of the organisation. Perhaps we may recognise in this the aim and purpose underlying the changes which have brought about the higher living things with their elaborate arrangement of parts. It may be that here is the principle we are looking for as operating behind the evolutionary process. To it we may give the name of the Principle of the Economy of Energy. We may suppose that each step in evolution has afforded further expression to it.

Applying the hypothesis to the elemental forms of life, we may account for the transition from unicellular to multicellular beings on the same ground: certain it is that the single-celled protozoa and protophytes have to perform every function for themselves, with very little of specialism about them. On the other hand, even with the simplest metazoa a saving of energy is recognisable in the way the business of living is shared among their cells. Yet again, the origin of life itself—the transformation of the inorganic into the organic—would come about by the operation of this principle also. We have seen that this is a process which is started in the life-sphere by the action of solar radiation, and that it is of a physico-chemical kind. We have now to recognise that it represents the economising of energy.

Just what the exact nature of this may be I must leave open for the present, except to predicate that the energy we are speaking of can have nothing peculiar about it, but needs to be considered the same as is found in other natural processes. What I have called the economising and sparing of energy must have some pretty exact equivalent elsewhere in science. This is a matter which I should ask to leave to the experts in physics and perhaps in chemistry, as lying within their province and outside mine. Perhaps one of them will feel sufficiently interested to wish to clothe these biological ideas in the dress of modern physics.

If the Principle applies all the way through from the simple to the complex, it should be demonstrable in human social life as the ultimate stage that evolution has reached. I think that evidence of the sort is to be found in plenty. The "division of labour" we have known about in communities since last century, when Milne Edward's idea of a "physiological division of labour" was extended and applied by Herbert Spencer as a "sociological division of labour." The Economy of Energy includes both these, but is more than these, since it is put forward as the physical process at the back of evolution, accounting for its inception, and explaining its successive steps. Both these categories of the division of labour are examples of the ways in which the Principle shows itself, and should be recognised as expressions of the theory underlying them. They are, in fact, testimony in its support.

To look now at the social relations of human beings for instances of labour saving. These abound on every side, and a couple will suffice. A water-supply to dwelling-places relieves the households from the old-time labour of fetching their own water. Again, modern co-operative methods are recent developments of the same nature. All such cases illustrate the Principle of the Economy of Energy.

Our every-day experiences furnish additional evidence, and we find that people recognise the Principle, not indeed consciously, but unconsciously in its practical applications to their common round. In support of this we may remind ourselves that there can hardly be a more effective condemnation of a project than to say of it that it is a "waste of energy." On the other hand, to be told that something "saves trouble," makes an instant appeal almost universally. Both these have become so axiomatic that few pause to question what they imply ; and fewer still have put the contrary propositions to themselves in order to realise their absurdity, namely, that saving energy does not interest us, and that what we really like is giving ourselves all possible trouble.

This disposition to economise energy certainly has its roots very far down in human nature, but I have never come across a satisfactory explanation of it. To say, as some do, that it indicates a "tendency to inertia" does not carry us anywhere as it is only re-stating the problem in other terms. Agreed that this tendency is an essential part of us all, I should interpret it as another expression of the Economy of Energy Principle.

From yet another direction confirmatory testimony is forthcoming. Are we not hearing much of the modern craze for labour-saving devices? A house designed on modern lines is almost synonymous with one that is arranged to save trouble ; and in scores of other instances the latest and up-to-datest is that which spares effort. All this may be derided by some, but it certainly affirms again how deep and widespread is the disinclination to spend energy.

But is it accurate to suppose that the craze is only a recent one? Surely not. Our parents and grandparents were as concerned about it as we are, and if my reading of historical events is to be depended upon, there has never been a time when our forebears did not plainly show the identical tendency. It has nothing exclusively modern about it, and for its beginnings we must go back far beyond even mankind, and, pointing to remote geological ages, indicate the first organism as the original culprit in the matter of shirking effort.

The Principle may prove illuminating in still another of its applications to the present-day world —to a subject of great importance, and yet one on which people find difficulty in agreeing. I refer to the much vexed question in human affairs:—is there such a thing as progress in civilisation, or is the notion chimerical? To this I would add the further interrogation :—and, if progress there be, how are we to know it ? It seems to me that the problem can be freshly interpreted in the light of this Principle. It provides what is really an easy answer. That which saves human effort is progress, and that which wastes it is regression and decay. If this is true, we shall have provided ourselves with a criterion of the value of social enterprises of whatever sort. It will serve in making our estimates of historical occurrences, but its chief help will lie with the present. The advancing course of civilisation is continuously throwing out all kinds of new ventures and contentious causes, from wise to scatterbrained, and the need is to be able to judge between them. Those undertakings which relieve human labour are in the direct line of civilised progress. And more, they are carrying forward the evolutionary process.

We can look, therefore, without misgiving on the inventions of modern science which has given us, among other things, railways, roads and bridges, steamships, motor vehicles and aeroplanes. How vast is the difference these have made to the amount of effort and toil required of men and in getting about compared with earlier generations when, without any of these discoveries, it was arduous to pass even from one town to the next.

III

Next let us apply the hypothesis of the Economy of Energy to the changes which are grouped under the term "adaptation to environment." These seem to have puzzled biologists. They are usually held to be developed by an organism in response to the stimulus of its environment. This is well illustrated by fins, legs and wings which have appeared as forms of locomotive organs in the respective surroundings of water, earth and air. Or the general shape of an animal or plant may go a long way towards disclosing the kind of outside conditions that it encounters. Most mammals for example are terrestrial, but it is easy to tell in this way those that live in the sea, such as seals and whales. In other cases, some detail of the exterior appearance may be similarly revealing—such as the long legs and necks of birds that get their food by wading, or the fore-legs of moles that burrow. Even the shape of the foot—a camel's for instance—may indicate the kind of surface that is walked upon.

These and the many other examples that can be found in the biological textbooks, go to confirm what has been stressed earlier, namely, the close and intimate relation between an organised being and its surroundings. It is when the dividing line between them has been removed, that adaptation would seem to be best understood. It then appears as a change which is brought out as much by internal factors as by external. It points to some economic need on the part of a living creature—a want that the new adaptation is able to meet.

Any outer modification of this sort would seem to fall into line with what is well-known physiologically—an organ altering as a result of a change in another. For example, when one of a pair of healthy kidneys is removed surgically, the other grows to nearly twice its size. Or a high blood-pressure in the arteries enlarges the heart. Both these increases are brought about by alterations, not of the external environment but of the internal. Should we not recognise in both, the phenomenon of adaptation occurring within the economy?

Or again, take the well-known instance of a labourer who is constantly scooping coal. Gradually the bones of his elbow alter their shape in such a way that the arm cannot be straightened. The joint gets locked, with the effect of relieving many of his arm-muscles that he uses in shovelling. Here an interior change has been produced by an outside condition. But is not this a third case of adaptation? If so, biological adaptation would seem to be also a physiological reaction ; and the latter is initiated not by the organ that becomes altered, but by changes elsewhere in its immediate surroundings. Must we not suppose, therefore, that adaptations themselves likewise result from altered external environment?

Here may be cited the familiar kind of adaptation in certain animal parasites, when they come, at one period of their growth, to live inside other animals. At this stage they lose entire organs which are no longer needed by them once they have begun subsisting on their host. This example would appear to be conclusive that biological adaptation and physiological reaction are the same thing.

Adaptation to environment is so prominent a feature of animal and plant life, that we should be able to fit it in with the theory of economising energy, if this latter is sound. In point of fact, it represents yet another whole series of evolutionary phenomena in which the Principle comes to expression. Fins for propelling and steering reduce the effort of swimming ; legs facilitate walking over land ; wings make movement even easier still. The torpedo shape of seals and whales gives them the mechanical advantages of streamlining. Long thin legs and long thin necks serve to reduce the labour of motion in shallow waters. The same applies to a mole's front leg in scooping earth. The pads under a camel's foot lessen the exertion of walking on desert sand. In the case of the parasite, dispensing with some of its organs plainly decreases the effort of living, as indeed does the parasitic life itself. In sum, biological adaptation is seen every time to be labour-saving. It is a means of economising energy. As such, it would seem to confirm the truth of the Principle.

If also, the physiological changes spoken of above are the same as adaptations, they, too, should be sparing of effort. In the case of the coalie, this would seem obvious. The surviving kidney that doubles in size, may appear to double its work, but in fact it relieves all the other somatic cells of the labour of excretion. The enlarged heart, too, continues to save the body as a whole from the effort of securing its own nourishment ; and so on. Organs get bigger and have themselves more work to do, but this is just what happens to fins and legs. In both categories the purpose is to lessen the energy consumed by the rest of the organism.

CHAPTER VI

THE STRUGGLE FOR EXISTENCE IS IT REALLY CRUEL? A NEW INTERPRETATION

I

Life as a struggle for existence is a conception which we owe, of course, to Darwin himself, together with the associated idea of the survival of those species and individuals which are the fittest. Darwin was the first to establish the fact of a vigorous competition of this sort going on all around, between not only animals but plants also. Since his *Origin of Species* was published, his view has been generally accepted by biologists, and has become current opinion almost universally.

At the same time, some of the implications of his theory have been felt to be as little pleasant as they are gratifying to certain of our human aspirations. In particular, the struggle is seen to be undeniably fierce and merciless, laying bare the cruelty of brutish instincts. It is typified in the law of prey—jungle law. Long ago its essential features were summed up by Tennyson in his much quoted line about Nature being red in tooth and claw ; and today it is still represented as a savage competition for life in which the inevitable penalty for one of the contestants is death.

All this could only distress the kindly-hearted among humanity. But not even those whose feelings were most offended by the cruelty and the brutality of this aspect of evolution, have been able to get away from the fact that the struggle for existence is stark and inexorable ; and many have blamed Darwin for drawing a picture of life that is so dark and uninspiring. Some at the present day are pointing to the savagery of modern wars as a noxious result of his teaching. All such critics forget, however, that Darwin cannot be held responsible for what is Nature's doing ; and he was under no obligation to gloss over his discoveries in order to spare any tender sentiments.

II

Nevertheless, to myself also, the biological generalisation of a ruthless fight in which the aptest participants survive, has for a long time now appeared unsatisfactory. I was conscious of this on two grounds. In the first place, as I realised more and more that science, wherever its method has been applied, has succeeded in finding that the world is governed by natural laws and ordered progress, I could not feel either contented with or convinced of the idea of a state of affairs which implies savagery and fierce lawlessness. But, no more than the others, I was unable to deny the facts. And yet it seemed to me that some other interpretation of them should be possible, which would reveal them as the regulated operations of the process of Nature. Gradually this other way of seeing them dawned upon me, and so far as my judgment went, resolved the whole difficulty.

Before stating it, however, let me give the second ground for my discontent. It is a psychological one. When I found biologists referring to the prodigal destruction of life that the struggle entailed, my suspicions were roused ; and they were confirmed by their further allusions to its cruelty and its mercilessness, to the suffering and the pain of it. Here a psychologically trained eye detected unmistakable evidence of human emotions. It seemed clear that feelings had got mixed up with an account of a scientific matter. The proper scientific attitude is, on the contrary, a detached one. The relevant facts are to be stated and studied, but without our sentiments being provoked by them, or, still worse, our emotional reactions becoming incorporated in our description of them. Yet this is precisely where biologists appear to have gone wrong.

We have had as psychologists to charge religionists with the error of projecting their ideas and feelings into the outside world, and so creating a race of imaginary spirits and gods. Now it would seem that biologists have been making the same mistake—though with less grievous effects—and have been projecting their emotions into this struggle for life, with the inevitable consequence of being precluded from interpreting it scientifically. The need is to study the biological facts relating to the strife, without concerning ourselves for a moment with the human considerations of cruelty, mercy, suffering and the like. In a word, to cease being anthropocentric about it.

III

So far so good. Next let us examine the struggle for existence afresh, keeping sentiment out of it, and attempting to discover in it the orderly operations of natural law. In doing this the original conception will probably require some measure of revision, but it has served usefully for more than three-quarters of a century, and I am going to try to show that today the facts can be better explained on other lines. Let us attempt to re-interpret them in terms other than those of competition and strife. Take as a starting point the beginnings of the organic life covering the globe. We have seen that every living thing has been produced as the result of the physico-chemical conditions at the site where it has come into being. It represents a stage in a process of this sort, with nothing mystical or supernatural about it. We recognise accordingly that every organism is a centre of physico-chemical energy. Indeed, we have learned that all life comes about in this way as a consequence of these activities going on over the world's surface.

If organised structures are to be regarded as being units of energy, a further conclusion would follow. It is that the attractions and repulsions that they exert on each other are to be explained in terms of physico-chemical reactions. From this it is an easy step to recognise that all that goes by the name of behaviour—instincts, habits, conduct, actions—is equally an expression of the same sort. In other words, the relations between organised beings of whatever kind, and their interdependence on one another, require to be investigated as problems in chemistry and physics. Among these questions at issue must be reckoned the Darwinian struggle for existence.

The standpoint from which this is to be studied would seem to be precisely that which is adopted in physiology. In this science nothing is represented as being in the nature of struggle and competition between the different organs, or between the cells comprising them. Physiological processes and their interrelations are explained solely as manifestations of chemical and physical laws. Must not the functional connections between living things be similarly accounted for, so that the behaviour of one organism to another, whether animal or plant, becomes a matter of chemico-physics? More particularly, the apparent strife between them, viewed scientifically and not anthropocentrically, must be the expression of scientific laws. Along these lines, so it appears to me, a savage struggle for existence takes on a new shape as the operation of natural order. Equally, the survival of the fittest is transformed and seen as the inevitable sequence of natural processes.

IV

By way of applying what has just been said let us revert to the law of prey. From the older point of view this is undeniably an outstanding feature of biological life ; no animals can live except by consuming other life, and man himself cannot be excluded from among the predatory beasts. The newer opinion would explain predacity in terms of chemico-physics. Consider first the case of the lowest organisms, such as diatoms, and nearly all plants. They subsist on the chemical elements of water, inorganic salts and carbon dioxide, with the help of the physical stimulus of sunlight. We do not say that they "prey" on these substances, nor do we speak of "hungry" diatoms, let alone "ravenous" ones. In accounting for their behaviour, it is usual to employ such terms as chemotaxis, phototaxis, thermotaxis. If now, in the case of the higher organisms also, we similarly reject the idea of preying, we shall see that their rapacious habits are no more and no less than the expressions of essentially the same chemico-physical reactions as those of a diatom. A like conclusion would apply to the cruelty impulse that goes with predacity.

If, in conclusion, we venture on a generalisation, we could say that preying—obviously a manifestation of hunger—represents the attraction, automatic and irresistible, to other living beings of an organism the chemico-physical forces of which impel it in the direction where its internal tensions are able to be relieved. In this way the merciless struggle for life becomes scientifically an exemplification of chemotaxis and phototaxis.

There remain to be mentioned two minor modifications of current views, once we desist from charging other living beings with human feelings. First, we must cease regarding them as either hostile or friendly to each other. Instead, their behaviour in this respect would become another expression of physico-chemics. Secondly, the ideas of "self-protection" and of "defensive mechanisms," though they appear to be pretty deeply ingrained in biology, must be open to the objection of being anthropocentric. Any notion of protection and defence seems to be inappropriate and to lack finality in explaining the relations between organisms. Here again physiology gives the lead. In describing the physiological connections between the parts of a living being, no ideas of attack and defence are employed, and instead everything is ascribed to chemico-physical processes.

To summarise this chapter. Its theme is the struggle for existence, insofar as it has come to imply a cruel and merciless competition for life—synonymous in most minds with jungle-law. On the other hand, I have tried to show that it is both unnecessary and mistaken to regard Darwin's great generalisation as indicating anything of the kind—and this on two grounds. First, since science has never failed to find law and order wherever its method has been applied to natural processes, the same result should be feasible in the case also of the struggle for existence, once its significance is rightly understood. Secondly, the use of expressions like cruelty and suffering, when referring to the contest, implies that it is being looked at anthropocentrically; whereas human emotions must be kept out, if a matter is to be viewed scientifically.

Regarded in this way, the behaviour of even the highest living things is to be explained on the same lines as that of the lowest, and terms like chemotactic and phototactic are appropriate to both. In this way, we recognise predatory habits as the expression of an organism's underlying physico-chemical state; and the whole struggle for existence, properly interpreted and with nothing of human sentiment brought into it, becomes transformed into the inevitable operation of physical and chemical laws.

CHAPTER VII

CLIMBING THE GENEALOGICAL TREE

I

THE hypothesis of the Economy of Energy, which has been put forward as accounting for the origin of organised existence, must be supposed to apply to every step in evolution. It has been propounded as the physical process underlying the whole of it. Here a possible objection can now be met.

On the one hand, my suggestion is that every living thing has come about by one and the same mode of operation ; and yet on the other hand it is common knowledge how very abundant and varied species are. How then can the vastness of their number—several millions at least—be reconciled with the assumption that in each an identical vital process has been set going, and has proceeded on a predetermined course? We have claimed that the requisites for bringing life about in its primal state are solar radiation and the aqueous medium covering the earth. If everywhere and every time this is the first step, how does it lead to all the multitude of living creatures?

Not for long are these primitive forms exposed to identical conditions. Quite otherwise. They encounter differences of warmth and light, and of the precise chemical composition of what lies outside them. In fact, their surroundings are almost certain to be dissimilar in these important respects, with the result that they must tend to grow along distinctive lines, and in many cases to develop individual characteristics. Later, in the course of many generations and with the externals still varying, they diverge more and more until they become distinct species. Later again, the circumstances continuing, many new species will have taken shape. No matter how many millions these may amount to, in each the original process has been the same, and the specific peculiarities have been gradually brought about as the local conditions have effected changes down the succession of descent.

Indeed, it is a fact established by the wealth of modern biological research—though perhaps without it being generally realised—that all the host of living creatures from the highest to the lowest, while unlike in details, are alike in essentials. They are variants of one and the same activity, combinations and permutations of a single process. Their dissimilarities are obvious, and conceal an underlying identity of development. We know, further, that the members of a species are never exactly alike. This is readily understandable, since no two of them have experienced precisely the same conditions. We need feel no surprise at Nature's exuberance in producing so many different individuals and kinds of organisms ; nothing else is to be expected from the almost infinite variety of the circumstances of their growth.

In this we have moved a long way since Darwin. He found his work cut out to convince his contemporaries that small variations could tot up in time to substantial differences. "Nothing can appear more difficult to believe than that the more complex organs and instincts should have been perfected . . . by the accumulation of innumerable slight variations." This from his *Origin of Species*, when he was contesting the accepted belief that species never change. "Why," he went on to ask, "have all the most eminent living naturalists and geologists rejected this view of the mutability of species?"

His task of satisfying others that mutations could occur at all, was difficult indeed. Today, so it seems to me, the position has advanced so far that we may suppose with little hesitancy that variations are taking place all around all the time. New species are being formed, as well as old ones dying out. These changes are occurring under our eyes much more quickly than has been believed. We must be prepared to query the old idea that species can be sharply marked off from each other; and to expect instead to meet more and more sub-species, and other intermediate forms. The existing gaps which have been introduced between species, and stressed for classificatory purposes, will probably tend to be filled in by variant types. In this way, the different sorts of organisms produced in the biosphere are likely to show gradations from one end to the other. This could hardly have been imagined by our predecessors who have been concerned to emphasise the distinctions between living things, at the expense of their resemblances and affinities.

II

Let us make one more attempt to identify exactly any heredity element which might be transmitted down the generations.

Assuredly certain portions of an organism's composition cannot be placed in this category. For instance, as we have already seen, living things are constantly incorporating ingredients from outside, both during the time that they grow up and throughout their maturity. In this manner they come to consist almost entirely of what was the other day their environment. None of this can be brought under the heading of inheritance.

Similarly, a germinal cell itself, while it ripens, takes in sustenance from without. This part of it, too, cannot be heritable. Even if we suppose, as most probably do, that some of the material of which it consists when immature, has been derived from its parents, most of this will have been obtained by them quite recently from their surroundings. Nothing transmitted in this manner can claim to be constitutional. Looking back over a long ancestral lineage, we can see this spurious sort of inheritance of outside substance all the way ; and not any of it can represent a heredity element proper.

But, parenthetically, is it correct to say that any part of an unripe sex-cell has come from its parent? I question this because of what we know about the life-line of germinal descent, and its habit of throwing out successive somas. At any given stage a gamete is the product of the previous one, and this latter has recently brought into being a soma also, which is the father or mother enclosing the present germ. It would seem impossible, therefore, that this cell in its first stage could owe any of its composition to its parents, since both it and they have a common origin in the last generation, and have subsequently branched off in different directions. Only as the cell matures does it draw material sustenance from its parent.

A paradoxical question arises here. If a germ and the parental body around it are the joint offspring of the previous gamete, how can the younger generation be the progeny of the next older? Both are directly descended from an earlier predecessor. Is it not biologically incorrect, therefore, that the younger are the produce of their parents? On the contrary, do they not stand in this relation to their parents' parents? This would mean, in the case of human descent, that a child is not the issue of its father or mother, but of its grandparents.

To return to our quest of a hereditary element. When every part that comes to an organism from outside has been excluded from our scrutiny, what remains that might be brought under this heading? Is there anything else which might be true inheritance? So far as I can see, this is hard to find, even if we search back to the beginning of the generations, before the line of descent had become complicated by all this business of incorporated material. Let us look just once more at the condition of things in the biosphere when life appeared—then, and a little before then. Prior to the first living thing, organised matter and environment were one, with no possible distinction between them. The earliest germinal substance must have originated as a specialised particle of what henceforth became its surroundings. This seems to prove that whatever heredity may represent, it could not at the start-off of the life-sphere have been other than environment.

Only one other possible source of a heredity ingredient appears to remain. Can it be in connection with the sun's radiations? We have seen that a minute portion of solar energy enters into germinal life. Is this what is transmitted? To me it is at any rate conceivable that a force of this kind might go on producing the effects which we recognise as life repeating itself in successive generations. Solar activity might function here as a catalyst, and, without itself altering, bring about changes in substances around it. This is a possible explanation of what has hitherto been insoluble, though it is the commonest of happenings—the recapitulation that characterises all biological growth. I can adduce no convincing evidence either for or against this, but I should think it to be more feasible than the reverse. In its support I should like to make some observations.

It seems to me that we have failed to recognise at all adequately the leading rôle of the sun in producing life. Our interest has been mainly given to the terrestrial conditions affecting it ; when in fact it must be the concern of two spheres—the sun as much as the earth. In an earlier chapter I stressed the part of solar radiation in generating plants and animals, both in the geological past and in present times. To what was said then, the following might now be added. Solar energy acting on terrestrial matter results in living substance. It is an essential of biological growth, wherever this occurs; and it is constantly producing fresh amounts of primal living matter in the life-sphere. We may suppose that it is also the stimulus to breeding and procreation everywhere. From this, we might infer its probable function of bringing about the ripening of immature gametes. In fine, we can hardly be content to overlook any longer the share of solar radiation in causing the new life of each coming generation.

This important conclusion is not invalidated by the fact that some plants and animals, from micro-organisms up, live and multiply in the dark. We may suppose that where they develop, some of this energy has access, however feeble; and that when it is totally excluded, nothing grows.

Two conjectures about solar activity might be worth mentioning here. The first relates to the unexplained fact that in the highest animals the male sex-gland is carried outside the body. Can this be in order to bring it nearer the sun, and so promote the growth of its gametes? The second is to suggest yet another explanation of the phenomenon of waking and sleeping. All down the ages, the biosphere has been daily alternatively flooded with sunlight and left in darkness. Is it possible that the active state of waking represents the physiological result of being irradiated by the sun, and passive sleep the want of it?

III

Before bringing this book to an end, let us pass to another biological problem—that of an individual in its development repeating the history of its race. From the study of embryos we know that many organisms as they grow, pass through stages which correspond with less specialised types. In the course of reaching their mature structure, they begin as unicellular, and step by step by the process of cell-division, become more and more elaborated. This was first noted by Haeckel, and is called the Biogenetic Law. It says that ontogeny recapitulates phylogeny. The condition applies to man also. Indeed, a human embryo at one period is furnished with gill-slits, indicating that our remote progenitors were aquatic. The question why plants and animals should re-echo their ancestral descent in this way—climb their genealogical tree, it has been called—is as yet unanswered.

Organised growth may in this way go through the whole sequence of its geological past, but with a remarkable difference. It is speeded up enormously, an age in evolution being completed in hours or even in minutes. Perhaps this will give the clue to the puzzle. What purpose can this quickened process serve? How does it fit in physico-chemically as it should, with what we have learned about primitive life and its subsequent course? We can surmise for the present that it must contribute in some way to the germ-cell's need, because this is the main theme all the while. How have the cell's conditions altered since its ancestors were only monocellular? Casting our eye back over the whole range of evolution, we shall find the following sequence of changes.

In its first and simplest stage, the vital process is transmitted asexually—that is to say, a unicellular organism multiples by diving into two. As yet these cells show no hint of sex differentiation; and they do not possess any store of accumulated nourishment.

At its next stage, life begins to be carried on sexually. Male and female cells are produced; and in one of them—the ovum—collects a quantity of nutritive material of a kind possessing an unusually high amount of energy. This is consumed as the embryo begins to grow, and as a new gamete is formed simultaneously. From this we may infer that force is used up in development. We see also that one of the alterations accompanying the ascent from simplicity to complexity, is that energy becomes concentrated around the vital process. Perhaps we may even suppose this to be the principal change as evolution advances.

What can its significance be in respect to the germ-cell? It would seem to accord with the idea already discussed at length that the cell always functions in order to retain its own energy, and not to dissipate it. The aggregation of force within the female gamete would help this.

At the next stage of evolution after sex has appeared, we should anticipate that the accumulation of energy would be increased. This is found to be the case in some invertebrates, in amphibians and, still more, in reptiles. Among the last, for the first time the germ is provided with a regular egg, which contains more nourishment than ever before. This can only further serve to protect the germ from loss of energy.

In the next stage again—that of birds—we see that energy has collected in the egg around the ovum more copiously even than in reptiles. Birds, too, also as a novelty, are warm-blooded. The germ inside is now enveloped by a soma which keeps at a steady heat several degrees higher than the air outside. After being extruded, the zygote is still warmed for a time by being incubated—another new development. All these changes at the avian level support the view that evolution is accompanied by an increasing concentration of force in the neighbourhood of the vital process. Moreover, the fresh contrivance of a hot wrapping plainly contributes to a still greater degree to prevent the germ within from dissipating energy.

The final stage brings us to mammals. Here we see the same alterations carried another step. A mammalian soma has acquired the avian peculiarity of a constant temperature raised above that of its surroundings. But the female shows the innovation that it is specially contrived to permit the zygote to remain inside in the warm, and not to pass out into the cold, as with birds and lower animals. This must help yet again to economise the germ's energy ; but, even more important, we recognise that the maternal mammalian body takes the place of the large avian egg. Indeed, it is first and last a glorified egg.

In this capacity a mammalian mother provides a further and unstinted supply of energy through the placenta to the developing germ within. Very considerable as is the increment in accumulated force when we pass from reptiles to birds, this is small compared with its subsequent increase in mammals. With them it is nothing less than enormous. Even after gestation has ended, the mammary glands continue this function temporarily, furnishing a rich and ample quantity of every kind of nutritive. In fact a maternal mammalian soma is the most highly effective mechanism in nature for aggregating energy in the immediate neighbourhood of a zygote. Contrast this with the very different situation of a newly formed monocellular organism, which has access to nothing of this sort, except what is comprised in its near surroundings.

Another point to be mentioned about warm-bloodedness. The body temperature is the same in all the members of a species, but varies between species. We might opine that in every case, mammal or bird, the degree of heat is that which is best suited to the kind of sex-cell within. It might be also worth adding that the warm-blooded principle as applied by a soma to a germ, appears to be hardly different from the familiar instance of a hothouse for forcing plants.

Before continuing, let us summarise as far as we have gone. We have traced a continuous modification of the life-conditions the whole way from unicellular organisms to mammals. This consists of a progressive accumulation of physico-chemical energy in the immediate neighbourhood of the germ. It begins seemingly very slowly indeed, and is not recognisable until after the sexes have become differentiated, when it is seen first and only to a moderate degree in the female gamete. When somas develop, their prime significance is to concentrate still more power around the sex-cells. Later, in reptilian eggs, the store of this has come to be greatly increased. Later again, in birds, it has been further added to very considerably, partly by their bigger eggs, partly by their body heat. Finally, in mammalian somas, it shows another—and this time immense—increment. At this stage, the female retains the zygote until it is far developed, all the while surrounding it in a huge agglomeration of energy. We may suppose that both maternal love and the dependence of young on their mothers, equally represent in the first instance the mutual attraction of their corporeal masses.

The process which I have tried to delineate is a mechanical activity beginning altogether slowly, and so continuing for a very long time, but thereafter quickening in something like a geometrical progression. Has it a parallel elsewhere in science? It reminds me of a comet's motion when it approaches a planet, and accelerates in this way as a result of the pull of gravity. Is it possible that we have before us a gravitational phenomenon on an infinitely small scale, when matter is attracted faster and faster to germinal life?

The above account of the progressive concentration of energy, seems to bring into line all the major events in the course of evolution, save one. Can it also explain the change from aquatic existence to terrestrial? Not so convincingly, possibly, but nevertheless it will fit in without any great difficulty. When organised life spread from water on to the land, it met with more warmth and more light; and each of these changes can only have helped to increase the sum of energy around it. In this way amphibians are seen as conforming to the same process of aggregating power, and carrying it another stage. They are the necessary intermediate step between an aquatic ovum and a reptilian egg.

I have interpreted this accumulation of force as meeting the needs of a germ-cell by furthering its own physico-chemical evolution. It serves to prevent the cell from dissipating energy. Here we come again upon an old friend, the Economising of Energy, which now appears at work through all the big changes which have brought about the successive forms of life.

IV

Now we are in a position to examine the question of organisms recapitulating their ancestral descent. The suggestion I have already made about it is that it must meet in some way the requirements of the germ-cell, since the latter sets the pace and calls the tune at every stage. No biological phenomenon can be understood except in terms of this cell. Let us follow this up.

As a first step we note that repetition is to be found twice over in biology. Once, as just mentioned, in an individual's development repeating the history of the race. And again, in the ordinary succession of generations of unicellular living things. With these, parent and offspring carry on the line of descent all down the ages, and in both we see the same vital process recurring. Repetition and reproduction seem to be perfectly synonymous here. All such primitive life we know to be physico-chemical, started by solar energy in the biosphere, and once it has begun, it goes on over and over again, the conditions remaining suitable. Where is this tendency to repeat derived from? It must either be inherent from the start, or require the periodic access of some fresh impetus. It might come from chemical elements in the life-sphere, or from being energised anew by the sun. The latter alternative seems altogether the more probable in view of the part played by solar radiation in generating living matter. I have already alluded to it in this connection as possessing a catalytic action.

If we accept this physical explanation of the one kind of repetition, does it help in similarly accounting for the other—that of climbing the genealogical tree? Here a process of descent which has taken æons, is speeded up, and completes itself in a few days at the most. That it is accelerated seems to imply that it is intensified; and this suggests that it must be activated altogether in excess of the original events. Any quickening would be possible only when enough energy has become available. Where is this abundance to be found? We need look for it nowhere else than deposited as nourishment in an ovum or in an egg. The ontogenetic repetition of phylogeny would seem, therefore, to result from the force which is stored in the female gamete. In keeping with this is the fact that the simplest forms of life lack any such reserve, and they do not recapitulate their descent.

One final observation to conclude this chapter. It is with reference to the pace of evolution. We have supposed that, over a very long time, this must have been very slow indeed, for want of any accumulated energy in monocellular organisms; and that it gradually quickened as the sexes were differentiated and a moderate amount of nourishment appeared in female germs. Its subsequent course has been at a speed which has grown always faster because the force collected around the sex-cell has increased more and more rapidly. This kind of acceleration is, of course, borne out by geology. Fossil deposits show that life has changed in just this way—hardly at all over long ages, then less slowly, speedier in the recent tertiary period, and quickest of all in the pleistocene.

GLOSSARY

AMŒBA—Single-celled microscopic animal.

AMPHIBIAN—Animal living both on land and in water, such as a frog, and linking zoologically fishes with reptiles.

CATALYST—Substance producing alterations in other bodies without itself changing.

CHROMOSOMES—Paired constructions which appear in the nucleus of a cell about to divide into two.

COLLOID—Gelatinous chemical substance like gum or white of egg.

GAMETE—Sex-cell, male or female.

GENES—Paired bits of a pair of chromosomes. Each has come from one parent.

GERM-CELL—Gamete or sex-cell.

GERM-PLASM—Part of the nucleus of a sex-cell which conveys parental qualities.

GONAD—Organ which forms sex-cells—testis or ovary.

MAMMAL—Warm-blooded animal suckling its young.

METAZOON—(Plural metazoa). Many-celled animal.

ONTOGENY—Development of an individual being.

OVUM—(Plural ova). Female sex-cell.

PHYLOGENY—Ancestral evolution.

PROTEIN—Chemical substance containing nitrogen and forming the chief ingredient in protoplasm.

PROTOPHYTE—Single-celled plant.

PROTOPLASM—Living matter. The basis of life in plants and animals.

PROTOZOON — (Plural protozoa). Single-celled animal.

SOMA—Body of an animal or a plant excluding its germ-cell.

SPERMATOZOON—(Plural spermatozoa). Male sex-cell.

ZYGOTE—Fertilised ovum formed by a male and a female sex-cell joining. From it a new individual develops.

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