TEXT FLY WITHIN THE BOOK ONLY

THE BIOLOGICAL FOUNDATIONS OF SOCIETY

THE BIOLOGICAL FOUNDATIONS OF SOCIETY

BY

ARTHUR DENDY, D.Sc., F.R.S.

PROFESSOR OF ZOOLOGY AND FELLOW OF KING'S COLLEGE IN THE UNIVERSITY OF LONDON

LONDON

CONSTABLE & COMPANY LTD

10 & 12 ORANGE STREET LEICESTER SQUARE W.C. 2

1924

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS, LTD.,
LONDON AND TONBRIDGE.

PREFACE

THIS little volume, the outcome of a course of public lectures delivered at King's College in the autumn of 1923, is offered to the public as the contribution of a biologist towards the discussion of those social and political problems which confront us to-day in a peculiarly aggravated form, and upon the solution of which the stability of society and the progress of mankind must always depend.

I must, however, disclaim any intention of posing before my readers as an authority on the science of sociology. I have no new theory of society to bring forward and no panacea for social evils to recommend, nor do I propose to discuss the many theories that are already in the field. I wish to take up the subject at a much lower level than that usually reached by the sociologist, and if possible to trace to their sources, so far as those sources can be detected in the evolutionary history of the animal kingdom, the springs of human action, more especially in relation to the organisation and behaviour of human society. At the same time I hope to be able to show that from the study of biology we may derive much that is valuable in the way of actual guidance and inspiration.

One of the most distinguished philosophers of modern times, the late Bernard Bosanquet, has said that "the whole foundation of society is character," and from this point of view he has written his classical work on "The Philosophical Theory of the State." But human character is the outcome of a long and slow process of evolution, a process that has been going on for countless millions of years. Character, as Dr. Bosanquet would have been the first to admit, must always depend on what has gone before, and it is largely with what took place in the world of living things before mankind came into existence that I wish to deal, for it is upon this foundation that the pyramid of society is really based.

The laws which governed organic evolution in its earlier stages, moreover, were not repealed when man arrived upon the scene, and perhaps our best hope for the future lies in the correct understanding of the lessons of the past, and in the intelligent application of those lessons to our own particular case. The evolutionist differs from the historian in that he digs more deeply and endeavours to unearth the very roots of progress, and he has exactly the same justification for his labours.

ARTHUR DENDY.

KING'S COLLEGE, LONDON.
December, 1923.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

BIOLOGICAL FOUNDATIONS OF SOCIETY

CHAPTER I

Man's Place in the Animal Kingdom—The Doctrine of Organic Evolution—Man's Subjection to Biological Laws—The Beginnings of Life—The Mechanistic Point of View—The Protoplasmic Organism—Response to Stimuli—Educability—The Accumulation of Surplus Energy—Capital and Work.

THE sharp distinction commonly drawn between mankind and the lower animals, rooted, so far as the western world is concerned, in the biblical fable of the creation, has, from the evolutionary standpoint at any rate, long since ceased to be tenable as a logical antithesis. The light cast upon the origin of the human race by biological research has penetrated many dark places and left no shadow of justification for the old-fashioned dogmas of religious orthodoxy with regard to this important question. Indeed, orthodoxy itself has of late years found it necessary to abandon many of its old strongholds and seek a place more closely in touch with the advancing army of science.

This being the case it is indeed remarkable that, in what is usually regarded as one of the most enlightened countries of the world, a strong reaction should have set in quite recently against the doctrine of organic evolution, and that a vigorous attempt, which can only serve, in the long run, to defeat its own object, should actually be made by certain American politicians to prohibit the teaching of evolutionary biology. My distinguished colleague, Mr. Bateson, who considers himself to be the innocent striker of the spark that has kindled this belated conflagration, has recently summarised the position in a startling article in *Nature*, from which I venture to quote the following passage: "In Kentucky a bill for suppressing all evolutionary teaching passed the House of Representatives, and was only rejected, I believe, by one vote, in the Senate of that state. In Arkansas the lower house passed a bill to the same effect almost without opposition, but the Senate threw it out. Oklahoma followed a similar course. In Florida the House of Representatives has passed, by a two-thirds vote, a resolution forbidding any instructor 'to teach or permit to be taught Atheism, agnosticism, Darwinism, or any hypothesis that links man in blood relation to any form of life.' This resolution was lately expected to pass the Senate. A melancholy case has been brought to my notice of a teacher in New Mexico who has been actually dismissed from his appointment for teaching evolution."

If Mr. Bateson is correct in his view, these remarkable and possibly disastrous results are the direct consequences of a discussion that took place a few years ago at a scientific meeting in Toronto, at which he, while expressly and precisely proclaiming that his faith in evolution was unshaken, ventured to admit our ignorance as to actual modes and processes, especially as regards the origin of species. We need not concern ourselves now with this discussion, though I may perhaps be allowed to say that I think Mr. Bateson was unduly pessimistic and that the origin of species is by no means so insoluble a problem as it appears to him. But the doctrine of organic evolution does not depend upon the acceptance of any particular theory as to the manner in which evolution has led to the formation of those more or less arbitrary groups of plants and animals to which the term "species" is commonly applied.

This curious American revival of obscurantism makes it evident that the traditions and superstitions of centuries cannot be dispelled in any brief period, and that there is still much sentimental prejudice to be overcome before the great mass, even of partially educated men and women, can be expected to accept without reservation the essential unity of mankind with the rest of the animal kingdom. The prejudice is, of course, to a large extent excusable, for it is only by looking upward rather than downward, forward rather than backward, that we can hope to advance, and there seems at first sight to be something infinitely sordid and discouraging in tracing out the bestial affinities of the human race. Bestiality, however, is no reproach to the beast, and if we recognise it as such in ourselves it simply means that our path has really led us onwards, and justifies us in our hopes of future progress. The real danger is that evolutionary teaching might, perhaps, lead the less civilised members of society to regard the ancestry of the human race as an excuse for bestial behaviour. This is a danger that can be counteracted only by a rationalised insistence upon the spiritual side of man's nature, and in any case it is one that must be bravely faced in the interests of truth.

As the entire argument of this book rests upon the evolutionary hypothesis and its application to mankind I may be excused for recapitulating very briefly some of the evidence by which our belief in that hypothesis is supported, though I am somewhat loth to take this course for fear of giving you, in the limited space at our disposal, an altogether inadequate impression of the overwhelming strength of the case.

The human body, alike in its structure, functions and development, exhibits the most unmistakable traces of its pre-human ancestry, and of the common origin of mankind and the lower animals. Anatomically considered, and apart from the brain, the body of a man is actually less highly organised, a less complex and less specialised piece of mechanism, than the bodies of many other vertebrates. The limbs in particular, in their typical five-fingered or five-toed structure, have retained a primitive character, and are far less advanced in evolution than the wings of a bird, or even the legs of a horse. The bird, as a flying animal, has an immense advantage over the man, and it is only at the present day, by the invention of flying machines, that man is beginning to make good this deficiency in his bodily organisation.

If we examine the wing of a bird, or the fore limb of a horse, however, in comparison with the human arm, we shall find that, in spite of their great differences in external appearance and mode of action, they all exhibit the same fundamental plan of structure. All can be derived from the primitive pentadactyl or five-fingered type characteristic of the whole of the air-breathing vertebrates. In all, we recognise the arm, supported by the humerus, the forearm with the radius and ulna, the wrist with its carpal bones, and the hand with its metacarpals and phalanges. The differences are due simply to exaggeration, suppression or fusion of these primitive constituents, and the only rational explanation of the fact that such different organs as arms, legs and wings exhibit essentially the same structural plan is that that plan has been inherited from some common ancestor, and adapted to the special requirements of each particular case.

So also with all the other organs of the human body, we find their counterpart, more or less exactly, in the bodies of other vertebrates, and it is only as regards details that we see any great variations in structure. There is, in short, one fundamental plan of organisation common to all the great group Vertebrata; a plan which comprises the dorsally situated central nervous system, differentiated into brain and spinal cord; the cranium or brain case surrounding the brain; the vertebral column, based upon the embryonic notochord and surrounding the spinal cord; the ventrally situated heart and the respiratory pharynx. These are all characteristic vertebrate features, but the vertebrate type itself is but a modification of a still more fundamental plan of organisation which the vertebrates share with some of the invertebrate classes. These latter again possess many features in common, while all of them, vertebrates and invertebrates alike, are, on microscopic analysis, found to be built up of essentially similar structural units—those microscopical, nucleated masses of protoplasm known as cells.

Amongst the Vertebrata we can distinguish five great classes, the Fishes, the Amphibians, the Reptiles, the Birds and the Mammals, which, at the present day, are fairly sharply marked off from one another, although, when we trace their history backwards through geological time, we find them losing their distinctive features and gradually merging into one another.

The Fishes (amongst which we may, for the sake of simplicity, still include the lampreys) are undoubtedly the most primitive of these five classes, and in large measure represent the ancestral condition in which all the vertebrates originated. They are characterised above all by their thorough adaptation to an aquatic mode of life, entailing the possession of gills and branchial respiration throughout life, with corresponding arrangements of the heart and blood vessels, while their limbs retain the primitive form of fins, and have not acquired that pentadactyl structure which we have seen to be so characteristic of the air-breathing groups.

Next to the Fishes come the Amphibians, which still retain many fish-like features. Many of them, such as the common newts of our ponds and ditches, are still well adapted to an aquatic life, and some of them keep their gills as functioning organs of respiration throughout the whole of their existence. All of them, however, have developed lungs as outgrowths of the œsophagus, comparable to the swim-bladder of certain fishes, but highly vascularised, and thus forming organs which are capable of breathing air directly. The arrangement of the heart and great blood-vessels become modified accordingly, while the primitive fish fin has been transformed into the five-toed limb adapted for locomotion on dry land. Even the frogs and toads, which, in the adult condition, depart so widely from the fish-like form and habit, pass through a very typical fish-like condition in their development—the active, free-living tadpole.

The Reptiles differ from the Amphibians in many important respects, but especially in their more complete adaptation to a terrestial, air-breathing mode of life. At no period of their life-history do they possess gills; the lungs are the sole organs of respiration in the adult, and there is a further advance towards complete separation of the pulmonary from the systematic circulation. The free-living, fish-like larval stage has been completely suppressed, and the young animal, in its earlier stages, develops within an egg shell, where it is further protected by the sac-like amnion and nourished at the expense of the yolk stored up in the egg. The ancestral gills are replaced functionally, up to the time of hatching, by a new respiratory organ, the allantois, developed as a vascular outgrowth from the hinder part of the alimentary canal; but, strange to say, the gill slits in the neck still appear in the embryo, although they have entirely lost their original function.

From the reptilian stock two divergent lines of evolution have originated, culminating in the Birds on the one hand and the Mammals on the other. The former have become highly specialised for a life of great activity in the air. In adaptation to this their fore limbs have been converted into wings, but their most distinctive peculiarity is the replacement of the reptilian scales, over the greater part of the body, by a covering of feathers, which serve both in the formation of the organs of flight and as a means of maintaining the characteristically high temperature of the body. The separation of the pulmonary and systematic circulations has been fully accomplished by the complete division of the heart into right and left sides which no longer communicate with one another. In their egg-laying habit, however, and in the early development of the young animal, they still agree very closely with their reptilian forefathers.

The mammals, on the other hand, have advanced along a very different path. Instead of feathers they have acquired a covering of hair as a protection against excessive changes of temperature, and this is perhaps their most obvious distinguishing feature, though the name of the group is derived from their unique habit of suckling the young. The great majority of mammals, moreover, differ from the ancestral reptiles in that they produce very minute eggs, without shell or yolk, which, for a longer or shorter period, develop within the womb of the mother; the young animal or fœtus, up to the time of birth, being attached by a special organ, the placenta, to the parent. This very characteristic structure is formed mainly from the allantois, which has now taken on a nutritive as well as a respiratory function, absorbing nourishment by diffusion from the blood of the parent and conveying it to the fœtus through the allantoic circulation.

Certain very primitive types of mammal, the Echidna or spiny anteater and the Ornithorhynchus or duck-billed platypus, have survived to the present day in Australia and some of the adjacent islands, and in these, although they possess a hairy covering and suckle their young in a very primitive fashion, many of the reptilian features that have been lost in the more typical members of the class still persist. Thus they lay large and heavily yolked eggs provided with egg shells, within which the early stages of development are passed outside the body of the parent, and there is of course no placenta.

Nowhere else amongst existing vertebrates do we meet with such an admirable example of a connecting link between two great classes as that afforded by these curious survivals, but we have only to search the record of the rocks to find parallel cases amongst the vertebrates of the past. The celebrated Archæopteryx of the Jurassic period, whose fossil remains occur in the lithographic slates of Solenhofen in Bavaria, has long been known as a connecting link between the reptiles and the birds, occupying a position exactly analogous to that of Echidna and Ornithorhynchus between the reptiles and the mammals. In fact the geological evidence, now almost embarrassing in its abundance, entirely supports the conclusions derived from the comparative study of recent vertebrates as to the main lines of evolution within the group.

The order of appearance of the five great classes in geological time harmonises exactly with the theory that each great advance in organisation arose by modification of a pre-existing type ; the fishes giving rise to amphibians, the amphibians to reptiles, and the reptiles to birds and mammals.

The origin of the vertebrate phylum as a whole is far less easy to trace—largely, no doubt, because it took place at such an extremely remote period of the earth's history, and it is not necessary for us to attempt to solve this problem. There can be no doubt, however, that the primitive vertebrates were derived from invertebrate ancestors and that the chain of life has been uninterrupted from the time of the first appearance of the simplest organisms to the present day.

There is one great law of progressive evolution which we may consider briefly at this preliminary stage of our inquiry, though we shall have to refer to it again later on. Each new branch of the evolutionary tree, marked by some characteristic modification of structure, arises, of course, from some parent branch, but it seldom or never springs from near the apex. In other words, it is not the more specialised members of an ancestral group that give rise to fresh outbursts of evolutionary vigour, but more lowly organised and primitive representatives, which have retained a high degree of plasticity and are able to adapt themselves to new environmental conditions. This great principle is very clearly illustrated in the case of the five classes of vertebrate animals. Comparative anatomy and palæontology concur in teaching us that the amphibians arose from fishes of primitive type and not from the highly specialised forms that dominate the seas to-day that the reptiles arose from primitive amphibians and not from frogs or toads; and that birds and mammals in their turn sprang from primitive reptiles. Each great group, after giving off one or more vigorous offshoots in this manner, seems to exhaust itself in highly specialised experiments, which lead in the course of time to extinction.

This is nowhere better seen than in the history of the reptiles, which, after giving off the main stems of the birds and mammals about the commencement of the secondary period of the earth's history, branched out into numerous lines of descent which became highly specialised in adaptation to a great variety of conditions; crawling or walking on the land, swimming in the sea, or even flying in the air, and often attaining gigantic dimensions. Most of these lines are now extinct and their place has been taken by the mammalian and avian descendants of the primitive reptilian stock.

The same great principle is no less clearly seen in the history of mankind in relation to the remainder of the great mammalian class to which man belongs. We have already had occasion to notice that his bodily structure exhibits primitive features, especially as regards the limbs. In this respect he and the other members of the order Primates are far less specialised than most of the mammals, and it was the retention of this primitive, unspecialised limb structure that rendered possible the adaptation of the arms as prehensile organs, and the gradual assumption of the erect attitude and bipedal method of locomotion that followed upon an arboreal mode of life. It was this change of habit, and especially the increasing use of the hands in fashioning and grasping tools, that led, by way of greatly increased and diversified experience, to that extraordinary brain development that distinguishes mankind from all the lower animals and marks the commencement of a new evolutionary era.

Whatever view we may take as to the exact point at which the human stock branched off from the line of descent of the other primates—whether we regard man as a glorified ape or trace his direct ancestry further back to some more primitive lemuroid type such as Tarsius, makes little difference to our present argument, and the experts in anthropology may be safely left to settle their controversies amongst themselves. For us it is sufficient to insist upon the unity of mankind with the rest of the animal kingdom. If further proof of this unity be needed it is to be found in the mode of developmemt of the individual man, and it is perhaps worth while to consider briefly this aspect of the question.

In the days of our infancy, when a new arrival in the family circle suddenly disturbed the domestic harmony, our nurses would endeavour to satisfy our natural curiosity with some well-worn legend. The baby had been brought by a stork or dropped down the chimney by Santa Claus, or perhaps delivered by the postman with the morning letters. I would commend these remarkable statements to the earnest attention of the legislators of Florida and the other American states already mentioned, for they are exactly on all fours with the legend of the creation of

Adam and Eve. Every instructed person, however, knows that a human being comes into the world by a slow and gradual process of evolution, and it is impossible for those who have conscientiously studied the evidence to doubt that the same is true of the human race. Mankind, at any rate in civilised countries, is no longer in its infancy, and it is too late to attempt to impose upon rational men and women with legends that are suitable only for the nursery.

One of the most important generalisations as yet reached by biological science is that known as the Law of Recapitulation, which states that each individual organism, whether animal or plant, in its development from the egg, passes through a series of stages which more or less closely resemble the stages through which its ancestors passed, as adult organisms, in the course of their evolution. The ontogeny or individual life-history repeats the phylogeny or history of the race. We have already had occasion to refer to the tadpole stage in the life-history of the frog as reproducing, with considerable exactitude, the structure of the fish-like ancestor of the amphibia. There is no tadpole stage in man because the changes that have taken place in his method of feeding and protecting the young have rendered a free-living larval form unnecessary and even impossible. But if we examine a human fœtus while it is still sufficiently young we shall find a series of transverse grooves in the neck which are unmistakably equivalent to the gill slits of the tadpole, and clearly point to some extremely remote fish-like condition. At this stage the human fœtus has so much in common with those of other mammals that it would take an experienced embryologist to tell the difference between them, and, apart from the presence of the placenta, it bears an almost equally close resemblance to the embryos of the reptiles and birds. As we trace the development of all these embryos on towards the adult condition we find the differences between them becoming gradually more and more strongly marked as the distinguishing features of the groups to which they belong make their appearance; but if we trace it backwards we shall find that they all converge and meet, as it were, in a common starting point—the egg or ovum—for however much the eggs of the several groups may differ from one another in secondary features, such as the presence or absence of an egg shell and the amount of food yolk they contain, each is essentially a single cell, a single, nucleated mass of protoplasm. This egg may be interpreted as representing a unicellular ancestor, from which all the great multicellular groups of the animal kingdom have originated, while other descendants from the same primitive stock, of a more conservative character, have retained the single-celled condition to the present day and constitute the existing Protozoa.

Thus, while the study of comparative anatomy teaches that, organ for organ, even to comparatively small details, the human body shares a common plan of structure with other mammals, and, to a less extent only, with the lower vertebrates also, the study of embryology affords still more conclusive evidence as to man's place in the animal kingdom and his pre-human ancestry. So far as it goes—and it is to be regretted that as yet it goes only for a comparatively short distance—the geological history of mankind entirely supports the same conclusions. Whatever may be the exact period assigned by geologists as that in which the ancestors of the human race first acquired the right to be regarded as men, there can be no doubt that the human stock represents the most recent offshoot of any importance from the great vertebrate phylum, and in spite of the present deficiency of fossil remains we may fairly hope for a somewhat more satisfactory series of connecting links in the near future. We shall, however, probably never have anything like a complete chain, because, at the commencement of his evolution as a distinct branch, primitive man had not yet become a dominant type, and doubtless existed in very small numbers and for the most part under conditions which rendered it unlikely that his remains would be preserved for the edification of future generations.

Briefly as we have been obliged to deal with the evidence, we have perhaps said enough to justify us in the assumption that mankind, looked at as a part of the animal kingdom, must be subject to the same laws of evolutionary progress and retrogression as the lower animals. From this point of view the distinction between nature and man, between natural and artificial products and processes, however convenient it may be, cannot be justified, any more than a corresponding distinction between nature and insect, natural and of insect origin. From other points of view, no doubt, we see things differently, and the evolution of man's mental, if not of his moral qualities, goes far towards justifying us in placing him on a pedestal and according him special treatment. To this aspect of the question we shall return later on. Our immediate object will be to investigate the phenomena of evolution for the animal kingdom as a whole, with a view to determining the conditions that are conducive to well-being and progress and distinguishing them from those that tend in the opposite direction. In order to accomplish this object we must go back a very long way.

The human mind appears to be ever attempting to arrange the data with which it works in sharply defined categories, and undoubtedly this proceeding greatly facilitates the mental operations of the average man. Thus it seems only natural to draw a sharp distinction between the living and the not living, and to assume that as protoplasmic organisms cannot always have existed on the earth they must have made their appearance there at some definite time. The doctrine of the creation of the world, as enunciated in the book of Genesis, the theory of the spontaneous generation of living things by the sudden conversion of inanimate matter into organisms such as exist at the present day, and the theory of the population of the earth by immigrant germs of life from some other planet, all arose in response to the demand of the human mind for some definite beginning. The inconsistency of this demand is at length recognised by the student of evolution. He realises the absurdity of seeking a fixed starting point for the evolutionary process and a definite commencement for life. He recognises that the hunt for the first living things is the pursuit of a will o' the wisp, and that there never were any first living things either on this earth or anywhere else.

The great lesson that the study of evolution teaches is that nature knows no beginnings but only change. Evolution is continuous; without beginning and, so far as we can see, without end, and organic evolution is inseparable from the evolution of the inorganic world.

Astronomers and geologists tell us that the planet on which we live was at one time so hot that the elements of which it is composed existed only in a gaseous condition. As it cooled it condensed and partially liquefied, and further cooling and condensation led to the formation of a solid crust, surrounding a core which is still intensely hot and at any rate partially liquid, and surrounded by an atmosphere composed of certain constituents that remain gaseous at comparatively low temperatures. When the temperature had fallen sufficiently to allow of the condensation of aqueous vapour in this atmosphere, rivers began to flow and lakes and oceans to accumulate. It was then that the existence of living things on the earth's surface gradually became possible.

All along a process of evolution must have been going on amongst the constituents of which the cooling earth was composed. Chemical changes—combinations and decompositions of all kinds—were constantly taking place in strict accordance with the physical conditions existing for the time being, and it was doubtless the chemical reactions between the more superficially placed constituents of the earth's crust and the surrounding atmosphere, in the watery medium provided by the condensation of the aqueous vapour, and under the influence of the sun's rays, that led, slowly but surely, to the formation of that curious substance which we call protoplasm—a substance that occurs in the bodies of all living organisms and in the absence of which life—as the biologist understands it—is unknown.

The actual stages that led up to the formation of protoplasm as soon as the conditions at the surface of the cooling earth became suitable are unknown to us. We are equally ignorant as to whether the process may have taken place once or many times. It was, of course, a kind of spontaneous generation, but a spontaneous generation by slow and gradual evolution of the inorganic into the organic, and very different from the sudden conversion of inanimate matter into more or less highly organised plants and animals that has so often been imagined. So far as we can yet see, living organisms are never produced in this way at the present day, but always arise as the offspring of living parents.

It is the chemical and physical reactions between the protoplasmic organism and its environment that constitute what we call the "life" of the organism, and the more intense and varied these reactions are the more intense and varied will be the life. I am speaking now of life from the purely mechanistic point of view, but I do not wish to be understood as suggesting that this is the only point of view, or even that it is the most satisfactory point of view, though perhaps it is the only one that a scientific man, as such, can safely adopt, for it is the only one that gives a chance of investigation by purely scientific methods. It is, however, by no means irreconcilable with the views of those who hold that the spiritual aspect of the universe is no less real and no less important than the material. Life, it is true, appears to the pure mechanist to consist entirely of chemical and physical processes, but this may be merely because these are the only processes that are accessible to investigation by the very limited means at his disposal. However it may be with the lower forms of living matter, the case against pure mechanism appears to be conclusive when we come to consider the phenomena of consciousness and thought exhibited by human beings, and the biologist cannot stultify himself by admitting any breach of continuity between the simplest and the most complex of living things.

It would seem, then, that as the chemical evolution of certain carbon compounds progressed they slowly acquired those properties which we regard as distinctive of living beings, though we can by no means say at what particular point they first became alive, for the transition from the not-living to the living condition must have been perfectly gradual. Amongst the properties that are more especially characteristic of protoplasmic organisms is the power of taking in food material from the environment. This not only furnishes fresh supplies of energy but, inasmuch as the food material may be converted by chemical processes into new protoplasm, it leads to growth. Growth, however, is not continuous, but sooner or later results in the multiplication of protoplasmic units, and thus the swelling stream of living matter becomes broken up into individual organisms, each capable of reproducing its own kind, but always liable to further modification, which leads on the whole to ever-increasing complexity of structure—though under certain exceptional conditions the evolutionary process may be reversed and result in simplification. In this way we believe that the innumerable host of living things that to-day people the earth in all their endless variety has slowly and gradually come into being, the stream of life constantly branching out in new directions and the individual organisms adapting themselves in structure and function to every situation in which the maintenance of life is possible.

Amongst the more important factors that contribute towards the highly complex process of organic evolution we may safely give precedence to the power of the living protoplasm to respond to stimuli—that is to exhibit some change in behaviour as the result of some change in the surrounding conditions, or environment, both being of a more or less definite character. Even comparatively simple organisms, like the Amœba (Fig. 1), which look like microscopic specks of semi-transparent jelly, though in reality having a very complex structure, respond quite definitely to such stimuli as contact, light, heat, electricity and chemical action, contracting themselves into balls or changing the direction of their movements as the case may be. Similarly, in the higher plants, a root responds to the stimulus of gravity by growing downwards and a shoot by growing upwards. Not only does the complete organism, or its individual organs, respond in this manner, but the actual building up of its structure, as it develops from the egg, is determined in the same way. The protoplasmic cells divide and their products arrange themselves under the influence of the appropriate stimuli, and if these stimuli be changed beyond narrow limits the change will inevitably be reflected in the structure of the organism. Thus the growth and differentiation of a plant or an animal are merely expressions of its behaviour under the influence of specific stimuli, and the result is to be attributed ultimately to the responsive power of the living protoplasm, a power that seems to be quite capable of explanation in terms of chemical and physical science.

But the living protoplasm is not only capable of responding to stimuli, it is also capable of learning by experience and thus making its responses more and more prompt and accurate each time they are repeated. In other words, it can be educated and can establish habits. According to the experiments of Professor Jennings this power of learning by experience can be recognised even in the unicellular organisms, and it must, I think, be regarded as a fundamental property of living matter.

Perhaps the most potent stimulus that acts upon the living organism is that of hunger, which leads it to take in food from the external world, and with it fresh supplies of energy, making good what has been dissipated in its various activities and providing the material necessary for growth and reproduction. Hunger is an internal stimulus, arising within the organism itself, and when it is supplemented by the stimuli provided by the presence of suitable food material the organism makes the appropriate response, captures or absorbs the food and incorporates it in its own body, there to undergo the processes of digestion and assimilation. In ultimate analysis, of course, the act of feeding, even in the higher animals, is performed by all the constituent protoplasmic units, or cells, of which the body is composed, just as it is performed by free-living unicellular organisms such as the Amœba.

The living organism, then, whether it be a single cell or a complex multicellular plant or animal, learns by repeated experience to obey ever more promptly what we may call the feeding instinct. If food be abundant it may be taken in in excess of immediate requirements and stored up in some suitable form for future use. The fats, oils, starches and so forth, so commonly met with in the cellular tissues of plants and animals, and especially in eggs and seeds, constitute a reserve that can be drawn upon whenever the necessity arises, and this reserve represents so much surplus energy.

It is just this habit of accumulating surplus energy that has made progressive evolution possible. The parent organism accumulates a certain amount of capital which may, at any rate in part, be devoted to giving its offspring a better start in life. The methods by which this result is attained vary endlessly in detail, but the principle is always the same. In the animal kingdom, in the course of evolution, there has been a gradual improvement in the method of transmitting capital from parent to offspring. The first great discovery, so to speak, was the utilisation of the egg itself as a storehouse of food material transferred from the body of the parent. This method reaches its climax in the reptiles and birds. The chick embryo in a hen's egg is, indeed, an almost perfect example of a capitalist, and no one would think of calling it "bloated," for the accumulated capital is all required for perfectly legitimate and indeed necessary purposes.

The mammals, whose ancestors undoubtedly also laid large eggs, made two new departures in this respect, to which we have already had occasion to refer. In the first place they learnt to retain the young within the womb of the mother and feed it there by means of the blood circulation until it reached an advanced stage of development; and, concomitantly with this, they developed milk glands from the skin, and were thus enabled to continue the feeding process after the young were born. These two methods of transferring capital, or surplus energy, from one generation to the next have proved so successful that they have entirely superseded the older and more primitive method of the birds and reptiles, and the mammalian egg, being no longer used largely as a storehouse for reserve food material, has now reverted to the microscopic size that seems more consistent with its character as a single cell.

It seems sufficiently obvious that the habit of accumulating capital for the benefit of the next generation must lead to progressive evolution, for each successive generation, on the average, gets a slightly better start in life than its predecessor and is thus enabled to carry on its individual development a little further. This conclusion is not open to the objections that have, rightly or wrongly, been urged against Lamarck's theory of the gradual adaptation of the organism to its environment through the inheritance of acquired characters, for whether the supplies of energy be accumulated in the egg cell in the form of yolk and albumin, or whether they be transferred from parent to offspring by the processes of gestation and lactation, we are able to demonstrate quite clearly the means by which the accumulation is handed on. Unless something occurs to prevent it, it must continue to increase like a sum of money at compound interest, and each generation, in virtue of the inherited experience of its living protoplasm, will tend to accumulate more rapidly than its predecessor.

The mere accumulation of surplus energy cannot, of course, determine particular lines of evolution; it supplies, so to speak, only the motive power that renders progress possible. What it is that directs this progress so as to ensure the close adaptation of the organism to the conditions under which it has to live is another question, which we must endeavour to answer later on.

It seems, then, that the accumulation of capital, which is simply another name for surplus energy, is no mere human invention, but an essential condition of progress throughout the organic world. So also is the transmission of capital from parent to child. The great principle involved in capitalism is, perhaps, as old as life itself ; it is only the abuse of that principle that has been reserved for mankind.

There is one other primary factor of organic evolution that is at least as old as capitalism, and that is work, for capital and labour have been co-operating ever since the beginning of things, and neither can do without the other. We have already seen that life, from the biological point of view, consists in the constant interchange of energy between the organism and its environment. The organism takes in energy in the form of food and expends it in a great variety of ways in overcoming the antagonism of its surroundings. Now if we define work as the expenditure of energy, which seems to be the only satisfactory definition, it follows immediately, not only that life is dependent on work, but that life and work are in reality one and the same thing, or, to put it more accurately, that life is nothing but work of a particular and very complex kind. The higher the type of organism the more complex is the work in which its life consists and the greater are its capacities for good and evil, pleasure and pain.

It is clear, then, that every living thing must work for its living, for the cessation of work means death. We cannot even attempt to distinguish scientifically between workers and non-workers without realising at once that the non-workers are all dead and that there can be no need for us to trouble ourselves any further about them.

CHAPTER II

Growth—The Cell as the Organic Unit—The Multiplication of Cells—Unicellular and Multicellular Organisms—Co-operation, Differentiation and Division of Labour—Individuality—Progressive Integration—Co-ordination and Subordination.

In every living organism there must be a balance between income and expenditure. If more food is taken in than is required to meet the expenditure of energy the organism will increase in size, either by the accumulation of reserves, such as fat and starch, or by additions to its stock of active protoplasm or of other substances. In other words, growth will take place. But this growth, on account of the necessity of maintaining a proper relation between surface and volume, cannot go on indefinitely. There is, indeed, for each kind or species of organism, a limit of size which is rarely exceeded by the individual. Nevertheless, enormous increase in size has undoubtedly taken place during the course of evolution. The remote ancestors of all living animals are believed to have been microscopically minute, but to-day we have such gigantic forms as whales and elephants, with every intermediate gradation. How are we to reconcile these apparently contradictory statements ?

Let us go back to the microscopic, unicellular Amœba (Fig. 1), where the problem presents itself in a much simpler form than in the case of the higher animals. In spite of its small size and comparatively simple structure, the Amœba is a complete organism, responding to stimuli, moving about, capturing and digesting its food and, in short, performing, in its own simple fashion, all those duties or functions in which life consists. Suppose the Amœba to be placed in a situation where it is impossible for it to obtain sufficient food to make good the protoplasm which is used up as a source of energy in seeking for it. It will diminish in size and may ultimately die of starvation. If, on the other hand, food is plentiful, the Amœba may take in more than is required to balance its loss and may grow. It does not store up any considerable amount of reserve material, but converts its food almost at once into active protoplasm, and then, when the limit of size is reached, it divides into two parts. The individual Amœba, then, cannot grow beyond a certain size, but the number of individuals can be increased indefinitely. Whenever the food supply is sufficiently abundant and conditions are otherwise favourable, this reproduction or multiplication of individuals takes place.

We must now consider rather more carefully, but still very briefly, what actually happens to the Amœba when it undergoes division. We shall find that the substance of which its body is composed is very sharply divided into two parts—the general mass of protoplasm, technically termed the cytoplasm, and the nucleus imbedded in it. The latter is a perfectly definite and constant structure, of rounded shape and comparatively small size. It is quite easily seen in the living animal and may be made still more distinctly visible by the application of suitable dyes. The nucleus exercises some sort of control over the behaviour of the entire organism, and always leads the way in the process of division. It divides into two parts and these move away from one another. Then the cytoplasm gets drawn out into a kind of bridge between the two nuclei and finally breaks across, and the process is complete. Two young Amœbæ have come into the world and the old one has ceased to exist as an individual.

This extremely simple method of reproduction, known technically as fission, is characteristic of a whole host of microscopic organisms more or less closely related to the Amœba—in fact, of all those organisms in which the body consists of what we call a single cell, that is, a single, nucleated mass of protoplasm, a single organic unit. It is doubtless by virtue of their power of taking in food material rather in excess of their immediate requirements, and thereby storing up a small amount of capital, that these organisms are thus able to increase and multiply. This apparently simple process of multiplication, however, though it secures for them a certain kind of earthly immortality—for they never die unless they meet with some accident—does not carry them very far along the path of evolution.

For further progress of a substantial kind new factors are required, and the first is found in the principle of co-operation. Suppose that two young Amœbæ, offspring of a common parent, instead of separating completely from one another, remain together in intimate contact and go on feeding and dividing. They may then give rise to a many-celled organism, with an increased size limit and an increased complexity of bodily structure. In this way the single-celled animals, or Protozoa, learnt to form intimate associations of individuals all derived by cell-division from a common parent. The zoologist calls these associations Protozoon colonies. In such a colony all the cells co-operate for the common welfare and a higher or more complex type of organisation becomes possible.

As an example of such a colony we may take the beautiful green Volvox (Fig. 2), often found in immense numbers in ponds and ditches. In this case the colony is spherical, having the form of a minute, hollow ball, the wall of which is made up of a single layer of cells placed side by side. All these cells, however, with the exception of a few that are set aside as reproductive elements, are exactly like one another. Each consists of a nucleated, pear-shaped body, enclosed in a mass of jelly. Two long, whip-like extensions of the protoplasm project freely into the surrounding water and, by their lashing movements, enable the entire organism to swim actively about with a characteristic rotatory movement, by which the name of Volvox was suggested.

So far, except for the special reproductive cells, there is no difference whatever between the constituent cell units of the organism, and that is why we regard such a form as Volvox as a colony of Protozoa rather than as a true multicellular or many-celled animal. The mere co-operation of a number of individuals in a common body has as yet produced no very great advance in organisation, but it has made possible the further operation of another principle, that of differentiation and division of labour. Let us see how this may take place. Suppose that one half of the hollow ball of cells in a Volvox-like organism somehow or other gets pushed into the other half, as an indiarubber ball may be pushed in with the finger. Then we at once get a new type of structure, shaped like a double-walled cup. The component cells are now divided into two layers differently situated, one on the inside of the cup and the other on the outside. This arrangement is actually realised as a stage in the development of most of the higher animals, known as the gastrula stage (Fig. 3), and its origin is possibly to be explained as the result of purely chemical and physical processes such as changes in surface tension. With comparatively unimportant modifications, such as the development of tentacles around the constricted mouth of the cup, it is even retained in the adult condition in such animals as the common fresh-water polype or Hydra (Fig. 4); indeed, it is the fundamental type of adult structure throughout the whole of that great group of animals known as the Cœlenterata, including the jelly fish and their relations, the sea-anemones and the corals.

In all these animals the outer layer of cells is devoted to the function of protection. Some of its cells also give rise to peculiar weapons of offence and defence, the stinging-cells or thread-cells, while others form the rudiments of a nervous system. The animal is now, moreover, provided with a definite digestive cavity, or stomach, into which food is taken through the narrow mouth, and the cells of the inner layer, lining this cavity, take on quite a different function from those of the outer layer; they are concerned with the digestion of the food, and for this purpose secrete a digestive fluid. As each cell, or group of cells, in the animal is now able to devote itself to the performance of a more or less narrowly limited duty it is reasonable to suppose that that duty will be performed much more efficiently than in such organisms as the Amœba or Volvox, in which each cell has to do everything for itself and may fairly be said to be Jack of all trades but master of none.

Obviously, then, a great advantage is secured by the adoption of the principle of co-operation, differentiation and division of labour. All the component cells of the body help one another in realising a more complex life, associated, as always, with a higher type of organisation.

That this is the way in which organic evolution, up to the Cœlenterate stage, has really taken place, is rendered more than probable by the remarkable fact that it is the way in which a typical cœlenterate animal actually comes into existence at the present day. Take, for example, a common jelly fish, such as Aurelia. It commences its life cycle as a microscopic egg, which is a single nucleated cell exactly comparable to an Amœba. This cell divides repeatedly, and the daughter cells arrange themselves in the form of a hollow sphere—the blastula, comparable to the Volvox colony. One half of the sphere then gets pushed into the other half, and a gastrula is formed, with inner and outer layers of cells, mouth and digestive cavity. Around the mouth, tentacles bud out and a stage is reached which closely resembles the fresh-water polype or Hydra. It would only complicate matters unnecessarily if we were to describe how the jelly fish itself is formed from this polype.

We have here another excellent illustration of the law of recapitulation; for the unicellular egg represents an ancestral Protozoon; the blastula, a hollow, spherical protozoon colony like Volvox, and the gastrula the most primitive type of cœlenterate organisation. The same series of stages may be observed no less clearly in the early development of much more highly organised animals than the Cœlenterates, *e.g.*, in Amphioxus (Fig. 5), and the study of comparative embryology fully justifies us in the conclusion that all the higher animals are descended from remote unicellular ancestors like the Amœba, and that they have all reached their present highly organised condition as the result of co-operation, differentiation and division of labour amongst the numerous cells of which their bodies are composed.

How far these processes may be carried, and to what surprising results they may lead, can only be properly appreciated by those who have made a study of the minute structure of one of the higher animals, say, for example, of a frog, or of man himself. Here we find in the fully developed body countless millions of cells, differentiated in many different ways for many different duties or functions, and all co-operating for the welfare of the organism as a whole.

Every part of the body is composed of such cells, or of their products, bound together in tissues and organs. To mention only a few examples—bones are composed of bone cells and their calcareous secretions; the blood contains innumerable cells or "corpuscles" floating in a liquid medium; the nervous system is composed of nerve cells with their fibres; the muscles of contractile muscle cells (Fig. 6); the outer part of the skin of scale-like protective cells (Fig. 7); the lining of the stomach of cells that secrete the digestive fluids, and so on; and all these cells have been formed by repeated division of a single, microscopic, nucleated mass of protoplasm, the egg cell!

Like all other benefits, the advantages secured by differentiation and division of labour have to be paid for, and the price paid is the loss of independence on the part of the co-operating units, which are, primarily, the individual cells. Each cell is more or less dependent upon its associates, and can no longer go its own way and live its own life without their aid. A muscle cell can only do one thing; it is an admirable piece of mechanism for bringing about movement by contraction, but it cannot feed itself and cannot protect itself, and life cannot be maintained solely by contraction. So with all the other cells of the body, each plays its own part to perfection, but it cannot do other things that are equally necessary for existence. The life of the entire organism has become much fuller and much more complex, but it is a composite life, requiring the co-operation of many cell units.

It is true that recent physiological investigations have shown that it is possible to separate certain of the constituent tissue cells of a complex animal body and keep them alive in suitable culture media for an indefinite period, even for as much as ten years. Under these conditions they may grow and multiply, but they cannot re-form the entire body, and their life has been reduced pretty much to the level of that of the Protozoa, for they have lost all the advantages of co-operation and division of labour. Moreover, it seems that such cells cannot even acquire their characteristic differentiation, or cannot maintain it if already acquired, unless they be associated with certain other cells of a different kind, so complete has the mutual dependence of the constituent body cells become.

The foregoing considerations bring us face to face with the problem of individuality, one of the most interesting and at the same time one of the most difficult problems of biological science, even when considered without reference to its psychological aspect. So long as the organism remains strictly in the condition of a single cell, however, it is easy enough to define the term individual. The individual and the cell are one and the same thing, a single, nucleated protoplasmic unit which is capable of carrying out by itself all the functions necessary for the maintenance of life. When the cell divides, the old individual ceases to exist and two new ones appear upon the scene. What are we to say, however, about a colony of Protozoa such as Volvox ? We might either regard the entire sphere of cells as an individual or we might still apply the term to each of the component units, for each is able, so far as we can see, to perform all the essential vital functions. Is the mere fact of their physical union with other cells to be regarded as sufficient to deprive them of their individuality? We must leave the question unanswered, for it seems impossible to agree upon any criterion by which it may be decided.

When we come to the cœlenterate stage of organisation, however, the answer, so far as it concerns the component cell units, is again no longer in doubt. The cells of a fresh-water polype are not only united together, but they are also differentiated, and dependent upon one another. The cells of the outer layer of the body cannot feed themselves, they must have their food prepared for them and passed on to them by the cells of the inner layer. They play a very important part, however, by means of the contractile movements of the tentacles and the paralysing action of the stinging cells, in catching the living prey and thus providing the cells of the inner layer with the raw materials of life. Clearly the cells can no longer be regarded as complete individual organisms; the polype, as a whole, is the individual in this case. The component cells have merged their own individuality in an individuality of a higher order. This process is known to the biologist as integration. It is the result of co-operation, differentiation and division of labour, and has played a very important part in the evolution of both animals and plants.

But even in such an animal as Hydra the old difficulty presents itself again in a new guise, and the individuality of the polype is by no means so well defined as might at first sight be supposed. For the polype is again capable of giving rise to colonies. This is effected by a process of budding. If food be abundant, hollow outgrowths of the body may make their appearance (Fig. 4). These develop mouths and tentacles and may repeat the process, and thus a branching system of polypes may arise—a very different kind of colony from that of Volvox. In Hydra itself the buds sooner or later part company with the parent, and their separate individuality becomes definitely established. There are, however, many cœlenterate animals, more or less closely related to Hydra, in which the buds remain attached to one another, forming permanent colonies, as in the so-called sea-firs, whose plant-like growths (Fig. 8) are so commonly met with in rocky pools on the seashore, or thrown up by the waves amongst the seaweed.

In other cases there may even be a high degree of differentiation and division of labour amongst the constituent polypes of which the cœlenterate colony is composed, with a correspondingly high degree of mutual dependence, so that the individuality of the polypes themselves has in turn become merged in that of the entire system, which may now be said to constitute an individual of the third order. Beautiful examples of this are seen in the floating Siphonophora, such as the so-called Portuguese man-of-war, which sometimes occur in vast shoals on the surface of the open ocean. What were originally individual polypes of a colony, produced by budding, have now become mere organs of the entire body, some fulfilling one function and some another, and all so completely integrated that it is impossible to conceive of them as leading independent existences.

In certain of the higher divisions of the animal kingdom we see the same process of progressive integration manifesting itself in a somewhat different way. Take, for example, the common earthworm. Even to the most casual observer this animal appears to be made up of a large number of joints or segments arranged in linear series. Careful dissection reveals the fact that each of these segments, with certain exceptions, is, to a large extent, a replica or duplicate of all the others. Each contains, for example, a division of the alimentary canal, a pair of excretory organs and a pair of nerve ganglia, and each is provided externally with a set of bristles which it uses for purposes of locomotion. In the earthworm the segments are no longer capable of separating from one another and living independent lives—the process of integration has gone too far for that; but that they actually represent individuals of a lower order than the worm itself is clearly proved by the case of some of the marine annelids, in which the segments, which are produced by a kind of budding, periodically separate in groups, and each group gives rise to a new and complete organism. The earthworm, then, may be looked upon as a highly integrated linear colony. Nor does the process end here, for the so-called metameric segmentation of the body of any vertebrate animal is a clear indication of a similar origin. Here, however, the segmentation is less easy to detect than it is in the earthworm, though obvious enough in the early stages of development. It is, indeed, one of the most fascinating tasks of the comparative anatomist to analyse the vertebrate body in terms of its component segments, and much progress has already been made in this direction. That remarkable structure, the human head, for instance, to which we are so apt to point as a proof of our superiority over the rest of the animal kingdom, has been shown to consist of about a dozen segments, each undoubtedly representing a very remote ancestral individual of a lower order, but all now so completely amalgamated as to have lost every external indication of their original condition, though sufficiently obvious traces are still recognisable internally in the structure of the brain and the arrangement of the cranial nerves.

The problem of individuality may also be approached from the experimental side. A single Hydra is undoubtedly one individual, but it is easy to make it into many by cutting it into pieces with a pair of scissors, for each piece will develop the missing parts and soon come to form a perfect individual once more. It is also possible to graft together parts of different Hydras and thus make a composite individual. The same has been done even with the tadpoles of frogs, and a composite frog, composed of parts of two individuals of different species, produced.

From the morphological or structural point of view, then, it is obviously by no means easy to give a clear-cut definition of animal individuality, and in the case of plants the difficulty is even greater. It seems as if we could hardly do better than adhere to the idea that an individual organism is one which can by itself perform all the functions necessary for its separate existence.

The problem arises once more, however, at a still higher level, when we come to consider animal communities, for here we find that our definition frequently breaks down owing to the fact that the members of the community, though undoubtedly individuals from the morphological point of view, have become so dependent upon one another that they are no longer capable of existence when separated from their fellows. We might even regard such a community as itself constituting an individual of a higher order than any which we have yet considered.

Take, for example, a community of bees, which consists of morphological individuals of three kinds —the queen, the workers and the drones. All co-operate for the common good. The queen lays the eggs, the drones fertilise the young queens, which are destined either to perpetuate the old community or to found new ones, and the workers build the comb and collect the honey and pollen which constitute the common food supply. There is no morphological or structural integration of the different units in this case, but there is a well-marked functional or physiological integration, if one may so call it, for neither queen, drone nor worker is capable of separate existence.

We shall deal more fully with the problem of the formation of animal communities in our next chapter. In the meantime we may assume that amongst the lower animals progressive evolution, even up to the formation of communities of separate but differentiated members, has always been accompanied by the merging of individualities of a lower order in individualities of a higher order. In other words, progress has been effected only at the cost of sacrifice of individuality and independence for the sake of a common life on a higher plane of existence.

We must now turn aside for a brief space in order to consider somewhat more in detail the phenomena of co-ordination and subordination as they manifest themselves at different stages of evolution. We may define co-ordination as the process whereby the constituent parts of the body are brought into that close relationship with one another which is necessary in order to enable them to co-operate for the common welfare, and subordination as the sacrifice of the individuality and independence of the parts in the interests of the whole.

These constituent parts of the body may, as we have seen already, be recognised in many cases as individuals of a lower order that have more or less completely lost their independence. This is, of course, true of the individual cells of which the bodies of all multicellular organisms are built up. It is also true of the component parts of a Portuguese man-of-war, and of the body segments, or metameres, arranged in linear series, which are clearly recognisable in such an animal as the earthworm, and only less clearly in the highest of the main subdivisions of the animal kingdom—the Vertebrata.

There are also, however, well-defined parts of the body which cannot be regarded as representing each one individual of a lower order; such, for example, are the brain, the stomach or the limbs of any one of the higher types of animal life. We commonly speak of such parts as organs of the body, but in some cases it is very difficult to distinguish between such an organ and a highly differentiated and subordinated individual of a lower order. The organs of the Portuguese man-of-war, for example, as we have already seen, correspond pretty closely to the original individuals of which the entire organism is built up.

It would seem, indeed, that bodily organs have originated in two ways: firstly, by transformation of individuals of a lower order in more or less complete subordination to the higher individuality; and, secondly, by further differentiation of the body as a whole, without reference to its possible composition out of subordinate individuals.

Even in the unicellular organisms, or Protozoa, a considerable amount of differentiation of the body into organs may take place. The nucleus of the Amœba (Fig. 1) may be regarded as an organ of control, and there is a well-defined contractile vacuole which is an organ of excretion. These are permanent organs. For other purposes the Amœba makes use of organs of a temporary character. Thus the pseudopodia are thrust out as required to form temporary organs of locomotion and prehension, and the food taken in is digested in the so-called food vacuoles, which may be regarded as temporary stomachs. Many unicellular animals exhibit a much higher degree of organisation than the Amœba, with permanent organs of locomotion in the form of hair-like cilia or whip-like flagella, permanent mouths and alimentary canals, protective shells, often of a very complex structure, and so forth.

In the unicellular body, again, we may find a high degree of subordination and co-ordination amongst the constituent organs. In the first place the entire organism seems, as we have said, to be under the control of the nucleus, though how this control is effected we do not yet understand. It has, however, been experimentally proved in certain cases that without the nucleus the cell cannot continue to exist. The experiment consists in cutting the cell into pieces, when it is found that such pieces as happen to retain a fragment of the nucleus will not only remain alive but will actually develop the missing parts again, while those that contain no nucleus will perish.

In a ciliated Protozoon, such as Paramœcium (Fig. 9), locomotion is effected by the rhythmical beating of the hair-like cilia against the surrounding water. There may be many hundreds of these cilia, and in order that the animal may move in a definite manner they must beat in unison ; in other words, their movements must be co-ordinated, like the movements of the oars in a rowing-boat. Again we do not know exactly how this co-ordination is effected, for it is extremely difficult to investigate such problems in the case of such very minute organisms. There are, however, indications of a system of control distinct from the nucleus, and we are probably safe in assuming that there must be some sort of nervous system, though in an extremely rudimentary condition ; indeed, the existence of such a nervous system has been recently demonstrated in certain Protozoa.

If we now turn to the case of Volvox we meet with a similar phenomenon. This organism, it will be remembered, is a colony of unicellular individuals arranged in the form of a hollow sphere, each individual having a pair of whip-like flagella which project freely into the surrounding water (Fig. 2). Here, again, the lashing movements of the flagella, whereby locomotion of the entire organism is effected, must be co-ordinated, but it is now a question of co-ordination between different cells, not merely between parts or organs of the same cell, as in the typical, non-colonial Protozoa. We are again in ignorance as to how the co-ordination is brought about, but we know that all the different cells of the colony are connected together by fine threads of protoplasm, and may feel sure that here again there must be some sort of rudimentary nervous system along which stimuli are transmitted from one cell to another.

In the fresh-water polypes and other cœlenterate animals there is clear and unmistakable evidence of the existence of a nervous system, with specialised nerve cells and conducting fibres, whereby the behaviour of the organism as a whole is regulated by nervous impulses or stimuli transmitted from one part to another. Many beautiful experiments have been made on some of the larger jelly fish, by the late Dr. Romanes and others, demonstrating the manner in which this nervous system fulfils its functions, and it is evident that a very high degree of co-ordination is thereby brought about. Even here, however, the nervous system is very feebly developed as compared with that which we find in the higher animals, and there is still nothing that can be regarded as a single, centralised brain.

We need not dwell further upon the lower stages in the evolution of the nervous system as the chief, though not the only means of co-ordination in the animal body. In the higher types, and especially in the Vertebrates, a definite brain appears which gradually assumes an increasingly dominant character and constitutes the great centre of control, though subordinate centres exist in the spinal cord and in various ganglia, or collections of nerve cells, that lie outside the central organs. By means of this highly elaborated, complex system of nerve cells and their fibres, all parts of the body are brought into intimate relation with one another. But in man, at any rate, there is much more than this, for the brain does not control and regulate the behaviour of the body in a merely automatic manner, by simply transmitting messages from one part to another. It exercises an intelligent supervision over all that is going on. It translates and censors the messages and becomes the organ of consciousness and thought, capable of initiating action on its own account. In this way a very high degree of co-ordination and direction of the body is assured, and every part encouraged in the performance of its proper function and kept in fitting subordination to the common welfare. The principle of centralised government has evidently been one of the chief factors in the evolution of the animal kingdom.

The nervous system, however, is by no means the only system of co-ordination and control that the animal body possesses. We have already referred to the fact that the development of an animal from the egg consists in a series of reponses to stimuli that seem to be largely of a chemical nature, and we shall have to refer to it more in detail later on. Physiologists now recognise that various parts of the body, especially the so-called ductless glands, give off secretions containing specific chemical substances, or hormones, that circulate in the body fluids and act as stimuli upon parts that may be far distant from their seat of origin. In this way, for example, the development of secondary sexual organs, such as horns and antlers, is regulated by secretions that arise in the sex glands themselves.

Thus we see that the progressive evolution of the animal body has been accompanied, we may even say has been rendered possible, by the gradual establishment of systems of control and co-ordination, without which it would be quite impossible to maintain that harmonious co-operation between the constituent parts upon which the existence of every individual organism necessarily depends.

It seems hardly necessary to point out that the innumerable diseases and infirmities to which the animal body is unfortunately liable are in very large measure the result of some derangement of this complex mechanism. Take, for example, the most dreaded of all human diseases, cancer. Little as we may know of the exact causation of this horrible malady, it seems quite certain that it consists essentially in the abnormal multiplication of cells that have in some way or another freed themselves from control. Their behaviour is no longer subordinated to the common welfare of the great cell community of which they form a part, and their unrestrained growth, if allowed to continue, must lead inevitably to the destruction of the entire organism. The analogy with what too often takes place in a society of human beings is sufficiently obvious. The slum areas of a great city, with their teeming population of inadequately controlled and often criminal individuals, are cancerous growths that constitute a terrible menace to the life of the community as a whole.

CHAPTER III

Insect Communities—The Social Organism.

THE study of insect communities, which represent the high-water mark of the process of integration in the animal kingdom, must always be particularly instructive from the point of view of the student of sociology, though less, perhaps, as affording a solution of the problem of how human societies have come into existence, than as an indication of what might conceivably happen to them in the remote future if certain popular ideals should ever come to fruition in all their crude simplicity.

Insect communities are enormously older than human societies. They have been in existence for a length of time in comparison with which humanity itself is but a thing of yesterday. Many of us have lately been almost staggered by the idea of the antiquity of the civilisation of Tutankhamen. The complex social organisation of the ants dates back twenty thousand times as far. We must accustom ourselves to think in millions rather than in thousands of years before we can hope to gain any clear conception of the slow processes of organic evolution.

As might be expected from their much greater antiquity, insect communities have attained a far more stable and, in a certain mechanical sense, a far more perfect organisation than any human society.

With them, everything goes like clockwork, and every activity is directed towards the interests of the community as a whole. Differentiation and division of labour are much more complete, and have resulted in the formation of sharply defined castes amongst the constituent individuals. There is no need to form trade unions or to forbid a member of one caste to perform the duties of another ; he is simply incapable from inherited structure and habit, of any such indiscretion. There is no central authority. We speak, indeed, of the queen bee, but she is a mere egg-laying machine, and the only excitement she gets in life is on the single occasion of her nuptial flight, though perchance at some future date she may be allowed the amusement of killing any superfluous queens that may have been reared up in case of emergency. A social insect never plays, he is a serious-minded individual and a strict utilitarian. If, like the unfortunate drones in the hive, he can find no job for which he is suited, he is remorselessly exterminated.

The social insects are communists of the most extreme type, and they have succeeded in reaching their very unenviable degree of perfection simply because they had not sufficient intelligence to enable them to fight against it before it was too late. There is little or no initiative amongst them, their individualities have been completely subordinated to the purely mechanical welfare of the community as a whole, and all possibilities of a higher life have been excluded. The insect community, in short, has reached a condition of complete stagnation, and its very perfection seems to preclude the possibility of any further progress. Professor Wheeler [1] tells us that "The ants have undergone no important structural modifications since the Lower Oligocene . . . they had at that time developed all their various castes just as we see them to-day . . . their larvæ and pupæ were the same, they attended plant-lice, kept guest beetles in their nests and had parasitic mites attached to their legs in the very same peculiar positions as in our own living species." These conclusions have been arrived at from the study of ants preserved in Baltic Amber, and probably apply also to the bees, wasps and termites. The age of such insect communities has been estimated at some fifty or sixty millions of years, and it seems safe to conclude that they have reached the limits of their progress. Let us consider somewhat more in detail to what that progress has brought them in the case of the white ants or termites.

Though in many respects their organisation exhibits an extraordinarily close resemblance to that of the true ants or Formicidæ, the white ants really belong to a widely distinct group of insects, of a much more primitive type, perhaps most nearly related to the cockroaches. Their social organisation must have been acquired quite independently of that of the true ants—a remarkable case of convergence in evolution.

The termites are found only in the warmer parts of the earth, but in tropical and semi-tropical countries they occur in enormous numbers and in considerable

[1] "Social Life among the Insects" (Constable & Co., London, 1923).

variety, and their ravages constitute one of the most serious obstacles to human civilisation. They feed mainly upon wood, and may also use the wood pulp which they prepare in the construction of their own nests. These communal dwellings, or termitaria, are often of great size, as much as 20 feet high, and in tropical Africa they are sometimes grouped in such a way as to resemble Kaffir villages. One of the larger termitaria shows a very remarkable architecture. Its external form varies greatly, but it is, perhaps, most usually a dome-shaped or conical structure with a very thick and hard outer wall composed of chewed earth, so hard that the material is sometimes used in South Africa for making tennis courts. Internally the nest is divided into chambers and galleries, of various shapes and sizes and used for various purposes. The centre of the entire organisation is the so-called queen, an enormous and unwieldy creature, perhaps 20,000 times as large as one of the workers. She lies imprisoned in a royal chamber in the basement of the establishment, where, accompanied by the far less majestic looking king, she is guarded and waited upon by soldiers and attendants. Her sole duty is to lay eggs, and she does it well and faithfully, producing about 30,000 a day for a period of ten years. These eggs are carried away by the attendants to special nurseries, and the young termites, when hatched out, may be reared upon the produce of special fungus beds carefully cultivated by the workers.

In return for her labours on behalf of the community, the queen, as we have seen, is looked after by her attendant workers, for it is quite impossible for her to escape from the royal chamber and forage for herself. It seems, however, that the workers require special payment for their services, and for this purpose the ever-fruitful mother places her own secretions at the disposal of her family. From the naked surface of her swollen body she exudes a substance which seems to be particularly attractive, and which the workers eagerly lick up, even tearing off bits of the royal skin to make it flow more freely.

As might naturally be expected, the termite population increases rapidly under these conditions. To remedy this evil periodic swarms of winged individuals, potential kings and queens, leave the nest, but very few of them ever survive the adventure. They are followed and preyed upon by innumerable birds, which are said to gorge themselves to such an extent that they can no longer shut their mouths ! A few of the adventurers, however, escape and mate with one another. After casting off their wings each pair excavates a burrow in the soil and founds therein a new community. Eggs are laid which develop into the various castes of which the community is composed ; workers which will build the nest, tend the queen and collect food ; soldiers which will protect the establishment from enemies, and perhaps act as overseers ; and young kings and queens, the latter alone being sexually perfect.

Such is life under the communal system of the termites' nest. Only those individuals that contribute to the welfare of the community as a whole are tolerated, the superfluous males and females, which are produced in enormous numbers, are, as we have seen, ruthlessly weeded out, but after all theirs is the great adventure, and we can readily imagine that they get more enjoyment out of their brief existence in the sunshine than the other members of the community do during the whole period of their underground and degenerate life.

If we enquire what it is that holds such a community together, the answer appears to be really self-interest. The queen secures the services of her attendants by offering them sweetmeats, which she has to provide at the expense of her own body. A similar exchange of secretions appears to take place between individuals of each of the different castes. There is also a very elaborate system of mutual feeding, presumably of a more substantial nature, even food that has already passed through the alimentary canal being handed on by one individual to another, so that little is wasted.

This curious communistic system of trophallaxis, as it is technically termed, finds a remarkable parallel in the case of the Formicidæ, where it is carried to extreme lengths by the honey-pot ants. In these species certain individuals of the community are filled with honey by their associates, until the abdomen is swollen out into a great, spherical receptacle. They are then kept hanging in rows on the roofs of underground chambers, to be tapped as required by the hungry workers. We might regard them as compulsory capitalists, completely under the control of labour.

It is the feeding instinct, then, the ever-driving force of hunger, that keeps the insect community together, and to the satisfaction of this one appetite all else is subordinated. The imperative necessity for satisfying this craving has led to behaviour which, in many cases, appears to be highly intelligent. Both ants and white ants, for example, may have their domestic animals of various kinds. Some of the true ants, as is well known, make use of the excreta of plant lice, or aphides, as food, and in one case at least they collect the eggs of these insects on the approach of winter, take care of them in underground chambers until the spring, and then replace them on the appropriate food plants, there to hatch out into new herds of ant-cows. We have here a curiously exact parallel to the behaviour of human beings.

In South America the leaf-cutting ants make themselves conspicuous by their habit of stripping trees of their leaves, which they carry off to their nests and use for making their fungus gardens. This also seems at first sight a reasoned action, but it may be regarded as extremely doubtful whether the ants have any definite ideas, either as to what they are doing or why they are doing it. They seem to act almost entirely by instinct, which we may, perhaps, define as an inherited habit of responding to a complex series of environmental stimuli by a complex series of actions. In other words, the actions of ants and termites appear to be mere tropisms, or automatic responses, akin to the growth of green plants towards the light, or to the response of a muscle on stimulation. This appears more probable when we consider a simpler case. In Northern Australia the compass termites build their wedge-shaped nests in such a manner that the long sides face east and west and the narrow ends north and south. No one would credit the termites with reasoning powers—much less with astronomical knowledge—on this account. The orientation doubtless arises in response to definite environmental stimuli—very possibly of heat, for it seems to offer the least exposure to the scorching rays of the sun.

The social insects seem to have become so perfectly adapted to their own peculiar mode of life that their behaviour has become almost completely stereotyped, and the degree to which this has taken place is an indication of the extent to which the integration of the community has progressed. They may have had some beginnings of intelligence in the early stages of their history, but there is little need for intelligent action in their present mode of life. Practice has made them perfect. We see the same sort of tendency in ourselves, for when we have done the same thing a certain number of times it ceases to require any conscious exercise of our intellectual powers and becomes purely mechanical. The philosophers have warned us against the dangers of automatism. It is, of course, an excellent thing if not carried to excess, but when everything comes to be done automatically what is there left to think about? unless—indeed we have reached the stage of pure abstract reasoning, divorced from all external activities, which will not be yet awhile.

It will be sufficiently obvious from the brief sketch that we have just given that the analogy between human and insect communities is in many respects extraordinarily close. Indeed, Professor Wheeler, than whom there is no better authority, goes so far as to maintain that human societies are so similar to insect societies that it is difficult to detect really fundamental biological differences between them. If, then, we may regard an insect community as an individual organism of the highest order of integration, it seems necessary to extend that conception to human societies. This idea, of course, has long been familiar to sociologists, especially to students of the works of Herbert Spencer, but it has by no means met with general acceptance. Professor Letourneau, for example, in his work on the "Evolution of Marriage and of the Family," [1] denies very emphatically the existence of a real social organism. "Let us," he says, "observe, by the way, that the expression 'social organism' is simply metaphorical, and we must beware of taking it literally, as Herbert Spencer, with a strange *naïveté* seems to have done. Societies are agglomerations of individuals in which a certain order is necessarily established; but it is almost puerile to seek for, and to pretend to find in them, an actual organisation, comparable, for example, to the anatomic and physiologic plan of a mammal" (p. 35).

Now, with this somewhat dogmatic pronouncement we must at once join issue, for the very possibility of a social science seems to depend upon the organic nature of society. After all, what does the biologist mean by the term organism? Is it not an aggregation of units co-operating with one another for

[1] The Contemporary Science Series (Walter Scott, London).

the fulfilment of some common end in the interests of the whole? We have already seen how, when a certain stage in the evolution of living matter has been reached, the cell becomes the unit of organisation; how, through progressive stages of integration, first comparatively simple multicellular organisms arise by the aggregation, co-operation and differentiation of individual cells, and then, by repetition of this process at successively higher levels, still more complex organisms come into existence.

The only ground for denying that a human society, or an insect community, is an organism of a yet higher order, would seem to lie in the fact that the subordinate individuals of which it is composed do not remain in a state of physical continuity with one another, like the cells of the animal or vegetable body, or the component individuals of the Portuguese man-of-war, or the segments of such an animal as the earth-worm. But it must be observed here that in different groups of plants and animals we find almost every degree of cohesion between the constituent units of the body. A fresh-water Hydra, producing buds, thereby forms a temporary colony; in the closely related marine zoophytes, such as Obelia, the buds remain permanently together and acquire a certain, though very limited, degree of mutual dependence, which, in the Portuguese man-of-war is enormously increased.

We must, it is true, admit that the buds of the Hydra become independent organisms when they separate from one another, but this is because, when they lose their physical connection, no other bond arises to keep them in any sort of close association. But in a human society it is very different, for, owing primarily to the development of the mental and moral faculties, which, so far as we can judge, are entirely lacking in such an organism as the Hydra, new bonds arise, which are quite as effectual in producing integration as those which exist in many animal and vegetable bodies. It is highly interesting and important to observe that such a distinguished student of sociology as Dr. Bosanquet has, from the purely psychological standpoint, arrived at a very similar view as to the integration of human society. "There is," he says, "a distinctive and interesting communal life, which seems rather in fact to absorb individuals and to provide them with purposes or values, than to be itself deducible from an accumulation of private lots, as it were, or claimable portions, of welfare, each lot to each individual. This social substance or single social life, in which individual members blend their minds and wills by directing action to common indivisible purposes, is hard to represent as merely derivative from the separate claims of individuals to welfare, and as taking its value from being instrumental to these. It has rather the air of something new; of something which comes out of the co-operation of individuals, but reveals a fresh character in them, and exhibits them as something which, *qua* mere units set side by side, they would not appear to be." [1]

The chief criteria of individuality, from the

[1] "Some Suggestions in Ethics," p. 35 (Macmillan & Co., London, 1918).

biological point of view, may be taken to be the degree of mutual dependence exhibited by the component units of the body under consideration, and the extent to which these units co-operate for the common welfare. Judged by this test a civilised human society exhibits a very high degree of individualisation, for its members are dependent upon one another to a very large extent. We need not suppose that they would die immediately if separated from their fellows and removed, say, each to a separate island of his own. They might still be able to maintain some sort of existence, but it would be an existence of quite a different kind from that which they enjoyed as constituents of a social organism. In the same way it is quite possible, as we have already seen, to isolate cells and organs (such as the heart) from the body of the higher animals, and keep them alive for a long time under appropriate conditions, but no one would conclude from this that the body from which they were removed is not to be regarded as an individual organism.

There is another line of argument which leads inevitably to the conclusion that a human society is a living organism, with an individuality of its own, for it undoubtedly becomes organised in a characteristic manner that depends entirely upon the association of its constituent members. Just as, by the association and the activities of its component cells, the human body makes for itself organs of various kinds for the fulfilment of diverse functions, so a human society makes for itself, by the co-ordinated activities of its members, organs that are used by the whole community. A railway train or an aeroplane is no less an organ of locomotion than an arm or a wing ; a drainage system is an organ of excretion ; a telescope is an organ of vision and a telegraphic or telephonic apparatus is nothing more nor less than a nervous system shared by the community.

This is by no means mere metaphor. If it be objected that the various contrivances above referred to, and others too numerous to mention, are not parts of a living body, it is only necessary to point out that in any large tree the whole of the fully developed wood is dead, containing no living protoplasm, and that in our own bodies a great part of the tissues are composed of mineral substances that cannot strictly be said to be alive. The only really living substance is the protoplasm of the constituent cells. This protoplasm absorbs from the outside world, in the shape of food, materials that it builds up into the framework of the body, as, for example, the salts of lime that constitute the great bulk of the bony skeleton. If a man takes more or less similar mineral substances and builds them up into a false tooth, that tooth is none the less an organ of the body because it was rapidly constructed under the conscious direction of the man instead of being slowly built up under the unconscious direction of the growing boy.

It is one of the chief distinguishing features of man that he is thus able to make for himself new organs out of inanimate objects, and so to increase enormously the complexity of his organisation, and in so far as these extra-corporeal organs are common to a whole community they afford one of the chief means by which the organisation of the community as an individual of a higher order is brought about.

It is indeed curious to observe how closely the organisation of society follows the lines along which the organisation of the human body itself has been effected. Almost every organ that the body possesses has its counterpart in the social system, and as the organs are merely the means by which the functions of life are carried on it follows that the life of the community as a whole forms a close parallel to that of the individual man. It is, in fact, a composite life, the resultant of all the lives lived by its component members, just as the life of the human body itself is the resultant of all the lives lived by its constituent cells, which is, of course, quite a different thing from saying that it is merely the sum of those lives.

It seems worth while to examine the organisation and life of the community yet a little more closely from this purely biological point of view. We have seen in an earlier lecture that the life of an organism consists in the sum total of all the energy exchanges that take place between the organism and its environment, using the latter term in the widest possible sense, so as to include both external and internal factors. Thus also the life of a human society is made up of energy exchanges that take place on the one hand with other societies, and on the other between its own constituent members. International politics, war and commerce are its chief external activities; while legislation, administration, social and business activities of every kind, including the joint performance of all necessary functions, such as communication, food supply, water supply, drainage and so forth, all contribute to the internal life. The due performance of all these manifold activities is rendered possible only by a very complete carrying out of the principles of co-operation, differentiation and division of labour.

The first thing necessary for the life of an organism is, of course, an adequate food supply, and the maintenance of this brings in its train all the other vital activities. The food supply is, or ought to be, collected and distributed by certain sections of the community in such a way as to secure the adequate nutrition of the whole society; the process of distribution being comparable to the circulation of the blood in the animal body. If the food supply is abundant the community as a whole grows, by increase in the number of its constituent members, just as the body grows by increase in the number of its constituent cells. If that growth exceeds a certain limit, determined by the conditions of the environment, geographical or otherwise, the community may reproduce its kind. Small communities may separate off and start life as more or less independent organisations in some more or less distant locality. In this way new human societies, off-shoots of the older ones, have taken root all over the world, reproducing in each case most of the distinguishing traits of the community from which they sprang. We have here a very close analogy with the process of reproduction by budding that takes place in many of the lower organisms. Moreover, in the development of each daughter community from a small handful of colonists, we see a repetition of the gradual progress from simplicity to complexity that characterises the development of organisms in general, and it may take place in strict conformity with the law of recapitulation.

There is one point in this comparison of the human society with the individual body that deserves special attention. The body is the product of a single fertilised egg, all the countless millions of cells of which it is composed being directly descended from one and the same parent cell. It thus comes about that there is a certain homogeneity in the protoplasm of which all these cells are composed, for the stream flows from a common source. Probably no other source can ever be exactly the same, for its nature depends upon the various factors that the male and female germ cells contribute to the common stock, and these, as we shall see presently, may be endlessly diversified, so that the probability of exactly the same combination occurring twice, *i.e.*, in any two fertilised eggs, is infinitely remote.

Now we know from recent physiological researches that there exists a curious incompatibility between samples of protoplasm (or their constituent proteids) having different ancestral histories. They are unable to work harmoniously together and tend to be mutually destructive. The blood of one animal cannot be made to replace that of another species, even if closely related; and amongst human beings, in cases where transfusion is necessary, it is essential to obtain the blood from a near relative of the patient.

This physiological incompatibility prevents the complete fusion of organisms of different kinds one with another. There are, of course, partial exceptions, and it is even possible, as we have already seen, by grafting the hinder part of one tadpole on to the front part of another, to produce a composite frog belonging to two distinct species, but such exceptions only serve to prove the rule. Animal bodies produced in such a way are thoroughly artificial and probably far from healthy.

When we come to look at the origin of a human society we find again in this respect a striking analogy with the animal body. A community may be a natural one, in which all the members have a common ancestry, or an artificial one, in which the members have been brought together, perhaps from the four corners of the earth, and more or less successfully or unsuccessfully combined in a composite organism. It is in such artificial communities, as history abundantly shows us, that disharmonies are most apt to arise from incompatibility of temperament on the part of the constituent members. The old saying that blood is thicker than water embodies the popular sentiment with regard to the mutual ties of blood-relationship, and here, as so often happens, popular sentiment is found to be in accord with scientific truth. The instinctive aversion to foreigners which lies at the root of national feeling is perhaps not altogether so irrational as it appears at first sight, for it naturally tends to keep apart elements that are incapable of being welded together into a stable organisation. We have here a biological justification for that principle of nationalism that has played so large a part in recent political discussions.

Should any one feel disposed to argue that the existence of a physiological incompatibility between the blood of all except the most closely related individuals has no bearing upon the problems of social science, it may be pointed out that in this respect the blood must be regarded as typical of the entire organism, and that differences in the brain cells themselves, upon which all human affections and disaffections depend, may be expected to determine incompatibilities of temperament of the kind alluded to.

Perhaps the strongest argument that can be brought forward against the analogy between the organisation of a human society and that of the individual body is that derived from the consideration of the great difference in the nature of the bonds by which the constituent members of the respective organisations are linked together. This argument is, however, by no means convincing.

The degree of integration of any complex organism evidently depends upon the degree of intimacy, so to speak, that exists between the constituent units of lower order; upon the strength and permanence of the bonds which unite them one with another. In the lower animals these bonds are mainly physical connections, it may be little more than mere juxtaposition, and it is sometimes possible to relax them entirely without destroying the life of the component parts.

We have already had occasion to observe, however, that, in the case of the higher animals at any rate, certain chemical substances—the so-called hormones—circulating in the body fluids, aid to a very large extent in bringing about the necessary control and co-ordination of the manifold activities of the different organs.

Still more important is what Sir Charles Sherrington has termed the integrative action of the nervous system. The brain and spinal cord, and the various nerves and ganglia connected therewith, constitute, as we pointed out before, a most elaborate and efficient mechanism of co-ordination, whereby all the different parts of the body are kept closely in touch with one another.

Such a nervous system, in an extremely rudimentary form, makes its appearance even amongst invertebrate animals of the cœlenterate type. There is no reason to believe, however, that such lowly organised animals, when once physically separated, have any means of communicating with one another. With the higher animals it is different. Communication is no longer restricted to that which takes place between different parts of the same body. Sense organs are developed and separate individuals begin to be aware of each other's existence. Each smells, sees or hears its mate, and a new bond is established that is utilised primarily for bringing together those of opposite sex but of the same species.

With the gradual elaboration of the nervous system and sense organs, and the concomitant development of the intellectual faculties, the means of communication between separate individuals become more and more perfect, and a further stage of integration is rendered possible. Communities are established, in which the bonds between the constituent members, though of a different nature, are no less effective as a means of organisation than are those which unite the physically connected parts of the individual body.

In human societies it was, above all, the faculty of communicating by means of sounds that led the way in promoting integration and organisation on the higher plane. When this means of communication developed into definite language, and when, by the discovery of writing and printing, it was made to embrace the past and the future, as well as the present, human communities acquired a degree of coherence and individuality previously impossible. The advantages of co-operation, differentiation and division of labour became more and more intensified and the bonds connecting the individual members became stronger and stronger. Family life, tradition, custom and religion all played their part, and not only served to promote the integration of the community itself but also tended to separate it ever more and more sharply from similar communities established elsewhere.

In short, the bonds by which the solidarity of a human society is secured are mental and moral in their nature, rather than chemical and physical, or even physiological. Mental and moral phenomena may be regarded, however, as expressions of the activity of one particular organ of the body—the brain, and the mental and moral ties that unite human beings with one another are essentially organic. It may be urged that it is for psychologists rather than for biologists to deal with them, and with this view I agree, so long, of course, as it is clearly understood that psychology is merely a specialised department of biological science, and that the biologist cannot be expected to relinquish his right to survey the entire field.

Taking all these facts into consideration, and observing how the nature of the bonds that hold together the constituent units of a complex organism changes as evolution progresses, there seems little reason for refusing to admit the organic nature of human societies, or for maintaining that the laws of organic evolution are altogether inapplicable to them.

The existence and progressive evolution of human societies depend primarily upon just those factors that we have seen to play a leading part in the evolution of lower organisms—upon the response to stimuli, the accumulation of capital, co-operation, differentiation and division of labour, and upon the integrative action of a well organised system of control or government. A human society, however, contains within itself possibilities of progress which even an insect community does not possess. These lie in the far more highly developed mental faculties, and above all in what, were it not for fear of being misinterpreted, I should like to call the spiritual faculties of man. It is just the existence of these faculties in its individual members that makes it so difficult for many people to concede the organic nature of human society as a whole; for, by virtue of their existence, the individual man has, in the slow course of evolution, developed a soul—if again I may make use of a term which each will interpret according to his own convictions. At any rate he has developed something which he will never be willing to sacrifice in the interests of the community, for "The essence of man is freedom." The individuality of a man, though in a certain sense of a lower order than that of the community to which he belongs, is something much more real and much more valuable, and it is by the more perfect development of individual men and women that the welfare of society as a whole will be best promoted.

Dr. Bosanquet tells us that there is no true whole but mind, and that the social whole, by which I take it he means human society, differs from an "organism" pure and simple by the presence of the whole in every part, through the action of consciousness. He also observes that the mind of an individual is not a separate entity.

In human societies, nevertheless, it is the individual man who counts and who must, if possible, be saved by the joint efforts of himself and of his fellows, and this anomalous state of things brings about a new struggle for existence between progressive human ideals and what are sometimes called the laws of nature. We must return to this question later on.

CHAPTER IV

Modification of the Individual under the Influence of the Environment—Reproduction and Heredity—The Law of Continuity — Mitosis and Cell Division — Body and Germ Cells—Why the Child resembles its Parents.

WE have already had occasion to observe that the life of an individual organism consists in a series of responses to stimuli of various kinds, and that this statement applies not only to the life of the adult, but also to that of the embryo or fœtus, during which the responses consist chiefly in all those complex processes of growth and development by which the body gradually builds itself up from the absorbed food material. Any departure from what we may term the normal stimulation brings about responses which result in some corresponding modification of bodily structure, and this may take place at any period of life. Students of experimental embryology are well aware that definite abnormalities of structure, or monstrosities, can be produced at will by a variety of means applied to the developing animal. We shall say more about this presently. In the adult organism it is less easy to bring about such changes in structure; indeed it is only possible within much narrower limits, for the various tissues and organs have, to a very large extent, lost their embryonic plasticity. It is possible, however, to effect a good deal of structural modification even at an advanced stage, not only by training, as in the case of athletes, but by more obviously mechanical means, as in that of the malformed feet of Chinese women; whilst in the case of plants every gardener knows how strongly marked may be the response to differences in treatment. A potato, sprouting in a dark cellar, produces enormously elongated shoots, with no properly developed leaves, as different as can well be imagined from the same plant growing under normal conditions. But if such a shoot manages to find its way to a window, the mode of growth at once changes; properly developed leaves are produced and the stimulus of the light also causes the formation of chlorophyll, so that the leaves and stem acquire their normal green colour.

It is obvious that such structural modifications may be of immense advantage to the individual organism in enabling it to adapt itself to special conditions of life. The horny-handed labourer acquires a protection which enables him to perform with ease and comfort tasks that would otherwise be difficult and painful, and the sailor develops a constitution which makes it possible for him to live under conditions that would be fatal to a delicately nurtured man. In short, it cannot be denied that the individual animal or plant may respond to environmental stimulation by modifying the structure of the body in what looks like a purposive manner, and all are agreed that many individual characteristics are explicable on this principle. It is also sufficiently obvious that the same adaptive features make their appearance generation after generation when the same conditions of life are repeated, for the organism, other things being equal, will always respond to the same stimuli in the same manner. But when the environment changes and the stimuli are varied, are there any limits to the responses which the organism can make in adapting itself to its new conditions? We know very well that there are. An acorn cannot develop into an oak tree if it never be allowed access to the light and air, and the egg of a fowl can only develop into a chicken if incubated at the proper temperature. Moreover, an acorn can never, under any conditions whatever, develop into anything *but* an oak tree, and a hen's egg can never develop into anything but a fowl. We express these facts by saying that every organism inherits its general plan of organisation (and, indeed, in many cases even its minute individual peculiarities) from its ancestors, and especially from its immediate parents, and we have next to inquire exactly what we mean by this statement.

The biological term "heredity" has obviously been derived by analogy from the peculiarly human custom whereby property of various kinds is handed on from one generation to the next, but, in spite of the efforts of our legislators to make that process as complicated as possible, it cannot compare in intricacy with the phenomena of inheritance with which the biologist concerns himself. Indeed, the analogy between the two processes, which is only of very limited application, has led to much confusion of thought, and it is perhaps to be regretted that the terms "heredity" and "inheritance" should ever have found their way into biological science. We can hardly hope to eliminate them, however, and must do the best we can to mitigate the evil by giving them as precise a meaning as possible from the biological point of view.

I will therefore venture to define "heredity" as meaning the whole complex of processes whereby the child comes to resemble its parents, and the term "inheritance" may be taken to mean the total result of these processes. It is true that certain definite materials are directly transmitted from parent to offspring, and it is in respect of these that the analogy above referred to is least objectionable. Such transmission, however, by itself, would do little to bring about the resemblance which we seek to explain, except, indeed, in the case of those very lowly organisms in which reproduction is effected by the division of the entire body into two precisely similar halves, each resembling the parent. In the higher animals, owing to their immense complexity of structure, such a method of reproduction is obviously impossible, though even here there is a certain degree of continuity in the living substance, and this continuity forms the foundation upon which the resemblance of child to parent is gradually built up.

The elementary facts connected with the reproduction of the living organism are so little understood, even amongst the educated classes of society, and are at the same time so fundamental from the point of view of social welfare, that it seems desirable to devote a reasonable amount of attention to them before proceeding any further. Every type of reproduction, in organisms that have reached the cellular stage of evolution, is essentially a process of cell division, and as the reproductive or germ cells [1] constitute the sole material link between one generation and the next, they may be regarded as the bearers, in a very limited sense, of all those characters that are capable of being transmitted by heredity from parent to offspring. It is therefore necessary to consider, in more detail than we have hitherto done, what really takes place in the process of cell division.

To the earlier observers this phenomenon appeared comparatively simple. The nucleus constricted into two parts, which separated and moved away from one another, and then the body of the cell followed suit, the result being two daughter cells each with its own nucleus. We have already described this process very briefly in the case of the unicellular Amœba (Fig. 1), in which, it will be remembered, the daughter cells separate completely after the division has been accomplished. The application of modern methods of microscopical investigation has shown, however, that even in such a primitive organism as the Amœba the process of cell division is by no means so simple as it appears at first sight.

In nearly every case, whether it be the division of a simple unicellular organism, or of one of the innumerable cells which build up the multicellular body, a certain series of events present themselves

[1] We are not concerned here with the various processes of budding and fission that take place in many of the lower multicellular organisms, which have little direct bearing upon the problem of heredity.

in orderly sequence, constituting collectively the remarkable phenomenon known as mitosis (Fig. 10). The nucleus, which is the part of the cell mainly concerned in this important business, is in reality a body of very complex structure, by no means a simple, undifferentiated mass of protoplasm ; but its structure is fully revealed only while the process of division is actually going on. At other times, during what is commonly, but inaccurately, spoken of as the resting condition (Fig. 10, *A*), it usually appears as a more or less spherical mass enclosed in a delicate membrane and surrounded by the general protoplasm of the cell body, the cytoplasm. Within the nuclear membrane the protoplasm (nucleoplasm) exhibits a granular appearance due to the presence of small particles strung, as it were, on a network of fine threads. The substance of which these particles are composed is remarkable for its power of absorbing certain dyes, so that the granules themselves can be made very clearly visible under the microscope. For this reason it is termed chromatin, a term derived from the Greek word for colour. In the immediate neighbourhood of the nucleus, usually just outside the nuclear membrane, there is to be found, at any rate in animal cells, another extremely minute granule known as the centrosome, which is destined to play a leading part in the process of division.

The first indication that mitosis is about to take place consists in the division of the centrosome into two parts, which presently move away from one another (Fig. 10, *B*). As they do so a system of very delicate fibres makes its appearance in the cytoplasm.

These have a very definite relation to the two centrosomes, forming a kind of spindle with a centrosome at each end, and also radiating from each centrosome in a star-like manner. In the meantime the nuclear membrane has disappeared, having apparently been dissolved in the cytoplasm, so that there is no longer any boundary between the protoplasm of the nucleus and that of the cell body (Fig. 10, *C*, *D*). While all this is taking place the chromatin granules collect together in the form of a long, coiled thread, and presently this thread breaks up into a number of longer or shorter pieces. These pieces are called the chromosomes. They vary greatly in shape, size and number in different species of plants and animals. They may even vary in shape and size in the individual nucleus in which they make their appearance, but it is a very remarkable and important fact that, with certain exceptions which we may disregard for the moment, their number, and probably also their form or forms, remain constant in all the cells of which the organism is composed, and in all individual organisms of the same species. Some animals have only two chromosomes in each cell at the time of division, others have considerably more than a hundred; in some they are relatively large and perhaps rod-shaped or V-shaped, in others they are merely small, rounded granules, or there may be a mixture of small and large, round and rod-shaped in the same chromosome complex.

By the time the chromosomes have made their appearance the nuclear spindle will have been completed, and the next thing that happens is that the chromosomes arrange themselves across the middle of the spindle in a more or less definite manner (Fig. 10, *D*). The critical phase of the whole performance has now been reached and each chromosome splits into two parts, so that their number is doubled. Two groups of chromosomes are thus formed, each group containing one of the halves of each of the original chromosomes (Fig. 10, *E*). These two groups then move away from one another to opposite ends of the spindle, as though attracted by the centrosomes in the same sort of way that iron filings are attracted to the poles of a magnet. At each pole of the spindle a new nucleus is constituted (Fig. 10, *F*). The chromosomes break up into granules again, a new nuclear membrane is formed and each daughter nucleus enters once more upon the so-called resting stage. Meanwhile, the cytoplasm has divided into two masses, one around each nucleus, and the process of cell division is complete (Fig. 10, *G*).

It is unnecessary for us to discuss the physico-chemical explanation of mitosis. It must suffice to point out that it appears to be essentially an electro-magnetic phenomenon, though the comparison with the magnet and the iron filings is by no means an exact one.

In any case it is obvious that we have here a very elaborate mechanism, the function of which is to secure a very accurate division of the chromatin substance between the two daughter nuclei. This substance is evidently of first-class importance to the organism. We shall see later on that there are excellent reasons for regarding it as the actual bearer of something that is responsible for the transmission of heritable characters from cell to cell, and thus from one generation to the next.

In unicellular organisms the process of reproduction is, as we have already seen in the case of the Amœba, a comparatively simple affair, for the cell is itself the complete organism, and, when it divides, two complete new organisms are formed. In multicellular plants and animals, where the body may consist of many millions of cells, it becomes much more complicated, though cell division is still the fundamental phenomenon. It is not every cell in such a body, however, that is capable of detaching itself from its fellows and developing into a new individual. As they become more and more specialised in structure for the various functions that they have to perform, the cells of which the tissues are built up may even lose the power of division altogether. They then either become gradually worn out and cast off, or perhaps absorbed, or they persist with a greater or less degree of vitality until the death of the body as a whole, or even longer.

Certain cells, on the other hand, never become highly specialised as tissue-cells, but retain a comparative simplicity of structure, at any rate so far as their cytoplasm is concerned ; taking no share in the activities of the body at large, but absorbing food material from it and increasing greatly in numbers by mitotic division. These are the germ cells. In many animals it can be observed that they are set apart from the body or somatic cells at a very early stage of individual development, and it was such observations that formed the chief ground upon which Weismann built up his celebrated theory of the continuity of the germ plasm.[1] He conceived of the germ cells as being equivalent to so many unicellular organisms, continually multiplying by division, so as to give rise to a ramifying stream of living protoplasm. But the products of the repeated divisions do not all remain in the unicellular condition, like so many Amœbæ. Let us suppose that, under certain conditions, repeated at regular intervals, a germ cell gives rise to two daughter cells, of which one goes on dividing into germ cells while the other gives rise to a multicellular body or soma, and that things are so arranged that the soma grows around the new generations of germ cells and encloses them.[2] In such a case the germ cells would clearly have to be regarded, not as products of the body in which they lie, but as of common origin with it. They would be in the body but not of the body, and their relation to it would be of quite secondary importance.

This idea of a fundamental distinction between germ cells and somatic cells exercised the deepest influence upon the views of Weismann and his numerous followers with regard to the laws of heredity. Unfortunately for such views, however, the distinction in question is by no means universal. Not only is the conception inapplicable to, at any

[1] Compare Fig. 3, showing the early segregation of the primordial germ cells in the gastrula stage of the Arrow Worm (Sagitta).

[2] The segregation into germ cells and somatic cells has, so far as I am aware, been traced back to the first division of the fertilised ovum only in Ascaris. It cannot, as a rule, be recognised until a much later stage in the development of the individual.

rate, the great majority of plants, but even in animals it has recently been shown that specialised tissue cells may in certain cases give rise, by a process of de-differentiation, to germ cells. These cases, however, appear to be exceptional, and the fact remains that an ordinary somatic cell cannot play the part of a germ cell, presumably because, in the process of specialisation for its particular function, it has lost some—probably the great majority—of those potentialities that would be necessary in order that it might develop into a complete organism.

Thus it has come about that every one of the higher plants and animals has to start its own individual life as a protoplasmic cell of apparently simple structure, but with tremendous potentialities. This cell, however, is itself rarely a single germ cell, but nearly always the product of *two* germ cells, male and female, the union of which constitutes one of the conditions that are essential to the development of a new individual. This consideration brings us face to face with the phenomenon of sex, which has played one of the principal rôles in the drama of organic evolution, and which is of such vital importance from the sociological point of view that we shall have to devote our next chapter to its consideration.

In the meantime we may content ourselves with the statement that in all the higher organisms, whether plant or animal, the starting point of the individual life is the fertilised egg, formed by the union of a male germ cell or spermatozoon with a female germ cell or ovum (Fig. 11). The fact that this statement requires qualification in certain cases need not concern us here.

We may now restate the problem of heredity as it presents itself in the case of any of the higher plants or animals, including man himself. How is it that a minute and apparently simple cell, formed by the union of an ovum and a spermatozoon, and consisting of a single nucleated mass of protoplasm, is able to give rise to a complex body, consisting, perhaps, of thousands of millions of cells, differentiated in many different ways for the fulfilment of as many different functions, and the whole resembling, not only in its general structure, but also frequently in minute individual peculiarities, the parents from which the ovum and spermatozoon were derived?

The question seems a very formidable one, but, so long as we content ourselves with generalities, the answer is not difficult to find. The fertilised egg develops gradually in the likeness of its parents, because it starts with the same kind of material as that with which its parents started and is exposed to a similar series of influences or stimuli throughout its development. The multiplication of living organisms is in some respects very like the multiplication of loaves of bread. In the making of a new loaf you have to go back to the dough. If the dough from which each batch is made is similar to the dough from which the preceding batch was baked, and if it be exposed to exactly similar conditions throughout the process of baking, the resulting loaves will be similar. Like causes must produce like effects. If the dough be different, or if the conditions be different, then the loaves will be different. Every housewife knows this and there is no sort of mystery about it. The case of the developing organism is of course much more complicated. The protoplasm of which the fertilised egg is composed is a far more complex substance than dough, and, moreover, it is alive. It may be insignificant in quantity in comparison with the body to which it gives rise, but it takes in nutriment from its environment and grows, and as it grows it constantly divides and subdivides into cells (compare Fig. 5). But still our analogy holds good in its essential features, for the child will only come to resemble its parents just in so far as it starts with similar material and is exposed to similar stimuli following upon one another in due sequence.

As a matter of fact we know that the child never does exactly resemble either of its parents. It always exhibits variations, which are due partly to differences in the original composition of the fertilised egg and partly to differences in the conditions to which it has been exposed during its development. These two sets of factors that influence the developing organism are often popularly spoken of as "nature" and "nurture," but, like most catch words, the phrase is somewhat misleading. Where does nature end and nurture begin? and when does nurture cease to be natural? We must have much more precise ideas than can be expressed by any such formula if we are to gain any real comprehension of the infinitely complex processes concerned in heredity and variation.

The life of the individual organism certainly begins in the egg, and its first manifestation is a response to the stimulus of fertilisation. This stimulus is supplied by the spermatozoon and is supposed to be of a chemical nature. Probably the spermatozoon brings with it some definite chemical substance, which acts upon the proteid constituents of the egg and causes a rearrangement of material. The nucleus of the spermatozoon joins forces with that of the ovum, the elaborate mechanism of mitosis is set going and the fertilised egg divides into two daughter cells. The division is repeated again and again and a ball of cells is produced. In a typical animal water accumulates in the middle of the ball and the cells arrange themselves in a single layer around the central cavity. We have now reached what is called the blastula stage (Fig. 5, *VII*). The whole process must be controlled by chemical stimuli, for if we change the chemical composition of the medium in which this development is taking place we can bring about a totally different result, at any rate in certain cases. Thus Herbst has shown that if the fertilised eggs of the common sea urchin are placed in sea water from which every trace of lime has been removed the cells will separate from one another after each division instead of remaining together, as they do in the case of a dividing Amœba, so that instead of a blastula there will be 808 separate cells, all swimming about independently in the water, like so many unicellular Protozoa.

The next stage in the normal development of a typical animal is the gastrula (Fig. 5, *VIII*, *IX*), produced by the wall of the blastula becoming pushed in on one side, as a perforated tennis ball may be pushed in by the thumb. This again is no doubt the result of chemical and physical processes, though it is difficult to say exactly what they are. Here again, however, it has been shown that the result can be varied by changing the chemical composition of the water in which the embryo is developing. Thus in certain cases, if lithium salts be added the part of the blastula wall that is normally pushed in, or invaginated, will be pushed out and come to form a protuberance.

The gastrula stage, as we have already seen, marks the commencement of the differentiation and division of labour amongst the many cells of which the organism is now composed. It is needless, for our present purposes, to trace the development further, but we may give one or two more experimental facts in support of the view that the entire process consists of a series of responses to stimuli and that if the stimuli be varied the resulting organism will vary accordingly, provided, of course, that it does not succumb to the treatment. We could hardly have a better illustration of the effect of changing the chemical composition of the medium in which development takes place than that afforded by Stockard's classical experiments with the eggs of the fish Fundulus. If chloride of magnesia be added to the water in which these eggs are developing a most remarkable result follows. The young fish, or at any rate a large proportion of them, appear with a single eye in the middle of the head instead of a pair of eyes, one on each side, while the mouth is displaced downwards.

It can also be shown experimentally that it is not only stimuli originating in the external environment that control the development of the organism. The different parts of the body itself stimulate one another and if their mutual relations be disturbed abnormal results will generally ensue. Perhaps the most convincing proof of this statement is furnished by certain well-known experiments upon the development of the lens of the vertebrate eye. The facts are briefly as follows. The sensitive layer of the eye—the retina—arises very early as a hollow outgrowth from the fore-brain, known as the optic vesicle. As this approaches the surface of the head it becomes invaginated to form the optic cup and at the same time the embryonic skin or epiblast, exactly opposite to the mouth of the cup, becomes thickened and pushed in. The thickening presently separates from the skin and sinks down into the mouth of the cup, where it forms the lens, exactly in the right position for focussing the rays of light upon the retina. This seems at first sight an almost miraculous happening, for why should the embryonic skin form a lens exactly in the place where it is required and nowhere else ? The answer is that it is stimulated to do so by the approach of the optic vesicle, and that this is the correct answer can be proved experimentally. It has been found possible in certain cases to cut off the optic vesicle from the brain and graft it in beneath the skin in some quite different place. When this is done the epiblast opposite the vesicle in its new position begins to thicken and forms an embryonic lens.

This remarkable correlation between the development of the retina and that of the lens is again probably brought about by chemical means. It is supposed that the optic vesicle secretes some substance of a specific nature that stimulates the overlying epiblast and that the epiblast responds to the stimulation in a perfectly definite manner, by thickening so as to form a lens.

It cannot be doubted, then, that the life of the developing embryo, like that of the adult organism, consists in a series of responses to stimuli, and it is evident that these stimuli originate partly in the external environment and partly in the body of the embryo itself. By these responses the developing animal gradually builds itself up into the likeness of its parents. But obviously it can do this only if the whole series of stimuli, following one upon the other in due sequence, is practically identical with that to which the parents were subjected during their own development. Any deviation from the parental experiences will bring about a corresponding deviation in the result.

How much, then, does the child really *inherit* from its parents? Can we justly say that it inherits any single organ of the body—the eye for example? Obviously only by a gross misuse of language. The actual inheritance is confined to the minute quantity of living protoplasm that makes up the fertilised egg. Everything else the child has to win for itself by its own exertions in response to stimuli of various kinds. Everything has to be acquired in the truest sense of the word.

Perhaps the most astonishing thing about the whole process of individual development is the marvellous accuracy with which the conditions are regulated, so that at every stage the necessary stimuli are supplied. The first duty of parenthood is to secure for the next generation a suitable environment in which to develop. The frog, which lives habitually on land, goes back to the water to lay its eggs, because it is only in the water that these eggs can meet with the stimuli that are essential for their development into tadpoles. The bird builds a nest in which the eggs can be incubated at the proper temperature. Most wonderful of all is the case of the mammals, where the egg never leaves the parental body at all as such, but undergoes its development within the womb of the mother until it has reached a very advanced stage. Here all the conditions are regulated with the utmost nicety and disturbing influences almost completely eliminated. This is the very perfection of parental care, all the more perfect because exercised automatically and for the most part unconsciously, and much more effective than the conscious and often misdirected efforts, at any rate of human parents, to guide the development of their offspring after birth has taken place.

We may safely lay it down as a general rule that those organisms that have learnt how to provide the most favourable conditions of life for their developing young have made most progress in evolution. Human societies are no exception to this rule. The position of each nation in the scale of civilisation may be pretty accurately gauged by the amount of care and education that the children receive before they are turned loose in the world.

These considerations arise quite naturally and inevitably from any discussion of the problems of heredity, and what we have said about the earlier stages of individual development is no less applicable to the later stages. The son that is brought up to the same trade or profession as his father will certainly come to resemble that father more closely than his brother who is brought up with a different aim in view, for the stimuli to which the young man responds in the first case will approximate more closely to those to which the father responded in his own youth.

It is to the stimuli operating upon the developing organism in its later stages—in the case of human beings after birth has taken place—that the term "nurture" is commonly applied. But it is important to realise that they differ in no essential respect from the stimuli operating at earlier stages, right back to the commencement of development. All the characters that any organism exhibits, at any stage of its existence, have been acquired as the result of responses to stimuli of one kind or another, some arising in the external environment and some in the body of the organism itself, which is part of its own environment.

We must reserve for a later lecture the consideration of the differences in the composition of the fertilised egg to which many special peculiarities of the individual organism can be attributed, but we may anticipate what we shall then have to say by remarking that here also we shall be dealing with stimuli, probably of a chemical nature, and it is only the fact that they emanate from substances in the fertilised egg itself that makes it desirable to deal with them separately.

CHAPTER V

The Evolution of Sex—Sexual Differentiation as the Basis of Social Organisation—Maturation of the Germ Cells—The Significance of Fertilisation—The Chromosomes as Bearers of Heritable Tendencies—The Rôle of Chance—Sex Determination.

BEFORE we can proceed with our discussion of the problem of heredity it is necessary that we should gain some insight into the meaning of sex. The subject is one that is of fundamental importance, not only to the sociologist but to every member of society. Unfortunately it is beset with peculiar difficulties and fenced in by a wall of prejudice that has in the past made free discussion an impossibility and been of great disservice to the cause of rational education. If young people were introduced to the subject from the evolutionary point of view, as part of an elementary course in Biology, neither more nor less important than any other part, their further education in sexual matters would follow naturally and harmlessly. It is in approaching the subject from the wrong end, and in the emotional atmosphere created by the application of general principles to the particular case of man and woman, that perhaps the chief danger really lies.

It is only in the very lowest organisms that the phenomenon of sex is altogether unknown. The Bacteria, whose organisation has not yet reached the level of the typical cell, seem able to go on multiplying by fission and spore-formation quite indefinitely without having recourse to that remarkable process of fusion of protoplasmic units which is the essential feature of what is commonly but inaccurately spoken of as sexual reproduction. When we come to the true unicellular organisms, however, we find the sexual process almost universal and in some cases the differentiation into male and female already fully established in all its essential features. This differentiation is, however, itself a secondary phenomenon, as we see at once when we study such simple cases as that of Hæmatococcus (Fig. 12).

This microscopic aquatic organism, which, like all typical cells, consists of a single nucleated mass of protoplasm, is claimed by the botanists as a plant because it possesses the characteristic green colouring matter known as chlorophyll, or a red modification thereof, and by the zoologists as an animal, because of its obviously close relationship with those flagellate Protozoa in which no chlorophyll is developed. It stands very near the point at which the animal and vegetable kingdoms parted company with one another in the course of their evolution.

It is unnecessary for us to go into details with regard to its structure. Suffice it to say that it occurs in two very different-looking forms, active and resting. It assumes the first of these conditions, in which it is known as a zoospore (Fig. 12, *C*), when living in water, supplied with the necessary food materials and exposed to sunlight, when it swims about very vigorously by means of two long, whip-like extensions of the protoplasmic body known as flagella. If the water be dried up or the conditions otherwise become unfavourable it comes to rest, draws in its flagella and rounds itself off within the firm cell wall (Fig. 12, *A*). It may be kept in this desiccated state for long periods without losing its vitality, and its cosmopolitan distribution is no doubt due to the fact that in this condition it may be blown about by the wind in the form of fine dust.

Multiplication is effected by means of repeated cell division, which gives rise usually to four daughter cells (zoospores) within the cell wall of the parent (Fig. 12, *B*). These develop flagella and escape into the surrounding water. In this way, under favourable conditions, increase takes place rapidly and may apparently go on indefinitely without the intervention of any sexual process. Occasionally, however, the proceeding is varied, and instead of only four comparatively large daughter cells a large number of much smaller ones is produced, all within the old cell wall (Fig. 12, *D*). They make their escape as minute, pear-shaped bodies, each again provided with a pair of flagella at the narrow end, but differing from the ordinary active form in the absence of a cell wall. These are the sex cells or gametes (Fig. 12, *E*), and their behaviour is very remarkable. After swimming about for a time they approach one another in pairs, the members of each pair finally fusing together into a single cell with a single nucleus (Fig. 12, *F—J*). The flagella are withdrawn and a cell wall is again formed around the combined mass of protoplasm (Fig. 12, *K*), which presently begins to multiply again by ordinary cell division.

We have here the simplest possible expression of the essential sexual phenomenon, the union of two separate cells, or gametes, to form a single cell known as the zygote, the process being technically termed conjugation or zygosis. It will be observed that it is not in itself a process of reproduction or multiplication, for the number of individuals is actually reduced by half in the first instance—the exact opposite of what occurs in cell division. It is more than probable, however, that the zygote has been in some way reinvigorated by the act of conjugation and endowed with fresh powers of multiplication. It has been suggested that repeated cell division brings about exhaustion and that periodic conjugation is necessary if the vigour of the race is to be maintained. Possibly each of the gametes makes good some physiological deficiency that has arisen in the other. The mutual attraction of the two is a very interesting phenomenon and is supposed to be a response to chemical stimulation by some substance secreted by the gametes themselves. There is direct experimental evidence for this view in the case of the male sex cells of ferns and mosses, which are attracted in the one case by malic acid and in the other by cane sugar.

We must emphasise the fact that in Hæmatococcus there is no sign of differentiation into male and female. The two gametes appear to be exactly alike and to behave in exactly the same way. In the vast majority of cases, however, sexual differentiation takes place and the gametes are distinguishable into female egg cells or ova and male sperm cells or spermatozoa. It is not difficult to understand how this has come about; it is a typical case of differentiation and divion of labour, from which the new individual resulting from the act of conjugation derives much advantage.

We have already pointed out that one of the chief factors in organic evolution is the accumulation of surplus energy or capital, which may be stored up in the egg cell in the form of food yolk. At the expense of this food yolk the young individual gets a good start in life before being thrown altogether upon its own resources. The accumulation of food material, however, is incompatible with that activity which is necessary to bring the two gametes or sex cells together. The advantage can be secured only if one of the two abstains from such accumulation and remains in an active condition. This is the case with the spermatozoon (Fig. 11), which is of extremely minute size and usually swims about vigorously by means of flagella or cilia.

We get this typical differentiation into male and female even in many Protozoa (Fig. 13), in which the entire unicellular body periodically becomes converted into spermatozoon or ovum as the case may be. The ovum is relatively large and inert, and the spermatozoon seeks it out and, if fortunate enough to find it, bores its way into the soft protoplasm. This process is commonly spoken of as the fertilisation of the ovum, but it is obvious that it differs in no essential respect from the conjugation of Hæmatococcus. In both cases two gametes unite to form a zygote or fertilised egg and their nuclei combine to form the zygote nucleus.

In multicellular organisms the gametes or germ cells are, as we have already seen, sharply contrasted with the somatic or body cells, which are differentiated in many ways and grouped together to form the various tissues and organs. Within the highly complex body thus formed the germ cells are collected together in special organs known as the gonads—the male testis containing the spermatozoa and the female ovary containing the ova.

In many of the lower animals, such as Hydra (Fig. 4) and the earthworm, ovary and testis occur in the same individual, which is said to be hermaphrodite, but in practically all the vertebrates, and in many invertebrates also, not only are the sexes separated but the differentiation into male and female pervades the entire body. This differentiation is especially pronounced when we come to the mammals, which are characterised above all things by the habit of retaining the young within the body of the mother during a large part of its development and suckling it after birth for a further period. In this case it is obvious that the relative activity and passivity that distinguish the male and female germ cells are extended to the body as a whole, by which the germ cells are carried. The maternal duties of the female impose upon her restrictions that are not shared by the male. The male, on the other hand, has responsibilities in the way of fighting and foraging from which the female is comparatively free. It is all a question of differentiation and division of labour in the interests of the next generation.

We need hardly insist that a true appreciation of these elementary biological facts is of vital significance from the point of view of human society. The talk about equality of the sexes is all nonsense. There is no question of equality; the only question is that of differentiation and division of labour. Men and women are fundamentally unlike. You cannot make a woman into a man, nor a man into a woman, by Act of Parliament, however much some enthusiasts might like to be able to do so. The primary duty of woman must always be the rearing of children, which must necessarily incapacitate her from many of the activities that fall to the lot of man. The entire constitution of woman, mental, moral and physical, differs in certain respects from that of man, and woman can get the best out of life for herself, and give her best to society, only if she recognises this fact.

From this point of view it may very justly be asked whether the present trend of our educational policy is not likely to prove in the long run disastrous rather than beneficent, for both men and women should undoubtedly receive the kind of education that will bring out the best that is in them, and how what is best for the one sex can also be best for the other is hard to see.

It seems clear that there should, if possible, be a differentiation in education adapted to the differentiation in sex, rather than a compromise on something that is not best for either. We have to educate our boys and girls in such a way as to enable them to play their own proper parts and not so as to enable them to act as substitutes for one another. We cannot, however, discuss these problems here. We are concerned only with general principles, but even so we must emphasise the fact that any policy that withdraws large numbers of men or women from the duties for which they are naturally best fitted must react unfavourably upon the society to which they belong and place that society at a grave disadvantage in the struggle for existence.

Since the differentiation into male and female concerns primarily the germ cells themselves, it seems logical, though perhaps not strictly in accordance with the usual practice, to regard all the sexual characters of the body itself as secondary. Whatever may be their nature they have for their ultimate object either the bringing together of the male and female germ cells or the nourishment and protection of the young organism resulting from the union of these. The romance of love, the responsibilities of parenthood and all the joys and sorrows of family life have their origin in the imperative need for mutual completion that impels two germ cells to unite with one another in the production of the fertilised egg ; and if we look upon the family as the starting point of social organisation we cannot avoid the conclusion that the study of sexual phenomena lies at the very root of all sociological inquiry.

The primary function of the sexual instinct is clearly to prevent deterioration of the race ; indeed, amongst all the higher animals the continuance of the race at all has become absolutely dependent upon the union of the sexes, for it is only quite exceptionally that an unfertilised egg is capable of development, and there is no other process of reproduction. Amongst civilised men and women, however, sexual attraction has undoubtedly acquired a further significance. Not only does it result normally in the production of offspring by the mutual completion of two germ cells, but it may also result in the mutual completion of two human lives, neither of which could obtain full realisation of its possibilities without the co-operation of the other. This is one of the most wonderful achievements of organic evolution. Though a psychological phenomenon of the highest order, it is clearly based upon the mutual attraction of the germ cells, which in itself may be merely a physico-chemical reaction!

The part played by sexual differentiation in bringing about the formation of animal communities and in promoting their stability demands some further attention. Our brief study of the evolution of sex amongst the lower animals has made it sufficiently obvious that the primary attraction that brings two separate individuals of the same species together is the sexual impulse—the need for mutual completion, whether it be in the case of unicellular organisms like Hæmatococcus, of the germ cells of the higher animals, or of the most highly organised animals themselves. A shoal of mackerel, an example of perhaps the lowest type of animal community, is kept together primarily in order that the eggs deposited in the water by the female may have the opportunity of being fertilised by the sperm discharged by the male, but there need be no individual mating, beyond that accomplished by the germ cells themselves as they swim or float in the sea. In the case of animals that do not live in water it is different, for the sperm cannot live when exposed to the air, and a more intimate association of male and female individuals becomes necessary. This leads, in the case of the social insects, to the formation of communities in which all the members are descended from the same parents. However numerous they may be, and however much they may be differentiated amongst themselves, they all belong to one family, and this constitutes another difference between an insect community and a community of human beings.

Nevertheless, the human community is also obviously founded upon the family organisation and only reaches a high degree of development upon this basis. There is, however, no reason to believe that man is by nature, so to speak, a monogamous animal. The physiological requirements of the two sexes are so different that we can hardly avoid the conclusion that the ancestors of mankind were polygamous, a condition of things that must have brought about an intense competition amongst the males for the possession of the females, in which the greater activity of the males would find full scope. Such a state of affairs would naturally tend to wholesale extermination of males and a large preponderance of females, and the welfare of the community as a whole would be seriously imperilled.

We have already seen how the insect communities have met such difficulties. The sexual functions are usurped by particular individuals. Amongst the honey-bees, for example, the queen is the only member of the community that is permitted to attain to sexual perfection, and this perfection appears as the result of special feeding. The workers are imperfect females, brought up on inferior food. The males are far more ruthlessly treated, for the vast majority of them are exterminated after a brief spell of existence, and though they are sexually perfect it is hardly one in a thousand that can ever succeed in realising his sexual potentialities.

In civilised human communities the monogamous habit has evidently arisen as a compromise between the physiological requirements of the individual and the common welfare. Something has got to be sacrificed. In any case there must be an enormous wastage of male germ cells, for these are produced out of all proportion to the number of egg cells requiring to be fertilised.

There is no necessity, however, for a similar wastage amongst the males themselves, and it is very undesirable that there should be such, for the male has many functions to perform which are at least as important both to himself and to the community as that of procreation, and which cannot be performed as well by the female.

The compromise of marriage, then, has rendered possible the formation of civilised communities in which the sexes are approximately equal in numbers, and has brought with it innumerable advantages that could not otherwise have been attained. Any change in our social organisation that tended to undermine the marriage system, and with it the family life of the nation, would probably result before very long in complete social disintegration, and this is one of the chief dangers that have to be faced by highly civilised nations at the present day. There is no possible substitute for family life and parental love as a means of educating the young, and there is no equally good cement for binding society together.

There may be some excuse, in the prosecution of high ideals of service, for deliberately refusing to contract any sexual relationships at all; but to seek the advantages of such relationships while at the same time evading their responsibilities is a deplorable example of that craving to get something for nothing which lies at the root of most of our social troubles.

We must now turn our attention more particularly to the germ cells of the higher animals, and inquire into their history before they unite with one another to form the fertilised egg, for upon this history the fate of any individual to which they may give rise very largely depends.

Whatever may be the stage of individual development at which the primordial germ cells become segregated from the body cells and set apart in the gonads, their subsequent behaviour up to the time of fertilisation is much the same throughout the animal kingdom, the entire sequence of events being known as gametogenesis (Fig. 14). They begin by multiplying by repeated fission, so that very large numbers may be produced, especially in the case of the male, for it takes far more material to form the relatively large ovum than to produce the spermatozoon. All these preliminary divisions, the result of which is merely to increase the numbers of the germ cells, are accompanied by the elaborate process of mitosis (compare Fig. 10), which we discussed in our last chapter. At each nuclear division the chromosomes make their appearance, a spindle is formed, and each chromosome splits into two halves, one of which goes to each pole of the spindle; so that when the cell itself divides, each daughter cell receives exactly the same number of chromosomes as the parent had. All this time, of course, the multiplying germ cells are drawing nutriment from the body of the parent organism, in the life of which they otherwise seem to take no part.

Presently the proceeding is varied and the young germ cells undergo a process known as maturation. The necessity for this will be obvious when we consider that every time two germ cells unite with one another to form a fertilised egg, ovum and spermatozoon each contributes its share of chromosomes to the zygote nucleus (Figs. 14, 16). If nothing happened to prevent it the number of chromosomes would, therefore, be doubled every time conjugation took place—the body cells of each generation would have twice the number of chromosomes that the preceding generation had, and in a very short time the number of chromosomes would be far too large for the nucleus, and the whole machinery of mitosis would become unworkable. Something is required to prevent this constant duplication, and that something is found in the process of maturation, which consists essentially in a halving of the number of chromosomes in each germ cell.

This reduction, as it is technically termed, is effected by a modification in the process of mitosis. The chromosomes arrange themselves on the spindle in pairs (synapsis) and then the members of each pair separate, one going to each pole of the spindle without any division. We thus get two groups of chromosomes, each group containing half the number that the parent cell contained, and around each group a daughter germ cell will be formed by division of the general protoplasm of the parent. One more division usually takes place after this halving of the number of chromosomes has been effected, but it is of the ordinary type, each chromosome splitting into two, so that no further reduction in number takes place.

The maturation of the germ cells is carried out in essentially the same way in the two sexes, but there is one interesting difference in detail which results from the differentiation of the germ cells into male and female. The ovum, as we have repeatedly seen, has much more cytoplasm than the spermatozoon, and, moreover, it usually stores up in that cytoplasm a quantity of reserve food material in the form of yolk. Now apparently it pays better, from the point of view of the welfare of future generations, to produce a small number of well-provisioned eggs than a much larger quantity of eggs each with a much smaller reserve of energy. Hence we find that the cell division that accompanies the reduction of the chromosomes in the ovum takes place in such a way that practically all the cytoplasm, with whatever yolk there may be, passes to one of the two daughter cells, the other receiving very little more than its share of the chromosomes.

This small cell, consisting almost entirely of chromatin, has long been known as a polar body, and so great is the disproportion in size between it and the ovum itself that it appears as if the polar body were simply a part of the nucleus cast out from the latter. At the next, and last, division a second polar body is formed, and the first one may itself divide into two parts. It is perfectly obvious that the three polar bodies are nothing but egg cells or ova which have not received their share of cytoplasm and yolk. They have been sacrificed to their more acquisitive sister, who walks off, so to speak, with all the family capital. The whole complicated process of gametogenesis—spermatogenesis in the case of the male gametes and oogenesis in that of the female—together with the ensuing fertilisation of the ovum and the commencement of segmentation of the zygote, is represented schematically in Fig. 14. The reader should also consult Figs. 15 and 18.

It follows from these considerations that spermatozoa must be produced in far greater numbers than ova, for all the potential spermatozoa may come to maturity, none need be sacrificed at this stage of their existence. There is a very good reason, moreover, for this excessive number of the spermatozoa. They are exposed to much greater risks than the ova, in the search for which they have to make long and perilous journeys, and, in the higher animals at any rate, it is only one out of countless millions that ever accomplishes its purpose in the fertilisation of an egg.

We must now consider very briefly the significance of the act of fertilisation, which is twofold. In the first place it stimulates the egg to commence its development. This stimulation is supposed to be effected by some definite chemical substance brought by the spermatozoon, which initiates chemical and physical changes in the protoplasm of the egg that result in cell division. In the second place it brings about the combination of two distinct sets of chromosomes, maternal and paternal, the one derived from the female and the other from the male parent (compare Fig. 16). Each of these sets is essentially a duplicate of the other, as can be seen very clearly in cases where the chromosomes differ amongst themselves in size or shape. There is the strongest reason to believe, as we shall see in the next chapter, that, in some way or other, the chromosomes are the bearers, so to speak, of heritable tendencies, each being associated, not with a single heritable feature only, but with a group of such. When the chromosomes pair with one another on the nuclear spindle, prior to the reduction division in the maturation of the germ-cells, each pair consists of a maternal and a paternal representative of some heritable complex (see Fig. 15). On the whole the two members of a pair seem to be equivalent to one another, and they are certainly interchangeable, but at the same time there can be no doubt that differences exist between them, corresponding to differences between the male and female parents from which they were respectively derived.

It follows from these considerations that the exact manner in which the chromosomes happen to arrange themselves when they pair off in the reduction process, must be of extreme importance. Upon it will depend the particular contribution of potentialities that the mature germ-cell receives, or rather retains; for each germ cell, in getting rid of half its chromosomes, will, at the same time, get rid of any special heritable tendencies that may be exclusively associated with those chromosomes. Whether it is left with the maternal or paternal chromosome of any given pair appears to be purely a matter of chance; it may retain the maternal members of some pairs and the paternal members of others. The final make-up of the double chromosome complex in the fertilised egg will further depend upon what luck the germ cells have in their mating.

There are thus two critical events in the history of the germ cells the issue of which seems to be determined entirely by chance and with which the fate of the young organism is inevitably bound up; namely, the reduction division, in which the double set of chromosomes is halved, and the process of conjugation or fertilisation, in which the single set is doubled again. An immense number of different permutations and combinations may be possible in these two processes, and corresponding permutations and combinations of maternal and paternal characteristics may manifest themselves in the young organism that develops from the fertilised egg. We shall have to consider this matter more in detail in our next chapter.

We may turn our attention now to the problem of sex determination, the manner in which it is decided whether any particular individual shall be male or female. This, it is true, is only a side issue, with which we are not immediately concerned, but inasmuch as it will give us a further insight into the behaviour and significance of the chromosomes, a brief consideration of the question before we resume

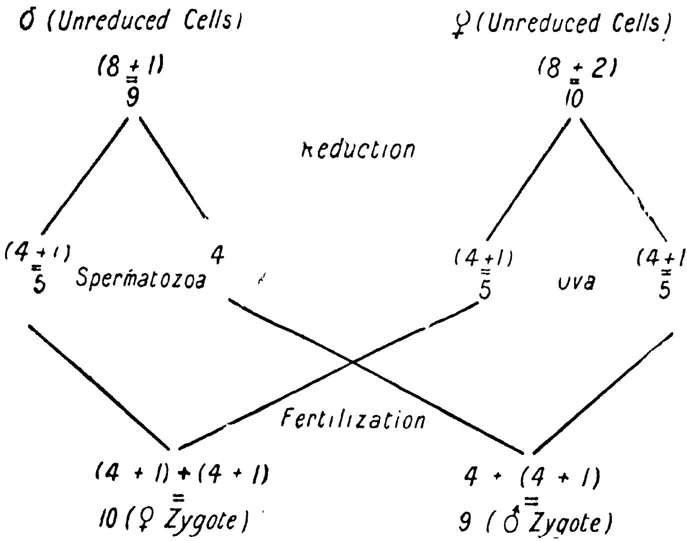

FIG. 17.—Diagram illustrating the Correlation between the Number of Chromosomes and the Sex in certain Insects. (The numbers of chromosomes given in this diagram are arbitrarily chosen and are obviously different from those which occur in Stenobothrus, as shown in Fig. 18.)

our discussion of the mechanism of heredity will not be out of place.

It has been observed, especially in the case of certain insects, that the number of chromosomes differs in male and female—in other words, it is closely correlated with sex. This difference can best be observed during the maturation of the germ cells.

Suppose we take a hypothetical case, such as is represented diagrammatically in Fig. 17, in which the ordinary body cells of the male contain nine chromosomes and those of the female ten. When the maturation of the germ cells takes place in the male two kinds of spermatozoa will be formed, for an odd number cannot be equally divided. Half the spermatozoa will contain each five chromosomes and the other half four. All the mature ova, on the other hand, will be alike in that they will contain each five chromosomes, half of the original ten. Two possibilities thus arise with regard to fertilisation. An ovum with its five chromosomes may be fertilised by a spermatozoon with five or by a spermatozoon with only four. In the former case the fertilised egg will contain ten chromosomes and will develop into a female, in the latter case it will contain only nine, and will develop into a male.

The particular chromosomes concerned in this sex determination can often be identified. This is very beautifully seen in the case of the grasshopper, *Stenobothrus viridulus*, as worked out by Meek. Here the immature sperm-cells (Fig. 18, $_1$) contain each seventeen chromosomes. When these pair off, prior to the reduction division, eight pairs are formed and an odd one is left over which has no mate (Fig. 18, $_4$). At the reduction division (Fig. 18, $_5$, $_6$) this so-called sex chromosome passes over into one of the daughter cells, which will accordingly have nine chromosomes (Fig. 18, $_7$), while its sister will have only eight. At the next division (Fig. 18, $_8$), which results in the formation of the spermatozoa themselves, all the chromosomes split in the usual way, but the sex chromosome (x) can still be identified quite easily because it lags behind the others in its division.

So far as I am aware, the corresponding processes in the maturation of the ovum have not been worked out in the case of Stenobothrus ; but, from what we know of other cases, we may safely conclude that there are two sex chromosomes in each immature ovum, so that at the time of pairing every chromosome finds a mate and each mature ovum will have nine.

This correlation between certain chromosomes and the sex of the individual which carries them has now been demonstrated in many cases, and is believed to occur even in human beings. Inasmuch as the difference in the number of chromosomes affects every cell in the body it seems reasonable to conclude that sexual differentiation is a very deeply seated phenomenon. We are not, however, justified in supposing that the sex chromosomes are the only factors concerned therein. It has long been suspected that the nutrition of the parent, and therefore of the young germ cells, has a great deal to do with the sex of the offspring, and cases are known in which the sex gradually changes as the animal grows older. This may be a perfectly normal phenomenon, as, for example, in the slipper limpet, Crepidula, which begins its life as a male and ends up as a female, or it may be the result of disease, as in the remarkable instance of the fowl recently investigated by Dr. Crew at Edinburgh, which laid eggs in a perfectly normal manner in its youth and became the father of chickens later on in life, the ovary having been destroyed by disease and replaced by male organs.

Briefly as we have been obliged to deal with the subject, it has become very obvious in the course of our discussion that sexual differentiation has brought in its train all sorts of complications in the processes of heredity. It has introduced elements of chance and given them an importance that can hardly be exaggerated. From this point of view, Nature, if we may still be allowed to personify the universal mother, appears as a careless gambler, throwing the dice on behalf of her helpless children, whom later on she is to weed out with relentless severity in strict accordance with their good or evil fortune, which is perhaps, after all, the best she can do for them.

CHAPTER VI

The Mendelian Experiments in Heredity—The Factorial Hypothesis.

We shall devote this chapter chiefly to the consideration of the question—What is there in the fertilised egg that causes the appearance in the adult organism of individually heritable characters that do not depend, or depend only in a secondary manner, upon the conditions under which development takes place ?, and we may begin by mentioning a few examples of the kind of character with which we shall be concerned.

Had I been preaching a sermon I might have taken as my text a passage from the second book of Samuel xxi., 20. "And there was again war at Gath, where was a man of great stature, that had on every hand six fingers, and on every foot six toes, four and twenty in number." So far as I am aware, this is the first record of a phenomenon now well known to students of heredity under the name of hexadactyly. Unfortunately, nothing seems to be recorded about the family of this remarkable man except that he was the son of a giant, but we may be pretty sure that he was not alone in his misfortune. A more instructive story was told me many years ago in New Zealand. The head of a well-known New Zealand family happened to be in Melbourne and saw his own name, a rather uncommon one, over a chemist's shop. He went in and said to the chemist, "Excuse my asking, I've got them myself, but have you got six toes?" The chemist had got six toes, and the inquirer was able to restore a long-lost branch to the family tree.

A still better example was mentioned in the *Westminster Gazette* some years ago.[1] "In the village of Koshilovo (Grodno Government) there are, says Reuter, over fifty peasants who have more than the usual number of fingers.

"According to interesting particulars published in the *Novoe Vremya*, St. Petersburg, the people are all descendants of a peasant who married in the first half of last century, and who had extra fingers on one of his hands.

"In the present generation this abnormality is reproduced to the extent of two, three, four, or even five additional fingers. Some cases simply show a thumb duplicated from the first joint. As the result of intermarriage the deformity is spreading to neighbouring villages. It dispenses the young men from military service, however sound they may be constitutionally."

I have since been informed by a Russian student, to whom these facts were familiar, that this gradual establishment of a polydactylous race was deliberately encouraged by a certain nobleman who was interested in the village.

Such phenomena are met with amongst mental as well as bodily characters. The lamentable and by no means uncommon condition known as "feeble-

[1] March 18th, 1912.

mindedness" is one of the best known instances of a heritable peculiarity which may be multiplied by in-breeding. But it is not only deformities or abnormalities with which we are concerned. Many perfectly normal features, such as the colour of a flower or the shape of a seed, belong to the same category. We shall deal with such a case directly.

The mechanism whereby characters of this kind are transmitted from parent to offspring has been very fully investigated in recent years, and an extensive literature has already grown up in connection with the subject. The modern experimental science of genetics, founded by the Abbé Mendel about the middle of the last century, has thrown a flood of light upon the problem and already achieved results that are of inestimable value to mankind. All these results depend upon one experimental method—that of hybridisation.

It has long been a matter of common knowledge that it is possible to cross one variety of plant or animal with another, provided they be sufficiently nearly related, and thus to produce a hybrid between the two forms. Take, for example, the common garden plant *Mirabilis jalapa*, popularly known as the Marvel of Peru. There are two varieties, the one producing white flowers and the other red, and both breeding true. Now, if the two be crossed, which is effected by fertilising, or, to speak more accurately, pollinating, the flower of the one kind with the pollen of the other, the resulting hybrid will be pink flowered, a blend of white and red, a hybrid. If now the pink flowers be self-fertilised (pollinated) and another generation raised from the seed produced, we shall find plants of all three kinds making their appearance, white flowered, pink flowered and red flowered. Moreover, and this is the most important point to remember, they will appear in definite proportions. For every white flower there will be two pink and one red. The generation in which this so-called segregation occurs is known as the second filial or F_2 generation, that is, the second from the original cross. Each plant of this generation will continue to breed in the characteristic way so long as it is self fertilised, no further crossing being allowed to take place; the white producing white offspring, the red, red, and the pink splitting up, so to speak, into white, pink and red in the proportion of 1 : 2 : 1. This is the fundamental Mendelian experiment, and all others are variations on the same theme.

Perhaps the first thing that strikes one in considering the result of this experiment is that the numerical proportion in which the three varieties occur in the second filial generation is the same as that which results from chance pairing of any two possible alternatives, in accordance with the law of probability. Suppose, for example, we take a thousand white counters and a thousand red ones, all alike except in respect of colour, and mix them up thoroughly in a bag. If we draw them out two at a time and place those of each pair one on top of the other, without looking, we shall find that we get, approximately, for each white over white, one white over red, one red over white and one red over red, for the chances for each combination are exactly equal. If we regard white over red and red over white as the same thing, then the proportion will be 1 : 2 : 1 exactly as in our Mendelian experiment. If we take enough counters the proportion will be exact, but, of course, if we only take a few we cannot expect to get a fair average result, and the same applies to our hybridisation experiments.

We are tempted, therefore, to attribute the Mendelian result to the chance combination of alternative characters in pairs, and it is not difficult to see how such combination may be brought about. The fertilised egg, or zygote, is formed by the union of two germ cells, a female ovum and a male spermatozoon (but the actual differentiation into ovum and spermatozoon does not affect the question). Suppose, now, that each germ cell is the bearer of something—let us call it a factor—that is responsible for the appearance of one of a given pair of alternative characters, say whiteness or redness. Suppose, further, that the white and red germ cells—to use a shorthand expression—are produced in equal numbers, and that their mating depends entirely upon chance. Then we shall have a mechanism which must produce the results actually obtained in our experiment—provided, of course, that there are no other complications to be taken into account, as there very often are.

We are thus led to the following conclusions as the result of our experiment :—

(1) Certain characters form pairs of alternatives and the organism may inherit one alternative or the

other, or a combination of the two, one from each parent.

(2) Each character must be represented by something, which we may call a factor (or gene), in the germ cell, for the germ cells constitute the only material link between one generation and the next.

(3) Each germ cell can be the bearer of only one of any given pair of factors, representing one of a corresponding pair of alternative characters.

(4) The germ cells of the two kinds must be produced in equal numbers by the hybrid.

(5) The two kinds of germ cells, with alternative factors, must assort themselves freely in accordance with the laws of chance when conjugating with those of the opposite sex.

To go back to the case of our white and red flowers. If a germ cell bearing the factor for whiteness unites with a germ cell bearing a similar factor, the fertilised egg will contain two factors for white and will produce a white-flowered plant. In the same way red mating with red will produce red-flowered plants. But if white mates with red the fertilised egg will contain one factor for red and one for white, and the result will be a pink flower, a hybrid.

This hybrid will produce germ cells of two kinds, white and red in equal numbers, for one germ cell cannot carry both factors, and segregation must take place. Therefore, when the hybrid is self-fertilised there are four possibilities as to the mating of the germ cells. An ovum bearing white may be fertilised by a sperm bearing white, or by a sperm bearing red ; and an ovum bearing red may be fertilised by a sperm bearing white or by a sperm bearing red. This is most clearly illustrated by what is known as the method of squares, in which each square represents a fertilised egg or zygote, thus :—

Male Germ Cells (Sperms).

Female Germ Cells (Ova).	R	W
R	RR Red	RW Pink
W	WR Pink	WW White

The chances for each combination are equal, and so we get the Mendelian proportion, 1RR : 2RW(= WR) : 1WW.

So far we have said nothing about the way in which the segregation of the factors in the germ cells of the hybrid is effected. This is fully explained by what takes place in the maturation process, which we described in our last chapter. It will be remembered that each immature germ cell contains two sets of chromosomes—one derived from the male parent and the other from the female. When the reduction division is about to take place the chromosomes pair off, maternal with paternal, and then separate, one of each pair going to each daughter nucleus (compare Fig. 15). It is this separation of the maternal and paternal chromosomes that brings about the segregation of the Mendelian factors, for we must suppose that it is really the chromosomes that bear the factors, and that, in the case of a hybrid, the paternal chromosome of a given pair bears the one factor for an alternative pair of characters and the maternal chromosome the other. If this is the case, and we shall find abundant evidence later on for believing it to be so, it is obvious why both factors of the same pair cannot occur in the same mature germ cell.

We may now take another example of Mendelian inheritance, in which the interpretation is not quite so simple as in the case of Mirabilis, but which is of a type more commonly met with in actual experience. The little fruit fly, or vinegar fly, Drosophila, has in recent years become the principal subject of Mendelian breeding experiments in America. It has many qualifications for this honourable position. It breeds rapidly, it is easily kept in captivity, it frequently exhibits variations, or mutations, which are inherited in Mendelian fashion, and it has a small number of chromosomes, differing in size and shape amongst themselves, so that they can easily be identified. In the able hands of Professor T. H. Morgan and his colleagues this tiny insect has already yielded immense additions to our knowledge of Mendelian phenomena and rendered possible some very remarkable conclusions as to the location of the factors or genes in the chromosomes. About 237 individually heritable peculiarities have been studied, and the fact that these are mostly abnormalities of one kind or another in no way detracts from their value as material for breeding experiments.

Thus the normal fly has long wings, but a mutation occurs in which the wings are quite short, reduced, in fact, to mere vestiges. Long wing and vestigial wing form a pair of alternative characters and when the two forms are crossed we get a hybrid (Fig. 19, F_1). But this is not at first obvious, for all the immediate progeny of the cross, belonging to the first filial generation, are found to be long-winged. It seems at first sight as if the vestigial wing had disappeared. When, however, two of the hybrids are bred together, the vestigial wing reappears in the F_2 generation, in which we get long- and short-winged flies in the proportion of three to one, as shown in the illustration.

The hybrid must have contained the factor for vestigial in a latent state, unable, for some unknown reason, to exercise its influence. We have here an example of the very common phenomenon known as dominance. The long-winged condition, or its factor, is dominant over the short-winged, which is said to be recessive. But the recessive factor is only recessive in presence of the dominant; when the dominant is absent it becomes operative and short-winged flies are produced. Hence the proportion of three long-winged to one vestigial in the second filial generation. Two of the long-winged flies are really hybrids and the true proportion is one of the one parent form, two hybrids, and one of the other parent form, exactly as in the case of the red- and white-flowered plants of Mirabilis.

Hitherto we have considered only simple cases, in which we are concerned with a single pair of alternative characters—cases of what is technically termed monohybridism. But obviously it is possible to experiment simultaneously with as many pairs of alternatives as we like, so long, of course, as these are forthcoming and our arithmetic holds out. Let us take, for example, a case of dihybridism, in which two such pairs are involved, with dominance in both. We will again make use of Drosophila. The body of the fly may be ebony-coloured or it may be grey, and when these two colour varieties are crossed grey is found to be dominant and ebony recessive. Suppose, now, a grey-bodied fly, having vestigial wings, is mated with an ebony-bodied fly having long wings. The hybrid will show the two dominant characters, grey body and long wings. When two such hybrids are bred together the second filial generation will be found to comprise four different types—grey flies with long wings, grey with vestigial wings, ebony with long wings and ebony with vestigial wings, and if a sufficiently large number be obtained they will be found to occur in definite proportions, nine showing the two dominant characters, three showing one dominant and one recessive, three the other dominant and the other recessive, and one both recessive characters. The explanation of this 9 : 3 : 3 : 1 proportion, characteristic of cases of dihybridism with dominance in both pairs of alternatives, is by no means difficult. Each of the two hybrids that are mated together produces germ cells of four kinds in equal numbers, containing respectively the factors for grey and long, ebony and long, grey and vestigial and ebony and vestigial. That is, all possible combinations of one factor from each pair of alternatives. Applying the method of squares we see at once how these different germ cells may mate together. There are sixteen possibilities, all equally likely to occur; as follows:—

Male Germ Cells (Sperms).

Female Germ Cells (Ova).	g l	e l	g v	e v
g l	g l g l grey long	g l *e* l grey long	g l g *v* grey long	g l *e v* grey long
e l	*e* l g l grey long	e l e l ebony long	*e* l g *v* grey long	e l e *v* ebony long
g v	g *v* g l grey long	g *v e* l grey long	g v g v grey vest.	g v *e* v grey vest.
e v	*e v* g l grey long	e *v* e l ebony long	*e* v g v grey vest.	e v e v ebony vest.

9 grey long : 3 grey vestigial : 3 ebony long : 1 ebony vestigial.

Each square represents, as before, a zygote or fertilised egg, which will develop into an individual actually exhibiting the characters as stated, the result being modified by the fact that the recessive factor becomes inoperative when associated in the same zygote with the corresponding dominant. Such inoperative recessive factors are italicized in the diagram. It will be seen from this table that four only out of each sixteen individuals produced are formed by the union of ova and spermatozoa having the same factorial constitution, viz., 1 grey long, 1 ebony long, 1 grey vestigial and 1 ebony vestigial; these are termed "homozygotes" and will breed true if mated with their like. The remaining twelve retain the hybrid character for one or both pairs of factors; they are "heterozygotes" and will not breed true.

It is further to be noted in connection with this experiment in dihybridism that, whereas we started with only two types of fly, grey-bodied with vestigial wings and ebony-bodied with long wings, we have ended up with four types, grey long, grey vestigial, ebony long and ebony vestigial. We have, to all intents and purposes, created two new kinds of flies, which, if homozygous and prevented from crossing, will continue to breed true indefinitely. The possibility of thus combining previously separated characters by hybridisation is of great importance to those engaged in the breeding of animals or plants. It has already led, for example, to the production of new varieties of wheat that are of immense value, and there seems no limit to the improvement of our cultivated plants and domestic animals that may result from our knowledge of these simple Mendelian principles.

In the case of dihybridism which we have just been studying it is obvious that the factors for the two different pairs of alternatives must be lodged in different pairs of chromosomes, otherwise the permutations and combinations that actually occur would be impossible. If two or more factors were lodged in the same chromosome the characters for which they are responsible would naturally occur together in the same individual, and there would be no free assortment to give rise to the characteristic numerical ratio in the second filial generation. But we know that in Drosophila there are only four pairs of chromosomes, while the individual peculiarities,

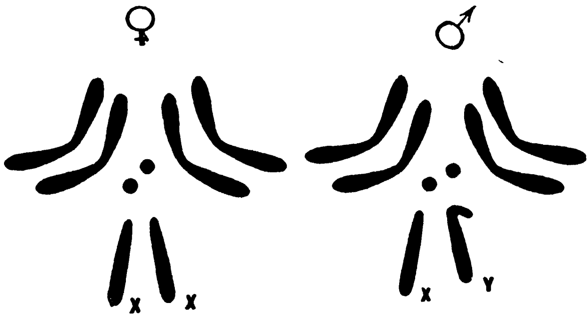

FIG. 20.—Diagram of the Chromosome Group as it occurs in the Body Cells of *Drosophila ampelophila*, male and female. *X* and *Y* are the sex chromosomes, the hook on *Y* is a convention. (From "The Mechanism of Mendelian Heredity," by Morgan, Sturtevant, Muller and Bridges.)

known to be inherited in Mendelian fashion, are about 237 in number. Evidently, then, a single chromosome may contain many factors, belonging, of course, to different pairs of alternatives, and so long as the chromosomes concerned retain their separate identity, the characters represented in them will remain linked together in inheritance. When we come to study the inheritance of a number of different characters simultaneously, this fact of linkage necessarily complicates the results very greatly. But it is just this fact that has rendered possible the complete demonstration of the existence of actual material factors or genes and their location in the chromosomes.

Let us consider the case of Drosophila, as worked out by Professor Morgan and his colleagues, somewhat more in detail. As already stated, there are four pairs of chromosomes in the body cells and in the unreduced germ cells (Fig. 20). The chromosomes of each pair are very similar to one another, but those of different pairs may differ widely in shape, or size, or both. In two pairs they are of approximately the same size and shape, in the third pair they are considerably smaller, and in the fourth they are very much smaller still, and spherical, while those of the other three pairs are rod-shaped. Breeding experiments show that there are also four groups of alternative characters linked together in inheritance. This coincidence alone suggests very forcibly a connection of some sort between the linkage groups and the chromosomes. But this is not all, for the groups of linked characters differ in size in much the same way that the chromosomes do. Thus one group contains about one hundred characters, the second about seventy-five, the third about sixty, and the fourth only two. In the third group the characters are always correlated with sex, and the corresponding chromosome is a sex chromosome, comparable to that which we have already studied in the case of the grasshopper.[1] Such characters are said to be sex-linked.

[1] Except that there are two sex chromosomes in both male and female.

But Morgan and his colleagues have shown that the characteristic linkages are sometimes broken, and new combinations of characters make their appearance. In such cases there has been an interchange of larger or smaller blocks of characters between two alternative groups. Suppose we have a linkage group *A*, *B*, *C*, *D*, *E*, *F*, *G*, inherited alternatively with another group *a*, *b*, *c*, *d*, *e*, *f*, *g*. Then we may find that suddenly the groups have changed, and we get, say, *A*, *B*, *C*, *d*, *e*, *F*, *G*, and *a*, *b*, *c*, *D*, *E*, *f*, *g* ; *D* and *E* having changed places with *d* and *e*. This phenomenon is known as crossing over, and is probably to be explained as follows. Each of the two alternative groups of characters is correlated with either the maternal or the paternal chromosome of a particular pair ; in other words, each individual character is represented by a factor in the paternal or in the maternal chromosome, all the characters of each group being, of course, represented by factors lodged in the same chromosome. Now it has been observed in certain cases that when the maternal and paternal chromosomes come together in pairs, just before the reduction division of the germ cells takes place, they sometimes tend to wrap round one another and stick together. Then when they get pulled apart, one to each daughter nucleus, they may fail to separate in their entirety, and two composite daughter chromosomes may result, each partly maternal and partly paternal in origin. If the two chromosomes have stuck together at one point only we get a single cross-over (Fig. 21),but if they have stuck at two points we may get a double cross-over.

If we suppose that the factors or genes are arranged in linear series in each chromosome it is obvious that blocks of them will change places, and the corresponding characters in the linkage groups will be reassorted accordingly.

By a statistical study of the number of cases in which crossing over of any given kind takes place in

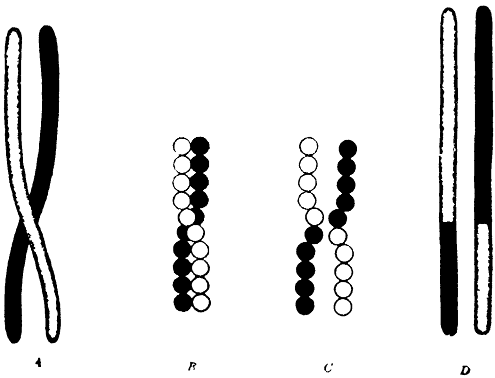

FIG. 21.—Diagram of single Crossing-over of Maternal and Paternal Chromosomes during Synapsis. Two composite chromosomes result (*D*), in which the factors form new linkage groups, as shown in *C*. (From "The Mechanism of Mendelian Heredity," by Morgan, Sturtevant, Muller and Bridges.)

long series of breeding experiments, Professor Morgan and his colleagues have been able to form certain very definite conclusions as to the relative positions of the individual factors in the chromosomes. These conclusions are based upon the obvious fact that widely distant factors in a linear series are more likely to be separated by crossing over than are those that lie nearer together. The chances in favour of a break occurring between any two are directly proportional to the distance between them. Hence if two given characters in a linkage group are found by experiment to be separated in 5 per cent. of cases and two others of the same group in 10 per cent. of cases, it seems reasonable to conclude that the two factors responsible for the latter lie further apart in the chromosome than the two responsible for the former. Thus, by studying the distribution of characters in a very large number of cases, it has actually proved possible to make maps of the chromosomes, showing the relative positions of the different factors they contain—truly an extraordinary triumph of painstaking ingenuity and laborious investigation. Although most of this remarkable work has been done in America, it is gratifying to reflect that the fundamental phenomenon of linkage, on which it is all based, was first discovered by two eminent British investigators, Mr. Bateson and Professor Punnett, in 1905.

The existence in the chromosomes of the germ cells of material factors or genes, responsible for the appearance of perfectly definite characters in the adult organism, seems to be established beyond all reasonable doubt by the Mendelian experiments in hybridisation. What may be the nature of these factors is another and much more difficult question, for no one has yet succeeded in making a gene visible even under the highest powers of the microscope. We know of their existence only from observing their effects, just as we know of the existence of ultra-microscopic, filter-passing germs or microbes from studying the diseases to which they give rise when introduced into the bodies of the higher animals. Indeed, the parallelism between the two cases in remarkably close. In both we must suppose that we are dealing with extremely minute entities, composed of some proteid substance and capable of multiplying by repeated division, and in both there is a longer or shorter incubation period before their effects begin to manifest themselves. In both also these effects frequently take the form of some disease or abnormality. There is no good reason however, for believing that the Mendelian factors or genes are actual parasites. They seem to be integral portions of the chromosomes in which they occur, being divided and distributed along with the chromosomes by the complex mechanism of mitosis.

There is yet another possible resemblance between these " factors " and the filter-passing microbes, for both probably produce their effects through the agency of chemical substances that act as poisons, or at least as modifying agents, upon certain parts of the organism in which they occur. These substances, whatever their actual nature, may be compared to the hormones secreted more especially by the ductless glands, which, as we have already seen, exercise so profound an influence upon the development of the body in all its stages.

We may, then, look upon the factors or genes in the germ cells as sources of chemical stimuli, and we are thus brought once more to the conclusion that the development of an individual plant or animal from the fertilised egg consists in a series of responses to stimuli, whereby the organism gradually builds itself up in the likeness of its parents, but with variations which depend upon differences in the stimuli to which it responds.

The Mendelian experiments reveal to us the mechanism by which the factors or genes are transmitted from parent to offspring and the manner in which they may be interchanged by hybridisation. They tell us nothing of how they originate in the germ cells or how they may be subsequently modified. This is doubtless a problem of molecular chemistry, and a great field lies open here for the exploitation of that latest recruit to the army of science, the biochemist.

We must guard ourselves carefully against the tendency shown by some enthusiasts to believe that the Mendelian experiments will some day furnish a complete explanation of the phenomena of heredity, and that the entire plant or animal may be built up of interchangeable standard parts, like a Ford car or a bicycle. The Mendelian factors seem rather to exert merely a modifying influence upon something that is already there, and this influence seems to be, usually if not always, strictly localised. There are probably factors capable, for example, of modifying the shape of the human nose, but it is hardly likely that any special factor is necessary for the production of the nose itself, though there might well be factors which, by producing some kind of disease, would prevent its development.

We must now touch briefly upon a wider question. What is it that determines whether one egg shall develop, say, into a dog, and another into a rabbit? The differences here involved are much more fundamental than any that can be associated with Mendelian factors. Can they be attributed to the conditions under which the egg develops? We cannot answer this question experimentally in the case of the dog and the rabbit, but we can readily do so in the case of animals whose eggs develop from start to finish in sea-water. The egg of a sea-urchin, for example, and that of a starfish may develop side by side under conditions which, so far as the external environment is concerned, are precisely identical, but the one will always develop into a sea-urchin and the other into a starfish. There is evidently something specific about the egg itself, which we cannot correlate with the Mendelian factors in the chromosomes. What this is we do not know.

All these considerations bring us back once more to our original conception of the nature of heredity. The child will resemble its parents just in so far as it starts its existence with the same kind of material and is exposed to the same kind of stimuli following upon one another in the same order throughout its development. The stimuli come from many sources, and what their nature may be in any particular instance is largely a matter of chance, expecially in the case of those that are furnished by the so-called Mendelian factors.

Those who talk so glibly about the equality of man should study the phenomena of heredity. They would soon learn that all men are not born equal, and never will be until we can secure for each at least an identical chromosome complex, which is beyond the powers of the most ardent reformer. When all is said and done it will still be better to inherit the right kind of chromosomes than to be born with a silver spoon in one's mouth, which is merely a new version of the old saying that it is better to be born lucky than rich.

CHAPTER VII

The Organism and its Environment—Lamarckian Factors of Organic Evolution—Use and Disuse—Degeneration—Parasitism—Vestigial Structures—Change of Function—The Inheritance of Acquired Characters—The Effects of Effort—The Regulating Action of the Germ Cells.

We endeavoured to show, in our first chapter, that the motive force of organic evolution, if one may use such an expression, is the accumulation of surplus energy, or capital, by each generation for the benefit of the next, so that each gets a better start in life than its predecessor and may be able to carry on a little further before itself succumbing to the inevitable "*Et quasi cursores vitai lampada tradunt.*" The progressive accumulation of capital itself seems to result primarily from the fact that the living protoplasm is able to learn by experience, so that each generation of egg cells, for example, may accumulate more food yolk on account of the increased capacity for food collection that will have been handed on to them in the ordinary course of cell division.

We have next to inquire what it is that makes for progress in particular and apparently determinate directions. When we come to examine the matter carefully we find that every organism is really a kind of expression or incorporation of the stimulating effects of the environment in which its life is passed. We might compare the environment to a mould, into which the organism has to fit itself or perish. It cannot get outside its environment and grow into any form that it chooses. Indeed it has very little choice in the matter, but must build itself up in response to the various stimuli which the environment furnishes. Thus the entire organisation of the fish speaks to us of water, and that of the bird tells us no less plainly of the air. The human foot implies the existence of solid ground and the structure of the eye tells us much about the properties of light. The biologist expresses these facts by saying that every organism is *adapted* to its particular environment.

It would seem, then, that it is really the environment that determines, directly or indirectly, the course of evolution in each particular case, and this is a fact of the deepest significance from the point of view of social organisation and human progress. An environment of slums and gin shops, for example, is bound to be reflected in the character of the population.

The life of the organism consists in a constant succession of efforts to meet the demands made upon it ; in a series of responses to environmental stimuli that ends only with death. This idea forms the keynote of the Lamarckian theory of organic evolution. In all the struggle and turmoil of life individual effort plays the most conspicuous part. The monkey climbs when stimulated by the sight of the nuts ; the mouse runs when it sees the cat, and the butterfly emerges from the chrysalis when the cold of winter gives place to the resuscitating warmth of spring.

All this effort has its effect upon the bodily structure of the individual and everybody knows that considerable structural modifications may be brought about in this way in the course of a single lifetime. The more an organ is used the more it tends to develop, and, conversely, neglect of exercise leads to deterioration. This is Lamarck's well-known principle of use and disuse, and we can prove the truth of it upon our own bodies without any difficulty. One of the commonest cases is the development of epidermal thickenings, or callosities, as a result of pressure or friction, as in the hardening of the hands by the constant use of tools. The wasting away and loss of power in the limbs of an invalid who has long been confined to bed is an example of the converse effect of disuse. The effects of education in improving mental ability are even more striking, and these must depend ultimately upon modifications in the intimate structure of the brain.

Lamarck held that such acquired modifications, resulting from the use or disuse of organs, are capable of being transmitted by heredity from parent to offspring, and may thus lead to cumulative improvement—or degeneration—of the race. This possibility was also admitted by Darwin, though he laid greater stress upon the more indirect modification of organisms by the action of natural selection. The immediate successors of Darwin, however, led by Weismann, denied altogether the possibility of the inheritance of acquired characters, and Lamarck's views were made the subject of quite undeserved ridicule. Already, however, the pendulum is swinging back again, and the question of the inheritance or non-inheritance of acquired characters is to-day as eagerly debated as ever. We shall return to it presently.

It has been quite unjustly said, or at least implied, of Lamarck, that he maintained that an animal could intentionally alter its bodily structure by making purposive efforts to that end. Any one who has studied the writings of this great biologist, however, knows that this is a gross misrepresentation. What he did maintain was that an animal, in endeavouring to carry on its life in the face of difficulties, exerted itself and made appropriate use of the organs which it possessed; that the mere exercise of these organs reacted upon them physiologically in such a way as to bring about their increased development in the individual, and that the increased development thus secured would be transmitted by heredity to the next generation. He did not say that the giraffe deliberately increased the length of its neck in order that it might reach the higher foliage upon which it browsed, but that the constant effort of stretching the neck brought about a gradual increase in length which was cumulative from generation to generation and finally led to the present remarkable state of things. Whatever may be our opinion as to the inheritance or non-inheritance of acquired characters there is certainly no absurdity in such a view as this.

Lamarck's ideas as to the effects of use and disuse are very clearly illustrated by the innumerable cases of degeneration that come under the notice of the biologist. The relaxation of effort, continued through many generations, seems to lead inevitably to progressive deterioration in bodily structure, sometimes confined to particular organs and sometimes affecting almost the entire organism. It is a well-known fact that in remote islands, widely separated by the intervening ocean from any continental area, the animal population exhibits great peculiarities. There are no predaceous mammals, such as cats and dogs and their relatives, because such animals have no means of transporting themselves to remote islands. Birds, on the other hand, are present in abundance, because they, or their ancestors, have been able to fly across the sea. In the case of ordinary land birds, however, the crossing of a very wide stretch of ocean can only take place occasionally, under exceptionally favourable circumstances, as, for example, under the influence of a long-continued gale of wind blowing in the right direction. Having reached their new island home in some such way they settle down there under new conditions of life. They no longer find themselves constantly harassed by the attacks of their old enemies, the cats, dogs, weasels, ferrets and so forth, under the stimulating influence of which their wings were no doubt originally developed. They may, therefore, give up using their wings with impunity, so far as the safety of their lives is concerned, though the punishment, as we shall see, may come later. On the other hand, they may continue to use them either as a mere means of enjoyment or to enable them to reach otherwise inaccessible supplies of food. Those that are tempted by their new-found security to live a life of inactivity gradually lose the power of flight altogether. Their wings undergo degeneration and may finally disappear completely, as in the gigantic moas of New Zealand. These moas, at one time existing in enormous numbers and great variety, are now, unfortunately, entirely extinct, but we still find in New Zealand several species of flightless birds, belonging to various families by no means nearly related to one another, and it is evident that in each family the loss of the power of flight which their ancestors undoubtedly possessed had taken place quite independently, though determined by the same conditions of existence.

One of the most interesting of these birds is the kakapo, a kind of parrot of nocturnal habits, that sleeps all day amongst the thick scrub and ventures forth to seek its food only under the cover of darkness. It is a poor, defenceless creature, which will doubtless soon become extinct in the renewed struggle for existence initiated by the advent of the white man with his attendant cats and dogs. Contrast this wretched animal with its near relative the kea. Also a parrot, and inhabiting the same islands, the kea is one of the most active and vigorous birds in existence. It frequents the rocky summits of the mountain ranges, where it seems to enjoy in full measure its exuberant vitality. It has even known how to take advantage of the advent of the European settlers and, much to their annoyance, pursues and worries to death the sheep grazing on the sub-alpine pastures. The shepherds are doing their best to exterminte the kea, but, unless it falls a victim to its own fatal curiosity, which constantly leads it into danger, it is very doubtful how far they will succeed, and I, for one, should be sorry if their success were complete. The world would be poorer without its keas.

Precisely the same phenomenon is, or was, to be observed in the case of the quaint and clumsy dodo of Mauritius, which was rapidly exterminated when once its island retreat had been discovered and invaded by European sailors.

A strictly analogous case is that of the Morioris, a native race lately inhabiting the Chatham Islands, about 400 miles east of New Zealand ; related to the Maoris but differing widely in culture and disposition. Having an abundant food supply and no external enemies, they waxed fat and gave up warlike pursuits. It is said that they even formed a peace society amongst themselves. This was all very well so long as their isolation remained unbroken, but the discovery of the islands by British explorers in 1790, followed by the advent of whalers and Maori sailors, brought about a change in their environment to which they were quite unable to adapt themselves. The warlike Maoris organised an expedition from New Zealand and soon almost exterminated the Morioris, already decimated by introduced disease and rendered incapable of defending themselves by their love of peace. At the time of my visit to the islands, in 1901, the last generation of Morioris was represented by a single boy.

The cessation of effort, rendered possible by the removal in some way or another from the struggle for existence, is invariably followed by the nemesis of degeneration, and in many cases the degeneration in bodily structure may proceed much further than in the case of the flightless birds. A degenerate animal like the kakapo or the dodo suffers in its own person for the accumulated sins of its race, but, after all, it lives a clean and decent life and inflicts no injury upon its fellow creatures. A parasite, on the other hand, feeding upon the living body of its host, may be the cause of the utmost discomfort, or even disease, while in many cases its own body has suffered an extreme degradation and its vital activities have become reduced to a minimum. There is something to be said for a flea, for it can still jump, and does it well, but a louse or a tapeworm is altogether beyond the pale of right-minded sympathy.

Many other examples might be given, taken from many divisions of the animal kingdom, of the physical degeneration that follows upon the abandonment of active and independent habits of life, and although it takes a great many generations to produce such marked results as in the cases cited, still it is in individuals that the disastrous process commences and is continued. The principle, of course, applies to human beings no less than to the lower animals, and to mental and moral faculties no less than to bodily organisation. The *panis et circenses* of ancient Rome, though doubtless intended to ameliorate the condition of the people, had probably much to do with the final overthrow of the Empire.

There are, however, cases in which an organ may degenerate as a result of changed conditions of life without any consequent injury to the body as a whole. It may be replaced by, or converted into, something better. We have already had occasion to point out, in a previous chapter, that the possession of gill slits at an early stage of development affords one of the strongest proofs of the evolution of the air-breathing vertebrates, even of man himself, from fish-like, aquatic ancestors. The remnants of the original water-breathing apparatus, though completely replaced functionally by other organs of respiration, still persist as vestigial structures in the embryo. Similarly, the *os coccyx* of the human skeleton is a vestige of the tail once possessed by our less remote arboreal ancestors; but no one, except in moments of extreme pessimism, would accuse a man of being a degenerate fish or even a degenerate monkey; he has found a better way of life in which gills and tail are no longer required.

It is interesting to observe that similar vestiges are to be found even in civilised human societies. The university graduate still wears a hood on state occasions, though he no longer uses it for holding the bread which he receives as a dole from the wealthier members of the community; and the backgammon board labelled "History of England" is a striking reminder of the ingenuity of our forefathers in evading the law.

It has also frequently happened in the course of evolution that, in adaptation to some change in the environment, an organ that is no longer required for its original purpose has taken on an altogether new function and become modified in structure accordingly. Indeed, this seems to be the only way in which new organs can be developed, and the principle involved is technically known as change of function. Perhaps the most typical examples are to be met with in the limbs of vertebrate animals, to which reference has already been made in our first chapter. So far as function is concerned the wing of a bird has little or nothing in common with the arm of a man. The one is a highly specialised organ of flight, while the other is an organ of prehension. Both, however, are merely modifications of a limb which was originally used for purposes of locomotion, as it still is in amphibians and reptiles and in the vast majority of mammals. Similarly, the chain of small bones which now serves to convey the vibrations of sound from the tympanic membrane to the internal ear, once formed parts of the bony framework of the first gill slit and of the jaw apparatus. We have, of course, an obvious analogy in human communities, where it sometimes happens that a body of men, whose services are no longer required for one purpose, have to learn a new trade and readapt themselves accordingly. Thus the art of wood engraving has, unfortunately, become almost obsolete owing to the introduction of process work of various kinds, and its craftsmen, or their descendants, have had to find some new means of earning a living. I fear, however, that, from the artistic point of view, the replacement of wood-engraving by process work might serve more fitly as an example of degeneration.

According to the Lamarckian hypothesis the structural modification that accompanies change of function must have been brought about, step by step, by the repeated efforts of the animal to use its old organs for new purposes. It is not difficult to imagine how such a process may have taken place in the case of the human arm, which first became adapted for grasping the branches of trees, as in the gibbons and other apes, and finally, with the assumption of the erect position, ceased entirely to be used as an organ of locomotion ; but it is not so easy to see how the same principle can be applied to the auditory ossicles, whose function is mainly passive and seems to involve very little effort on the part of their possessor. It is perhaps no less difficult to explain this case, as we do so many others, on the principle of the natural selection of chance variations, to which we shall turn our attention in the next chapter.

We must now return to the question of the inheritance of so-called acquired characters, for upon the answer that we give to this question must depend the place that we assign to individual effort as a factor in the evolution of bodily structure and mental capacity.

We have already seen that, strictly speaking, all the characters that an organism exhibits are acquired, for all arise *de novo* in each individual in response to the various stimuli to which that individual is exposed in the course of its development from the fertilised egg. This ambiguity in the use of the term "acquired," has been responsible for endless misunderstanding and much wearisome logomachy, and perhaps the chief service that Weismann rendered to biological science in this connection was in the formulation of the problem with some degree of scientific exactitude. He drew a sharp distinction between somatogenic or bodily and blastogenic or germinal characters, or, perhaps better, modifications—the former being such as are acquired during the lifetime of the individual as the result of the use or disuse of organs, or of the direct action of the external environment; and the latter being such as are dependent upon the character of the germ cells from which the body develops. As inheritance, in the strict biological sense, can only take place through the germ cells, the question may accordingly be stated thus: "Can a somatogenic character be converted into a blastogenic one?"

Weismann gave a negative answer, partly because of the unsatisfactory nature of the evidence in favour of such a view, and partly because he could conceive of no way in which a modification of the body could affect the germ cells so as to cause them to reproduce the same modification in the next generation. As we have already had occasion to point out, he conceived of the germ cells as being isolated from the rest of the cell community and taking no part in the bodily functions. They increase and multiply like so many unicellular organisms, and their protoplasm—the germ plasm—is continuous from generation to generation. The chain of germ cells gives rise to a body or soma at intervals, but the differentiated cells of the body do not, in turn, give rise to germ cells, these being produced more or less directly from the preceding germ cells, which have never become specialised as body cells.

We are by no means so sure to-day, either that differentiated body cells cannot give rise to germ cells or that modifications of the body, acquired in response to environmental stimuli, including the use and disuse of organs, cannot affect the germ cells in such a way as to secure their transmission to future generations by heredity ; indeed there is some reason to believe that both these things may actually take place. Direct evidence of transmission is, however, from the nature of the case, very difficult to obtain. While, on the one hand, it is certain, both from the results of recent experiments and from human experience extending over hundreds of years, that ordinary mutilations are rarely, if ever, inherited, on the other hand it seems quite possible that the effects of the environment or of individual effort, continued for many generations, may gradually become blastogenic and therefore heritable in the strictest sense of the term. The indirect evidence for the latter view is at present perhaps more weighty than any that has been obtained from direct experiment.

Take, for example, the thickening of the skin, or callosity, on the sole of the human foot. We know that such callosities can be produced at will by pressure or friction. When, then, we find that the characteristic thickening takes place on the foot-sole of the infant long before birth, so that it cannot be due directly to friction or pressure, we are naturally led to conclude that it must in this case be a modification which was originally acquired as a result of the use of the foot and which has now become fixed, so to speak, in heredity; in other words, that an originally somatogenic character has, in the course of many generations, become blastogenic. If it be argued that the inherited callosity is due to the action of natural selection in fostering and accumulating chance favourable variations, the answer seems to be that natural selection can have had nothing to do with it because the callosity would in any case develop as the result of pressure and friction as soon as the infant began to walk, so that the thickness of the skin at the time of birth could have no selective value.

Such cases as this seem quite irreconcilable with the opinion, widely held amongst biologists, that bodily modifications, due to the influence of the external environment, will continue to reappear in successive generations only so long as the conditions by which they were originally called forth remain the same. But changes in the environment are often of so permanent a character that it is extremely difficult to decide whether a particular adaptation to such changes, appearing in each generation for perhaps thousands of years, is really inherited or not. The case of the Alpine cushion plants is particularly instructive in this connection, and it seems quite impossible to decide how far their peculiar habit is a direct individual response to the peculiarities of the Alpine climate and how far it is the result of inheritance. That it is to be attributed to the influence of their environment, either directly or indirectly, there can be no reasonable doubt.

Many isolated cases have been brought forward which seem to prove the inheritance of acquired characters. We have already pointed out that mutilations are rarely if ever transmitted from parent to offspring. Were it otherwise, the effect of every great war upon future generations would be appalling. Nevertheless there are exceptional cases on record which seem to be well authenticated. Professor Gates, in his recently published book on "Heredity and Eugenics," quotes the case of a girl whose ancestors for many generations had worn ear-rings, and who was born with each ear-lobe perforated in the proper position. He judiciously remarks "That such cases of inheritance of a mutilation are admittedly rare does not necessarily prove that they are non-existent."

Perhaps it is in the domain of physiology, however, that we are most likely to find satisfactory evidence of the kind we are seeking. This, at least, is suggested by a very remarkable communication from the eminent Russian physiologist, Professor I. P. Pavlov, received at the International Physiological Congress held in Edinburgh in July last (1923), and reported in the *British Medical Journal* of August 11. In this communication Professor Pavlov deals with reflexes, that is to say, automatic responses to stimuli of various kinds, effected through the agency of the nervous system. He distinguishes between inborn reflexes, which he calls "unconditioned," and reflexes that are individually acquired, which he calls "conditioned." A dog, for instance, is naturally stimulated by the sight and smell of food. Certain characteristic movements are performed and saliva is secreted. The dog's mouth waters. This is termed the feeding reaction; an inborn and unconditioned reflex, or series of reflexes. If a bell is rung every time the dog feeds a connection is gradually established between the sound of the bell and the food reflex, and after the coincidence has been repeated a sufficient number of times the food reaction will take place in response to the sound alone. It is now a conditioned reflex, acquired as the result of individual training. The dog has learned by experience to associate the sound of the bell with the presence of the food. Now comes the most interesting part of Professor Pavlov's communication, which I venture to quote in full from the *British Medical Journal*: "A question of the greatest importance is whether the highest nervous activity—that is to say, individual attainment—is hereditary. We have tried to find an answer to this question. We established the conditioned food reflex in white mice, using the sound of an electric bell. With the first set of wild white mice it was necessary to repeat the combination of ringing of the bell and feeding three hundred times in order to form a well-established reflex. The next generation (second) formed the same reflex after one hundred repetitions. The third generation acquired this reflex after thirty repetitions, the fourth after ten, and the fifth after five only. The experiments had reached this point when I left Petrograd this summer. On the basis of these results I anticipate that one of the next generations of our mice will show the food reaction on hearing the sound of the electric bell for the first time. This result would be quite analogous to the well-known fact that a chicken newly hatched immediately tries to pick up any small objects or spots which it sees on the floor. If the stimulation of an eye, as in this case, leads to the food reaction, why, then, may not the stimulation of the ear in the former case produce the same effect ?"

All who are interested in the problems of heredity will look forward with the keenest interest to the announcement of the final result of Professor Pavlov's experiments, but they have already gone far enough provided there is no flaw in the argument, to establish the inheritance of an acquired facility in learning to make responses to new stimuli, and if, as we have been maintaining all along, the entire development of an organism is really nothing but a series of responses to stimuli that follow upon one another in due sequence, then Professor Pavlov's experiments appear to afford a sufficient explanation of progressive evolution. The root of the whole matter seems to lie in the fact that protoplasmic organisms learn by experience ; they can be educated.

We cannot pretend to offer any explanation of Professor Pavlov's results in terms of the germ plasm theory, but that is no reason why we should discard them, and Professor Pavlov is far too high an authority to be lightly treated. He gives us facts that any trained physiologist can confirm or refute ; if they are confirmed, and if no other explanation of them is forthcoming, as it well may be, we shall be justified in believing in the inheritance of acquired characters in spite of any amount of purely negative evidence, or of any preconceived notions of impossibility.

Such a conclusion would be quite in accord with the commonly received view as to the effects of education—using the term in its widest sense—upon human society. Admirers of that keen and thoughtful observer of human nature, Oliver Wendell Holmes, may remember a passage in "Elsie Venner" in which this popular view is very clearly expressed. "There is, however, in New England, an aristocracy, if you choose to call it so, which has a far greater character of permanence. It has grown to be a *caste*—not in any odious sense—but, by the repetition of the same influences, generation after generation, it has acquired a distinct organisation and physiognomy, which not to recognise is mere stupidity." A little later, speaking of the hero of the novel, he says: "He comes of the *Brahmin caste of New England*. This is the harmless, inoffensive, untitled aristocracy referred to, and which many readers will at once acknowledge. There are races of scholars among us, in which aptitude for learning, and all those marks of it I have spoken of, are congenital and hereditary. Their names are always on some college catalogue or other. They break out every generation or two in some learned labour which calls them up after they seem to have died out."

It seems possible, then, that we are to be allowed once more to believe in the permanent effects of individual effort in improving the human race through the process of heredity. Lamarck may be permitted to come out of his corner, and we may all take a more hopeful view of the future. We must not, however, be too sanguine, for we have always got the germ cells to reckon with, for good or evil, and it is evident that these are extremely conservative bodies. Usually, at any rate, they respond very slowly to changes in the environment and refuse to be influenced by merely temporary emergencies. In this way they undoubtedly act as a regulating mechanism, whereby the successive generations of any particular race are maintained in a state of adaptation to the average conditions of the environment. They do not allow the results of accident and disuse to be transmitted in any dangerous degree to the next generation; so that the sins of the fathers shall not be visited with undue severity upon the children. They may be compared to a House of Lords, which vetoes hasty and ill-considered changes of policy, and at the same time does not stand in the way of slow and orderly progress by the normal methods of evolution.

That the regulatory mechanism is imperfect is, however, abundantly evident from the phenomena of Mendelian inheritance which we discussed in our last chapter. These phenomena are apparently due to fortuitous changes in the composition of the germ cells; changes which have, primarily at any rate, nothing whatever to do with the adaptation of the organism to its environment. Indeed they seem much more likely to be injurious than beneficial in their effects. How such changes arise in the first instance we do not know. They are probably of a chemical nature and depend upon molecular rearrangements in the proteid substance of the chromosomes. Curious and sometimes undesirable elements sometimes find their way even into the House of Lords, and it is not always easy to understand how they get there.

CHAPTER VIII

The Excessive Multiplication of Living Organisms—The Struggle for Existence—Natural Selection—Adaptation to Environment—Selection and Instinct—Selection and Degeneration—Immunity of the Reproductive System and Sexual Instincts from Degeneration—Selection by Man and by Insects—The Importance of Isolation.

THE power of cell division confers upon the living organism, at whatever stage of evolution we choose to consider it, an almost unlimited capacity for reproducing its kind. Indeed, the reckless prodigality with which potential individuals are produced, amongst both plants and animals, is one of the most astonishing facts that confront the biologist at the very commencement of his investigations. The number of acorns borne by a single large oak tree in a single year is enormous, and each one requires only a suitable environment to enable it to develop into another tree as large and prolific as its parent. In the case of the ling, Professor Herdman tells us that the number of eggs spawned by a single female fish in the course of one season is 18,500,000. Writing in 1858, Charles Darwin remarked that "even slow-breeding mankind has doubled in twenty-five years; and if he could increase his food with greater ease, he would double in less time," and it was considerations of this kind, inspired by the study of Malthus's celebrated Essay on Population, that led both him and his contemporary, Alfred Russel Wallace, to formulate their theory of Natural Selection.

It is self-evident that this tendency to excessive multiplication, out of all proportion to the available food supply, or even to the available accommodation on the face of the earth, must lead to a bitter struggle for existence, in which the vast majority of the potential individuals produced are doomed to perish. We say potential individuals because most of them are never able to realise their individuality at all, but succumb to the struggle in the earliest stages of their career. Indeed most species, except under human influence, seem to have reached a condition of comparative stability as regards numbers, only sufficient individuals of each generation attaining maturity to balance the death rate amongst the older members of the population. This implies an almost incredible destruction of life, and we may well ask why all this host of living things should come into existence if they are merely to be destroyed as soon as they make their appearance? Nature, however, as has often been pointed out, does not concern herself with the fate of individuals, but with the improvement of the races of which individuals are the temporary and almost insignificant representatives, and if excessive multiplication is one of the means whereby such improvement can be effected, that must be, for the biologist at any rate, a sufficient answer.

There can be no doubt that the struggle for existence is a necessary condition of progressive evolution, operating directly upon the individual in providing the necessary stimuli to exertion, and indirectly upòn the race through the agency of natural selection.

The struggle itself is, of course, of the most varied kind, and is by no means entirely an internecine warfare necessitated by the overwhelming multiplication of living organisms. It is true that individuals of the same species must contend with one another for food and mates and dwelling places, and with those of other species in perhaps even keener strife, as the cat with the mouse, or the bird with the worm ; but all alike have to struggle against the adverse conditions of their environment, against heat and cold, flood and drought, and adapt themselves as best they may to the exigencies of the situation.

In all this struggle and turmoil of life, individual effort, amongst animals at any rate, plays the most conspicuous rôle, but to what extent it is efficacious in bringing about those more or less permanent changes in bodily organisation that mark the successive stages of organic evolution is, as we have already seen, still a matter of debate. Even if we grant in full the claims of Lamarckian biologists, there is evidently plenty of scope for the operation of natural selection upon variations that, so far as we can see, are due solely to the action of chance and are quite beyond the control of the organism in which they manifest themselves. Indeed, it is impossible to escape the conclusion that selection of some sort must always play a decisive part in determining the course of events, alike in the inorganic and in the organic world, from the arrangement of the pebbles on the seashore to the classification of candidates in the examination room. The principle is so obvious that one cannot help wondering at the sensation created by its biological application by Charles Darwin and Alfred Russel Wallace. We know now that these great biologists were certainly not the first to make this application, but to them is due the credit of having pointed out its far-reaching significance and demonstrated the action of natural selection in a thoroughly convincing manner.

The theory of natural selection is directly deducible from three cardinal facts that may be verified as often as may be desired. (1) All organisms tend to produce variations; (2) many of these variations are heritable; (3) all organisms are subject to a more or less intense struggle for existence, in which the weakest, sooner or later, go to the wall. The elimination of the unfit and the survival of the fit follow as inevitable consequences. If there is not room for all some must go, and those which go are weeded out by natural selection in accordance with their incapacity to cope with the conditions under which they find themselves placed, the question of fitness or unfitness at any given moment being determined entirely by the environment, that is, by the totality of the conditions under which the organism has to live its life. A fish in the water is a very good example of adaptation to the conditions of existence, but a fish out of water tells a very different story.

The adaptation, more or less perfect, of all organisms to their environment, is so universal as almost to escape the notice of the casual observer. It is only when the conditions of life are highly specialised, and the adaptation correspondingly peculiar, that the phenomenon appears to him as noteworthy. The fish out of water is an obvious anomaly, yet there are fishes that habitually leave the water and move about on land. This is the case with the so-called climbing perch of India, *Anabas scandens*, which can live out of water for a long time and breathe air directly. It is able to do this by virtue of a remarkable adaptation in the organs of respiration, the ordinary gills being supplemented by a highly vascular organ that serves as a lung. It was by the development of a true lung, from an outgrowth of the œsophagus, that the fish ancestors of the higher vertebrates were enabled to leave the water and gradually develop into permanently air-breathing animals.

As we saw in our last chapter, Lamarck attributed the adaptation of animals to their environment, mainly at any rate, to the efforts made to cope with new conditions as they arise. Even so, natural selection would still have scope for action, for efforts are not always successful and the unsuccessful individuals would be eliminated. Whatever may be the motive force of organic evolution natural selection must always exert a controlling and directing influence.

There are, moreover, many cases in which individual effort seems to be entirely ruled out as a factor in bringing about adaptation. The leopard cannot change its spots, and the very general adaptation of the colours and patterns of animals so as to harmonise with the natural surroundings, and thus afford protection by concealment, cannot be satisfactorily explained, if explained at all, on Lamarckian principles. Let us take a definite example. No doubt many of my readers are familiar with those extemporised fish markets that one so often sees in small fishing villages on the south coast. The catch usually consists largely of plaice, which, as is well known, are very differently coloured on the two surfaces. The upper surface is brown with reddish spots, the lower surface is pure, glistening white. When the fish is lying on the bottom of the sea, in its natural position, the upper surface is alone visible, and it harmonises so well with the colour of the sand or gravel that it is a very inconspicuous object. When the fishermen bring them in for sale they throw them out on the beach and carefully turn each one upside down so that its white under surface shall make it as conspicuous as possible to the buyers standing round. Adaptation from the point of view of the fish and adaptation from the point of view of the fisherman are two very different things.

The most wonderful cases of protective resemblance are, however, met with amongst the insects. On my daily walk to the railway station I pass a hedge, composed of a species of Prunus. During the summer months the leaves are almost stripped by some insect over a length of several yards. I never found out what was responsible for the damage until one day I noticed numerous caterpillars, some crawling on the pavement and others hanging from the hedge by silken threads. They were evidently leaving the hedge in order to pupate in the ground below. They were typical stick caterpillars, which so closely resembled brown twigs that they were quite invisible while on the hedge unless carefully sought for. This remarkable adaptation in form and colour undoubtedly saves them from being devoured by birds.

Still more remarkable are some of the leaf insects of tropical countries, which resemble the leaves of the plants they frequent in almost every detail of form and colour. Sometimes they are green, like fresh leaves, and sometimes brown like dead ones, and in the latter case even the spots of rust may be accurately reproduced.

The actual value of such protective resemblance was conclusively demonstrated by the experiments of A. P. di Cesnola, recorded in *Biometrika*.[1] The subject of these experiments was the well-known praying insect, *Mantis religiosa*, common in the south of Europe. There are two varieties of this insect, one green and the other brown, the green one being always found upon green grass and the brown one upon grass that has been burned by the sun. Forty-five green and sixty-five brown specimens were collected. Twenty of the green insects were tied by silk threads to green plants amongst green herbage, and twenty-five to brown plants amongst brown herbage. Of the brown insects twenty were tied to brown plants in a burnt-up area, and forty-five to green plants in a green area. During the seventeen days for which the experiment continued all the green individuals on green grass and all the brown individuals on brown grass survived. But of the twenty-

[1] Vol. 3, part i, 1904.

five green insects on brown grass twenty were killed in eleven days by birds, and the remainder by ants, while of the forty-five brown individuals on green grass only ten were left at the close of the experiment, which was terminated by a gale sweeping away the remainder of the insects.

The exact converse of protective resemblance occurs in numerous animals which exhibit what is known as warning coloration. This is associated, except, of course, in cases of mimicry, with the possession of some special means of defence, and is commonly found in poisonous insects like the wasps and hornets, who find it better to advertise their dangerous qualities than to seek concealment from their enemies. "*Noli me tangere*" is their motto, and the more conspicuous they are the more likely are they to escape the tentative but damaging attacks of hungry birds. The manner in which these genuine warning colours are imitated by insect mimics which are really perfectly harmless opens up another chapter in the history of adaptation into which we have not time to enter.

It would, perhaps, be going too far to claim that the existence of protective coloration is in all cases to be explained by natural selection. Some of the simpler types may have arisen suddenly by accidental variation on a comparatively large scale. Natural selection, moreover, must always have something tc work upon; it can only effect improvement by picking out something that is already there. Take the case of a leaf butterfly. The shape of the wings in all butterflies is more or less leaf-like, a purely accidental resemblance. The colour and pattern always vary; these variations, if of the nature of mutations, will be blastogenic and heritable. They will also be quite fortuitous. An individual that happens to vary in such a way as to increase the resemblance to a leaf will be more likely to survive and perpetuate its kind than one which varies in such a way as to become more conspicuous. The offspring of the favoured individual will tend to inherit the favourable variation. Variation will again occur amongst these, and the individuals which most resemble the leaves amongst which they rest will again stand the best chance of surviving and handing on their advantage. So it goes on from generation to generation, until at length an almost perfect assimilation of butterfly to leaf, as regards form, colour and markings, may be arrived at.

The environment itself is evidently a thing of many aspects. In the cases dealt with above there is a hostile element represented by the birds or other enemies that endeavour to destroy, and there is a friendly element that offers shelter and protection, and every ordinary animal in times of danger avoids the one and seeks the other. It is useless for the butterfly to resemble the leaf unless it is also provided with the instinct to fly to the tree on the approach of danger.

The part played by instinct in providing the raw material for selection is perhaps not sufficiently recognised. If we ask what instinct is, it seems to me that there is only one possible answer. It is inherited habit. Why does a duckling that has been reared by a hen take to the water at the first opportunity? It has not been taught by the hen, it can only have inherited the swimming habit from its aquatic ancestors. It no longer needs to be taught. For the same reason the newly-hatched chick no longer needs to be taught to peck, and the protectively coloured insect does not need to be taught to fly to the sheltering tree. But can instinct have played any part in bringing about the actual resemblance of animals to their surroundings? In some cases there seems to be no doubt about the answer.

The common spider crab, *Macropodia rostrata*, lives amongst seaweed and disguises itself very effectively by picking off bits of the weed and attaching them to its own body by means of its long hairs. This is certainly a case of adaptation brought about by individual instinctive effort, and natural selection will undoubtedly foster the instinct which is responsible for such a valuable means of concealment. But let us compare this case with another, in which a very similar result has been brought about in a different way. The sea-horse, Hippocampus, is a very remarkable fish, which also lives amongst seaweed, to which it can attach itself by means of its prehensile tail. The Australian Phyllopteryx is a sea-horse which appears to be dressed up in seaweed very much like the spider crab; but it is not real seaweed in this case. The Phyllopteryx makes its own fancy dress out of its own skin, which grows out into long streaming ribbons. This is again a beautiful example of protective resemblance, which must have been fostered and perfected by the natural selection of the most favourable variations. Here the idea of individual effort seems to be as definitely excluded as in the case of the colour and pattern of the leaf insects ; but instinct will again prompt the fish to take up its abode amongst surroundings which harmonise with its quaint costume.

It is evident, then, that the same result may be attained either by inherited modification of bodily structure or by inherited instinctive action. Amongst human beings it may be attained in a third way, by purposive action directed by the conscious intelligence. The principle of camouflage, which played so large a part in the Great War, is identical with the principle of adaptation to the environment by protective resemblance amongst the lower animals ; and camouflage, of course, is encouraged by selection, if only indirectly. The soldier in khaki is less likely to be shot than the soldier in scarlet, but this particular type of protective coloration can hardly be expected to become heritable. Soldiers will never be born in khaki, though emperors are sometimes said to be born in the purple.

It is very difficult to estimate the importance of the part played by natural selection in bringing about those modifications in bodily and mental characters that constitute organic evolution, because the process takes place so very slowly that to our time-limited human faculties everything appears to be at a standstill. We see only the results, not the innumerable steps by which they are achieved. We have just been considering some of the positive results. The phenomena of degeneration which follow upon removal from the struggle for existence, and which we dealt with very briefly in our last chapter, are often claimed as negative results, affording indirect evidence of the efficacy of natural selection. If there is no struggle for existence there can be no selection, for all must be equally fit, and if, under these circumstances, degeneration inevitably takes place, it seems only reasonable to attribute it to the absence of selection, and to conclude that it was selection that had previously maintained and improved the standard. When selection ceases, variations exhibiting all degrees of perfection and imperfection will be able to interbreed freely, with consequent lowering of the average.

It is hardly possible, in the great majority of cases, to decide between this view and the Lamarckian hypothesis of the accumulated effects of disuse. Probably in most cases the two sets of factors co-operate. In the case of the flightless birds the Lamarckian factors may well play the principal rôle for the effects of use or disuse in individuals are readily demonstrable. In the case of protective coloration, however, chance variations, fostered by natural selection, seem to afford the only possible explanation.

It is important to notice that, whatever other parts of the body may undergo degeneration, the reproductive system must always remain in a state of efficiency, for any line of descent in which it ceased to function would at once become extinct. Even the most degenerate parasites have usually highly complex reproductive systems, and in the case of internal parasites, such as flukes and tapeworms, that cannot move about freely in search of mates, each individual has a complete set, or it may be many complete sets, of complicated male and female organs.

The remarkable Sacculina, a parasitic barnacle growing upon crabs, starts its life as an active, freely swimming nauplius, as highly organised as any other crustacean at the corresponding stage of development, but when it attaches itself to a crab it rapidly degenerates, losing its organs of locomotion, its eye, even its alimentary canal, and finally settling down in the form of an almost shapeless bag, containing little but reproductive apparatus and drawing its food supplies from the crab by means of long, branching roots which penetrate deeply into the body of its unfortunate host.

The reason why the reproductive organs can never undergo degeneration is self-evident, and it is no less clear that the instincts associated with the use of these organs must also remain in force, for individuals in which they deteriorate will have little opportunity of handing on their deterioration by heredity. Natural selection must inevitably weed out all types that fail to reproduce their kind. This conclusion has an important bearing upon human problems. The rebellion against child bearing, of which we hear so much nowadays, is necessarily self-destructive. Those with normal parental instincts will tend to perpetuate their own kind, those with abnormal instincts will tend to perpetuate nothing, and must, therefore, always be in a minority. It is, of course, conceivable that a kind of neuter caste might be established in human society, as in the case of the worker ants and bees, which are nothing but imperfect females, but there is no need to provide for such a contingency at present.

In marshalling the evidence in favour of his theory of the origin of species by means of natural selection, Charles Darwin laid stress upon the well-known fact that many very distinct forms of plants and animals are met with in a state of cultivation or domestication, but do not exist in what is commonly called a state of nature. Such, for example, are our various breeds of horses, cattle, dogs, fowls and pigeons ; our fruit trees ; our cereals ; our cabbages, lettuces, peas and beans, and innumerable other vegetables, to say nothing of hosts of garden flowers. These animals and plants are, in fact, human productions, derived, of course, from wild ancestors, but often so much modified from their original condition that it is difficult to recognise their origin. The different breeds of dog differ so much from one another that if a zoologist had met with them first in a wild state he would not have hesitated to regard them as belonging to distinct species, and the same is true of our fowls and pigeons.

How have all these remarkable results been brought about ? There is only one possible answer—by the selection of variations that, so far as we can see, occur spontaneously. This process of selection has been going on since the dawn of civilisation. Man chose from the gifts of nature whatever was useful to him, and he always took what was best from his own particular point of view. When he began to cultivate his plants and domesticate his animals he would naturally choose for purposes of propagation those which best suited his requirements. Variation supplied him with plenty of material for choice, and as his own intelligence developed he was able to make better and better use of his opportunities. In recent years, as we have already seen, artificial hybridisation has been resorted to as a means of increasing the material for selection, and the improvement of our flocks and herds, our flowers, our fruit, our corn and our vegetables, goes on more and more rapidly. In this way man has become a creator, and a new world of plants and animals is developing under his fostering care, to the infinite detriment and perhaps ultimately the complete replacement, of the older world of life into which he was born.

Surely, if such wonderful results can be brought about by human selection, we are justified in attributing a like importance to the action of any selective agency that may operate in a state of nature. Such an agency we find in the environment, but though the organism must, of course, adapt itself to its environment as a whole, there is often, as we have already seen, some special feature therein to which special adaptation is desirable.

In the case of domesticated animals and cultivated plants the special feature of the environment to which they have to adapt themselves is the presence of mankind. They have become an expression of human needs and human ideals. The racehorse, the fat pig, the prize orchid, are all reflections of the human mind. Such things do not exist for themselves. Many of them could not exist at all in a state of nature. Take, for example, the long-tailed Japanese fowls, or, still better, the Japanese waltzing mice. Owing to an inherited abnormality of the inner ear, these unfortunate little animals are unable to run for any distance in a straight line. When taken out of the cage and put down on the floor they run round and round in circles. It is a curious human taste that has led to the selection of these quaint monstrosities as pets. We have a closely similar example in the case of the hexadactylous, or rather polydactylous, Russian peasants, referred to in an earlier chapter. Here the chief motive at work seems to have been the desire to escape the obligation of military service; or we might say that military service was the particular feature in the environment that determined the evolution of a polydactylous community.

Man, however, is not the only animal that, either consciously or unconsciously, influences the course of evolution by his powers of selection. It is very well known that there is a most remarkable and precise mutual adaptation between the characters of many insects and those of the flowers which they frequent in search of honey and pollen. This is because there is a mutual advantage to be secured. The flowers are fertilised—or, to speak more accurately, pollinated—by the insects, which bring with them pollen from other flowers of the same kind; and the insects are paid for their services with the superfluous pollen and with the honey that lies hidden in the cup of the flower. All sorts of devices have been adopted by flowers of various kinds to attract their insect visitors and to secure that they shall not be able to get their reward without carrying out their part of the bargain. The insects are attracted by bright colours and strong scents, and dainty traps are set for them baited with nectar. They, on the other hand, show corresponding adaptations of the organs concerned in gathering the honey and pollen. The appendages in the neighbourhood of the mouth form long sucking tubes, accurately adjusted to the position of the honey in the flowers which they visit. We may, if we like, suppose that use and disuse have played some part in the progressive evolution of the insect's proboscis, but there seems to be little, if any, scope for the Lamarckian factors as causative agents in relation to the colours and scents of the flowers. It seems clear that the insects select the colours and scents. The flowers which best suit their tastes will stand the best chance of receiving pollen and producing seed. Their advantageous colours and scents will be inherited by the next generation, amongst which insect selection will again take place, and so a more or less perfect adaptation to the requirements of the insects will slowly, but surely, be brought about.

That it is really the insects that constitute the determining feature in the environment in this case is clearly indicated by the otherwise inexplicable fact that those exceptional flowers that are fertilised by carrion-feeding flies, such as certain arums, have dingy colours, and odours of decaying flesh that to our senses are highly offensive; to us such odours are warnings of the presence of noxious substances, to the flies they are attractive because reminiscent of their natural food. The same conclusion follows inevitably from the fact that flowers that are pollinated by the agency of the wind, like those of the grasses and cereals, and of the common forest trees, are small, inconspicuous and scentless. The wind has no senses to be gratified and does its work without reward.

The love of flowers is one of the most agreeable features of human nature, and their presence has doubtless done much to cultivate our æsthetic sense. But flowers existed long before man appeared upon the scene. The standard of taste in scents and colours was first set by the insects, and man owes his likes and dislikes in these matters very largely to their initiative.

Whatever may be the selecting agent, there is always one thing necessary before it can bring about any improvement, and that is the isolation of the selected variations, the prevention of interbreeding with the less favoured individuals of the race, so that the incipient adaptations shall not be swamped by crossing. For this reason the pigeon fancier keeps his birds in separate cages and the stock breeder is scrupulously careful to allow no random mating. The numerous varieties of domesticated dogs, as is well known, breed freely with one another if allowed to do so, and the results are mongrels. Similarly, when different varieties of pigeons are mated together the offspring tend to revert to the condition of the original wild rock pigeon from which all the varieties were derived.

With what are called natural species the case is different. They rarely interbreed, and, if they do, the offspring are usually sterile, as in the case of the mule, which is a hybrid between the ass and the horse, two distinct species of the genus *Equus*. Mongrels, on the other hand, which are the products of different domesticated races, are perfectly fertile. These differences have frequently been cited as an argument against the validity of the comparison between the results of so-called artificial and those of natural selection. This argument was long since disposed of, however, by the late Dr. Romanes, who pointed out that it was merely a question of the different kind of isolation in the two cases. Natural species are not incapable of breeding together because they *are* distinct species, but they have *become* distinct species because they are incapable of breeding together. Variations in the reproductive system, or in the instincts associated therewith, may result in sexual incompatibility between the members of different groups of individuals of the same original species. These groups are then as effectually isolated, from our present point of view, as if they lived on separate islands, or as the animals which the breeder keeps in separate enclosures. It is only a physiological isolation, but inasmuch as it prevents interbreeding it will allow of the accumulation of adaptive modifications under the influence of natural selection, just as surely as they accumulate under the watchful eye of the breeder. The only real difference between artificial and natural selection seems to lie in the character of the selection practised. Man selects for his own advantage, while nature selects for the benefit of the selected organism, the benefit being a more or less perfect adaptation to the environment; and even this difference melts into thin air when the matter is closely considered.

It would be difficult to over-estimate the importance of isolation as a factor in organic evolution. Whether it be physiological or geographical makes no difference, the result is the same. It has been shown that the mere division of a species into two isolated groups must be sufficient to cause it to split into two distinct species, for the average characters of all the variations can never be exactly the same in any two sections, and when interbreeding is prevented each section will follow its own line of evolution. This is very clearly seen in the fauna and flora of islands that have been separated comparatively recently from larger areas. The Chatham Islands, for example, are merely detached portions of a New Zealand that was once of almost continental dimensions, and the plants and animals found on these islands are very like those occurring in New Zealand itself, but with just sufficient difference in most cases to cause them to be regarded by naturalists as belonging to distinct species. I am not aware that the experiment has been tried, but I see no reason to suppose that they would be incapable of interbreeding with their New Zealand relatives, for the specific differences in this case have not arisen through mutual sterility.

In other cases much greater differences have arisen owing to longer isolation and adaptation to different climatic or other conditions of the environment, as seen in the case of the flightless birds that form such a conspicuous feature of remote island faunas.

These considerations have a very direct bearing upon the problem of human evolution. Whether or not we are to regard mankind as composed of one or many species has long been a disputed question, and I gladly leave it in the hands of the anthropologists, for, from the biological point of view, it is a matter of very small importance. It is, in fact, a mere question of definition. It is certain, however, that the different races of mankind are still capable of interbreeding, and the differences by which they are distinguished must have arisen largely through geographical isolation and adaptation to different conditions of life, chiefly connected, in the first instance, at any rate, with climate and food supply. The analogy with the different breeds of domesticated animals is very close.

It seems probable, for example, that the British people owe such special virtues as they may possess to their long-continued, though only partial, separation from other nations, and the same is true throughout the inhabited world. It is also obvious that the different races of mankind have progressed to very different degrees under their different conditions of life. The Australian aborigines are still in the Stone Age, through which our own ancestors passed many thousands of years ago.

The differences between the various branches of the human family, especially as regards mental and moral development, are enormous, and there can be no doubt that they are maintained by geographical isolation. What, then, is to happen now that this isolation is being every day more completely abolished? Our modern means of communication are rapidly bringing all parts of the world so close together that the natural barriers to migration will soon cease to have any importance. All races will intermingle; they are already doing so. Under these newly arisen conditions, what is to prevent the interbreeding of all types of humanity and the gradual establishment of one vast mongrel population? Any one who is acquainted with the half-caste inhabitants of such a country as, for example, South Africa, will at once realise the dangers attendant upon such a state of affairs. A mongrel is no more desirable amongst human beings than it is amongst domesticated animals.

The humanitarian, but utterly unscientific, doctrine that all men are equal has much to answer for. If followed out to its logical conclusions it must lead to the general and permanent deterioration of the human race, for the highest types of mankind are in a minority, and it will be a case of levelling down and not of levelling up.

CHAPTER IX

The Law of Evolutionary Progress—Extinction of over-specialised Lines of Descent—Evolution of the Brain and Mind—The Mental Environment—The consciously Creative Mind—Problems to be Solved—The Amelioration of the Physical Environment—Education—The Control of Population—The Improvement of the Human Race by Selection—The Improvement of the Social Organisation—The Improvement of the Relations between Nations—Evolution not Revolution.

THE time has now come to bring together the different lines of thought which we have been endeavouring to follow out and take stock of the position to which they have led us. In the first place I should like to discuss a little more fully what we called in our first chapter the Law of Evolutionary Progress. Some there are, of pessimistic propensities, who seem to think that the idea of progress is entirely illusory, at any rate so far as mankind is concerned, but in view of the broad facts of history, even when limited to the human race, it is difficult to see how such a position can be maintained. Can we believe that the average citizen of ancient Greece, let us say, was no better than the cave-dwellers of the Stone Age; or that the typical Englishman of to-day is still on a level with the Australian aborigine?

When we take a wider survey and consult the geological records of the past, we find that each successive age has been marked by the advent of more advanced types of animal and vegetable life, the most advanced of all, man himself, being the latest to arrive upon the scene.

Progress, from the biological point of view, must be taken to mean increase in complexity of bodily structure, accompanied by increase in the complexity of all those varied relations with the environment that constitute life. Judged by this standard, the progress has been so great, since living things first came into existence on the earth, as to leave us in a state of almost helpless amazement and admiration at the achievements of organic evolution. Surely this is a much more worthy and much more hopeful conception of the method of creation than the worn-out dogmas that satisfied our forefathers.

In accepting this general conclusion we do not commit ourselves to the belief that progress has always been continuous in one and the same direction. That, we know, is far from being the case. Progress has been accomplished in successive waves of advancement, each wave retreating from its own high-water mark to make way for another which will outrun it. The tide coming in on a calm day over a level stretch of sandy beach affords, perhaps, the best analogy.

We see this wavelike progress first in individual lives, which begin at the lowest level of organisation and vitality, reach the high-water mark of structural complexity and physiological efficiency, and then ebb away into old age and death. Each new life begins again, a little in advance, it may be, of the starting point of its predecessor, and carries on, under favourable circumstances, a little further, before succumbing, in its turn, to the inevitable.

We see precisely the same thing in human civilisations; they rise and fall, and one gives place to another with almost monotonous regularity.

The zoologist has long recognised the same principle at work on a larger scale throughout the animal kingdom. Each new branch of the tree of life, as we have already said, arises, not from the apex, but from low down on the parent branch; in other words, each new line of progressive evolution commences with comparatively primitive and unspecialised representatives of the parent stock.

The reason for this wavelike method of evolutionary progress, whether we regard its manifestation in individual lives or in the larger theatre of the animal kingdom, is not difficult to find. The individual, during its lifetime, becomes worn out and ceases to respond to environmental stimuli. It accumulates products of its own physiological activity that sooner or later interfere with the functions of the various organs. Its cells lose the power of renewing themselves by division, and presently the whole machine comes to a standstill. This is far from being an unmitigated evil, for at the close of each life most, at any rate, of the imperfections and injuries that have been acquired in the struggle for existence are wiped out and room is left for new lives to make a fresh start, each with a comparatively clean slate.

It is the same with the successive branches of the evolutionary tree. They adapt themselves gradually to a particular mode of life, usually increasing in structural complexity as they do so, till they become so specialised, and it may be so burdened with accretions, that they lose all plasticity and power of adaptation. They may linger on so long as the environment remains unchanged, but if new factors are introduced into the struggle for existence, as is sure to be the case sooner or later, they will be found wanting and will have to give place to some less specialised type whose powers of adaptation are still unimpaired.

Perhaps no better illustration of this general principle could be found than that afforded by the gigantic reptiles of the secondary period of the earth's history, to which we alluded very briefly in our first chapter. These arose from small beginnings at the close of the preceding era, which soon, as geological time goes, branched out in all directions, until they came to dominate not only land and sea but even the air, a much more difficult element to conquer. They adapted themselves admirably to each mode of life, becoming beast-like, fish-like or bird-like as circumstances required. In each of these environments they attained huge dimensions, and this was especially the case with those that dwelt on land. The great Diplodocus, with its long tail and absurdly small head, attained a length of eighty feet. It consisted of an unwieldy mass of flesh and bone and guts, with a brain that was almost negligible in the feebleness of its development. Some of these huge monsters were vegetable feeders, others flesh eaters, and many found protection from their rapacious kindred in the development of a heavy external armature of bony plates and spines, reminding one of the mail-clad knights of the Middle Ages, only on a much grander scale, and with the disadvantage that the armour could not be discarded when it proved to be no longer a desirable possession.

What actually led to the extinction of all these terrific monsters we do not know. Somehow or other the struggle for existence became too much for them. Possibly the food supply gave out, for it must have required an enormous amount to keep them going. At any rate there are none of them left now, though the crocodiles and alligators still serve to give us some idea of what life in the age of reptiles must have been like, and the turtles and tortoises still show what strange devices may be adopted in order to secure protection.

It is quite possible that every highly specialised line of evolution would gradually become worn out and suffer extinction even if there were no change in the external environment to demand fresh adaptation in structure and function; that the life of the race is in this respect like the life of the individual, passing through the successive phases of infancy, youth, maturity and old age to death, even under the most favourable conditions.

Some organisms, it is true, seem to be exempt from this general law of decay. The Protozoa are still with us, and there is no reason to believe that they have changed very much since palæozoic times. Indeed, each of the great ancestral groups has left comparatively unmodified descendants which have survived to the present day. It seems to be only over-specialisation that leads, sooner or later, to extinction. Organic evolution is a long series of experiments, each one of which in turn has proved to be a failure as soon as it became too complicated ; but only to make way for another, still more ambitious. Death is the price we pay for progress.

It would, of course, be absurd to profess, either that evolution is always progressive, or that progress is necessarily the same thing as adaptation to the environment. There are, as we have already seen, many kinds of environment the adaptation to which results in degeneration, in simplification of structure and function, as in the case of parasites. Progress implies increasing complexity of structure and corresponding increase in the fullness of life.

Nowhere, perhaps, is this better seen than in the evolution of the brain of the higher vertebrates. As Professor Elliot Smith has shown so clearly, the gradual increase in complexity of structure has arisen in direct response to the stimulation which the different parts of the brain have received, through the sense organs and their nerves, from the external world, and through other nerves from other organs of the body. The brain is like a great telephone exchange, where all parts of the body are placed in communication with one another and, indirectly, with the external world. The body itself forms the immediate environment of the brain, and the structure of the brain is a reflection, or a representation in miniature, of that of the whole body, for each part of the body is represented by a corresponding part of the brain, just as each room in an old-fashioned house used to be represented by a bell in the kitchen. The brain, just like any other organism, or part of an organism, has built itself up by a series of responses to environmental stimuli, and this gradual development is repeated in every individual lifetime.

The process is automatic in its earlier stages, and effected without any consciousness of what is going on, as every physiological process tends to become automatic when repeated sufficiently often. Philosophers, as we have said before, rightly warn us against the dangers of automatism, but we should not make much progress if we had to think about the contraction of every muscle and the movement of every bone every time we made a step forward. Automatism liberates the conscious mind for the performance of higher functions, as when long practice enables a skilled performer to think about other things while playing the piano.

The enormous complexity of the brain structure in human beings has led to the creation of a new kind of environment, an environment of mental images and emotions which may have no relation to the physical environment for the time being, but under the influence of which the mind builds itself up in much the same way as the body builds itself up under the influence of physical stimuli. At the same time the mind becomes consciously creative—the human being must always be, in greater or lesser measure, a poet.

This new mental environment now leads the way in progressive evolution, just as the physical environment did at lower stages. The mind has, so to speak, got ahead of the purely physical environment, which henceforth takes a subordinate position.

Progress must now consist in the formulation of high ideals and in adaptation to these. It is just this power of formulating ideals to be lived up to, and at the same time consciously regulating the external environment so as to bring about the desired results, that distinguishes mankind from the lower animals and justifies us in regarding the human race as something more or less apart from the rest of the world of life. The evolution of the mind, however, is a subject for the psychologist rather than the biologist to deal with; but it is obviously one which requires a comprehensive knowledge of the evolution of the body and of its relations to the environment, if it is to be adequately dealt with, for there can be no doubt that the structure of the mind, however complex it may be, is dependent upon that of the brain.

In concluding this little volume, I should like to say a few words about some of the problems that will have to be solved in the near future, if our present civilisation is to escape the fate of its predecessors and enjoy any lengthened period of further development. As a mere matter of convenience we may arrange these problems under six headings, which, of course, are not to be regarded either as exhaustive or as mutually exclusive :—

(1) The amelioration of the physical environment.
(2) Education.
(3) The control of population.
(4) The improvement of the race by selection.
(5) The improvement of the social organisation.
(6) The improvement of the relations between nations.

(1) We have already insisted on the importance of the physical environment in determining the course of organic evolution. We have pointed out that the organism is, in fact, a kind of expression, or reflection, of its surroundings. Even such simple organisms as the Amœba, however, appear to have a certain amount of choice in the matter, for they can seek new situations when conditions become unfavourable. It may, of course, be said that their movements are mere tropisms, determined entirely by chemical and physical reactions, and the same can be said of man himself. We need not, however, concern ourselves here with the apparently insoluble problem of whether or not man is really a free agent. For all practical purposes it must be assumed that he is responsible for his actions and, with his increased mental and moral development, he has also taken upon himself responsibility for his own environment. The sailor loves the sea and chooses a profession that brings him into immediate relations with it. The literary man surrounds himself with books, and the student of experimental science is happiest amidst the paraphernalia of a laboratory. The environment has now become a kind of reflection or expression of the mind, there is a reciprocal action between the two, each in turn influencing the other, each becoming more and more completely adapted to the other. The slum is eloquent of the kind of people who live there, and the people who live there are often no less eloquent of the slum.

We cannot afford to lose sight of these facts when we talk about the amelioration of the environment.

The environment exercises its influence chiefly in youth, when mind and body alike are still in a plastic condition, still capable of being moulded for good or evil. If only the children of the slums could be brought up in the country, amongst healthy physical and moral surroundings, who doubts that the results would be beneficial, not only to the individuals concerned but to the entire social organism of which they form a part? That there are some individuals who would always prefer slum life is probable, but the slum habit has hardly continued long enough in the same lines of descent to have become hereditary.

The repatriation of the slum population on the land under proper conditions would perhaps do more than anything else to bring about a general improvement in the mental, moral and physical character of our population, now in a fair way to be ruined by the intensified industrialism of the past century. At present there seems to be no way in which this repatriation can be effected to any great extent, and we are thrown back upon the only less formidable task of improving the slums themselves. We can at least make them clean and comparatively healthy, and we can provide recreation grounds within easy reach, from which the beauties of nature will not be entirely excluded.

(2) Under the heading "Education" we must include far more than that term is usually taken to connote. Indeed, organic evolution is nothing but a long process of education in which the whole of the environment takes part, and the chief distinguishing

feature of living matter is its capacity for learning by experience. It is evident, therefore, that the amelioration of the physical environment must be one of the chief factors in any satisfactory educational system, and that the education of the body is no less important than that of the mind. The thing to be avoided is a lop-sided development, in which either mental or bodily culture is allowed to assume a dominating importance.

There can be little doubt that the most efficient education of the young—for good or evil—is that which they find for themselves outside of school hours, whether it be in their own instinctive amusements or in organised games. It is for this reason that country life affords the best field for their early development. Direct contact with nature is more valuable at an early age than any number of school books. It cultivates the powers of observation and provides a stock of experiences and ideas that form a healthy foundation for the mind to build upon. From these experiences the mind will select those that are best adapted to its own requirements, and the function of the teacher should be to assist it in making the best possible use of them. The great drawback of our present educational system is, as everybody knows, that it tends to force too many minds into the same mould, regardless of their individual differences.

Again, if it be true, as modern psychology teaches, that an idea that has once gained access to the mind can never be thoroughly eradicated, it is evidently of the first importance that the external environment from which ideas are derived should be as innocuous as possible, and our responsibility to the rising generation in this respect is obvious.

As the development of the mind progresses and ideas accumulate it tends to become more and more its own environment, and the proper control of this environment should be the chief aim of education. The power of the will to foster ideas that are beneficial to mental and moral development, and to repress, if not to eradicate, those of an opposite tendency, cannot be too strongly insisted upon, for it is upon this power that the building up of character depends. This is a fact that is perhaps not very self-evident to the young; yet how many teachers ever think of impressing it upon the minds of their pupils?

The future progress of the human race must depend upon the ideals which we set before ourselves and inculcate in our children. The worship of these ideals, I suppose, whatever they may be, constitutes the only true and universal religion. The religion of the savage is different from that of the civilised man because his ideals are different, but it is a religion all the same, and for him also progress consists in living up to his ideals. Upon the nature of these ideals everything must depend. It is a remarkable fact that, although men and women with the highest ideals seem always to be in a very small minority, yet they are able, by precept and example, to enforce their ideals, sooner or later, upon the rest of the community. I leave to moral philosophers the explanation of this phenomenon. Whatever may be their source, the nature of our ideals will certainly determine our attitude towards the remaining problems that I wish to put before you.

(3) The very existence of civilised societies to-day depends upon the accumulation of vast stores of potential energy; upon capitalism on the largest scale. Much of that energy was accumulated many millions of years ago by the vegetation that flourished in the carboniferous epoch of the earth's history, which absorbed it from the sunlight and locked it up in a form that has been handed down to us as coal. When our coal supplies give out we shall either have to find some other source of energy—and let us hope it will be a cleaner one—or our social organisation will have to undergo radical changes.

Human beings, however, cannot feed upon coal; they cannot directly utilise its potential energy in carrying out the necessary functions of the body. They require capital that is more readily available, food substances in which the energy has not been quite so securely locked up. There is no great accumulation of such substances to draw upon, as there is of coal. Mankind must always live more or less from hand to mouth, and he is obliged to produce or procure, in one way or another, his own food supply. Moreover, as the population increases, the food supply must be increased in the same ratio, and there is obviously a limit to the possibilities of increase in both cases, though that limit may not be reached yet awhile.

Unfortunately, however, population and food supply are very unevenly distributed over the earth, so that there may be a half-starving population in

Whitechapel while at the same time there is more wheat than can easily be disposed of in Australia or Canada. One naturally asks, why do not some of the inhabitants of Whitechapel go to Australia, where population is badly needed to develop the enormous resources of the country, and where the conditions of life are far more favourable than they are in Whitechapel? The answer appears to be twofold. The Australians very naturally do not want what they regard as undesirable immigrants, and the people of Whitechapel seem to prefer to stay where they are. They have become so adapted individually to their environment that they would find it very difficult to uproot themselves and settle down elsewhere. As we said just now, however, there is no reason to believe that the adaptation to slum life has yet become heritable, and the solution of this particular problem seems to be to encourage the emigration of the young, as, indeed, is already being done.

Some people seem still to cherish the strange delusion that a mere increase in the numbers of the population, even in districts where the conditions of life are highly unsatisfactory, is a sign of progress. It is supposed to be a triumph of industrialisation that more people can live, and are living, in Lancashire to-day than could have lived there a century ago. Anybody who knows what a Lancashire manufacturing town is like will be able to form his own judgment as to the desirability of this result. Surely it is better to have a small number of people living wholesome and happy lives amidst healthy and beautiful surroundings than a vast population enslaved to an environment of slums and factories. But then, you will ask, what is to become of our trade? Our trade is only necessary in proportion to the extent of our population—trade should exist for the people, and not the people for trade, and until we learn to write trade with a small "t" I fear the population problem will remain where it is.

If, instead of teaching the masses of the people to restrict their families by artificial methods, a proceeding which may be fraught with grave danger to the community, we encouraged them to go on the land, or even to emigrate, and discouraged them from accumulating in congested areas where the conditions of life are necessarily undesirable, there might be more hope. At present we certainly cannot say that the earth is not large enough to accommodate the human race. Migration and dispersal under the pressure of overcrowding have always formed an essential factor in organic evolution, and the exaggeration of the herding instinct is a disease of civilisation. When, on the other hand, we see, as we do to-day, a nation, with a birth-rate steadily diminishing under the influence of artificial restriction, obliged to protect itself by the aid of hired soldiers of an inferior race from being overwhelmed by a neighbouring nation whose population is steadily increasing, we cannot fail to realise the absurd and perilous position to which civilisation is drifting.

It may be useful to remind ourselves, in this connection, that there are, amongst the lower animals, two distinct methods by which the numbers of a given species are maintained at an approximately uniform level, and by which, at the same time, progressive evolution is encouraged. In the first case there is an enormous production of offspring, which are turned adrift to fend for themselves in an almost helpless condition, so that only a fractional percentage of them will ever attain maturity; and, in the second case, a strictly limited number of young are reared, by the aid of accumulated capital, until they stand a fair chance of getting on in the world by their own unaided efforts. In the first case progressive evolution may be effected chiefly by the natural selection of accidental variations in a favourable direction, for which there will be abundant opportunity. In the second the individual efforts of the parents, whether conscious or unconscious, play the more important part, and this, of course, reacts upon the parents themselves and leads to the gradual development of that parental instinct which is one of the chief factors in the higher life of mankind. The second method seems to have been the more successful of the two, for it is most fully developed in the highest groups of the animal kingdom, and amongst these the evolutionary status of any particular type is directly proportional to the length of time during which parental care is exercised.

It is, of course, true that the restriction of the number of young produced, in what we call a state of nature, must depend ultimately upon the sacrifice of a vast number of potential individuals, if only in the form of germ cells, but this hardly constitutes an argument for the artificial restriction of human families, for such sacrifice takes place unconsciously and does not violate any parental or moral instinct.

Marriage, however, as we have already said, is a compromise, in which much has got to be sacrificed for the benefit of the community, and, in this respect, as in others, each must decide upon his own line of conduct in his own special circumstances, and with as full a knowledge to guide him as may be available.

(4) These considerations bring us naturally to the problem of the possible improvement of the human race by some process of selection. We have already seen what astonishing results can be brought about by artificial selection systematically practised upon our cultivated plants and domesticated animals, and the question at once arises, why should not similar results be brought about in the case of the human race itself? No doubt they could be, if only there were a general consensus of opinion as to the type of mankind most to be desired and an authority sufficiently powerful to enforce the verdict. Fortunately this is not the case, or there might soon be an end of that differentiation within the social organism that is so essential for its well-being. In this respect, at any rate, the individual must count for more than the community, for he alone can choose the mate best suited to his requirements. As education progresses, and our ideals become more firmly established, we may hope that the particular type of natural selection which Charles Darwin distinguished as sexual will bring about progressive improvement.

There is, however, a limit to individual freedom; otherwise civilisation would be impossible. The community must be protected, not only against the vicious but also against the ignorant and foolish.

We no longer allow murder or theft, and we do our best, by sanitary legislation, to protect the health of the existing population. Why, then, should we permit the propagation of disease by inheritance? Have we no responsibility with regard to future generations? If we recognise the fact that the offspring of the mating of two feeble-minded individuals are bound to be feeble-minded, and that education can do nothing to cure their deficiency, however much it may mitigate its effects, surely we are morally bound to see to it that feeble-minded individuals do not mate. If we realise that feeble-mindedness, being a recessive character, may lurk unseen in an apparently normal individual, to manifest itself again as soon as an unfortunate mating furnishes the necessary conditions, the importance of endeavouring to root out this deplorable evil becomes still more manifest.

Professor Ruggles Gates [1] quotes a statement from Goddert to the effect that at least 50 per cent. of the paupers cared for in American institutions are feeble-minded, and at least 50 per cent. of the prostitutes are estimated to be in the same condition. How such a lamentable state of affairs may come about is made very clear by Professor Davenport in his valuable work on "Heredity in Relation to Eugenics." [2] Perhaps the most remarkable instance that he deals with is that of the notorious "Juke" family in the United States, whose pedigree is traced back to one Max, described as "a descendant of the early Dutch

[1] "Heredity and Eugenics," p. 149 (Constable & Co., Ltd., 1923).
[2] Henry Holt & Co. and Williams and Norgate, 1912.

settlers ; a good-natured, lazy sot, without doubt of defective mentality." I will not weary you with the painful details of this depressing family history, but will content myself with quoting the concluding paragraph :—

" Thus, in the same environment, the descendants of the illegitimate son of Ada are prevailingly criminal ; the progeny of Bell are *sexually immoral* ; and the offspring of Effie are *paupers*. The difference in the germ plasm determines the difference in the prevailing trait. But however varied the forms of non-social behaviour of the progeny of the mother of the Juke girls, the result was calculated to cost the State of New York over a million and a quarter of dollars in seventy-five years—up to 1877, and their protoplasm has been multiplied and dispersed during the subsequent thirty-four years and is still marching on."

Unfortunately, we cannot estimate merely in dollars the damage to the social organism due to the transmission of such undesirable qualities. Surely society has a right to protect itself against such dreadful possibilities. The segregation of the feeble-minded in special schools and colonies is a step in the right direction. Whether it is a sufficient safeguard is a matter of grave doubt. In a state of nature individuals that fail to adapt themselves to their environment are weeded out by natural selection. We are apt to flatter ourselves that we have got the upper hand of natural selection, but unless we can provide some form of control to take its place we shall find ourselves woefully mistaken.

The difficulty with which we are faced in dealing with such problems as that furnished by the Juke family is to reconcile the drastic measures that seem best adapted for the protection of the social organism with those altruistic tendencies that distinguish highly civilised communities from uncultured races. Problems of the same kind confront us every day. We pride ourselves on the advance of medical science that enables us to save or to prolong lives that only too often are but a burden and an infliction on all concerned. We do our best by active interference to prevent the beneficial action of natural selection, and at the same time dare not take the responsibility of selection upon our own shoulders. Indeed we do far more than this, for in times of emergency it is always the best that are selected, or more often select themselves, for the most dangerous services. We shall be told, no doubt, that the education of our moral nature demands all this pain and sacrifice, and that nobility obliges us to sacrifice ourselves and save the lives of others whenever possible; that it is our duty to help those who, from natural incapacity, are unable to help themselves, even though they be criminals, and that to neglect this duty would inflict an injury upon our own spiritual life that would be far more serious than any injury to society that might result from our philanthropic efforts. If all this means merely that we are to cultivate our own moral nature by prolonging the sufferings of our fellow-men, the argument is, of course, worthless. Let us hope that there is more in it than that. For one thing, the sanctity of human life is one of the foundation stones of our social system, and we dare not loosen it lest the whole structure should come tumbling about our heads.

It cannot be doubted, however, that we are on the horns of a dilemma. If our moral nature will not permit us to eradicate the seeds of physical and mental decay from our midst, what is to prevent the ultimate downfall of our present civilisation and its replacement by some less sensitive branch of the human family? There is at any rate one thing that can be done to mitigate the evil. We can educate the people to a fuller sense of their personal responsibilities with regard to the transmission of heritable defects. There has lately been established in Vienna a public clinic where men and women who wish to marry can obtain advice from the eugenic point of view.[1] This seems to be meeting a real need of the people, though it seems hardly to be expected that the most dangerous members of society will ever be amongst its patrons. We have also in London a Eugenics Education Society, which seems to have great possibilities of service. Perhaps still more can be accomplished by medical men in private practice, when more of them have realised the necessity of training themselves with this object in view.

(5) Whatever view we may take with regard to the future, we are faced with an immediate responsibility that demands the concentration of all our energies, and that is the improvement of our social organisation. It is becoming every year more evident that society cannot go on very much longer as at present

[1] See an article by Dr. Hugo Glaser, entitled "In der Eheberatungstelle," published in *Soziale Arbeit*, Vienna, 1923.

constituted. The spread of education has awakened the masses of the people to its more glaring anomalies, and universal suffrage has given them power to bring about vital changes, though whether these will be for good or evil remains to be seen. The danger seems to be that all that is worth having in our present system may be destroyed before there is anything better, or even as good, ready to replace it. In the course of organic evolution all progress is effected by slow degrees—by the gradual adaptation of the organism to new conditions of life. Abrupt changes, such as the sudden appearance of extra fingers or toes, seldom lead to progress, but are often disastrous, they are revolutionary rather than evolutionary, and they sometimes lead to immediate extinction.

If progress is not to be left entirely to chance, and to the ruthless operation of the law of natural selection, it must be guided by human intelligence, and the more intelligent the control the better will be the result. Before the masses of the people are fit to govern themselves they must be educated, so that they may understand something, not only about the complex machinery which they light-heartedly propose to direct, but also about the laws of nature which govern the evolution of every living organism.

We have a right to demand that our leaders shall not only be educated men, but that they shall be properly trained for the work that they propose to undertake. We do not allow a ship to be navigated by unqualified officers, and we have done away with quack doctors, but nobody seems to think it necessary to insist upon any real tests of the fitness of a member of Parliament, or even of a minister of the Crown, for his particular duty. We have undoubtedly made much progress in these matters since the days of pocket boroughs and corrupt electorates. There is a long way still to go, and we can only hope that the progress will be maintained.

(6) One of the chief problems that our political experts have to face just now is that of the improvement of the relations that exist between different nations. In our last chapter we pointed out the danger attendant upon the breaking down of the barriers that have hitherto, to a greater or less extent, prevented the intermingling of the different races of mankind. There is only one thing more that I should like to say in this connection from the biological point of view. We saw, at the outset of our inquiry, that progressive evolution has consisted very largely in the integration of individuals of a lower order to form individuals of a higher order, and that at every stage differentiation and division of labour amongst the constituent parts of each organism have played a vitally important part. If we regard a human society, or let us say at once, a nation, as an individual of the highest order yet attained, we cannot fail to see that its well-being, if not its very existence, must depend upon differentiation and division of labour amongst its constituent members. We must now follow up this idea a little further.

If ever the conception of a league of nations be fully realised we shall then have an individual of the highest order that is conceivable under earthly conditions. But, if we may judge by the analogy of what has already taken place in the course of organic evolution, the success of such an organisation will again depend upon differentiation and division of labour amongst its constituent units. Each nation must adapt itself to its own conditions of life and make the most of its own opportunities. The conditions and opportunities are widely different in different geographical areas, and there will always be abundant scope for the development of national character. But national character will soon cease to exist, and the whole earth will soon come to be populated by the teeming millions of mediocrity—or worse—if there are no longer any barriers to separate the different branches of the human family. Physical barriers are ceasing to be effective, and there is, as we have already seen, no physiological barrier such as separates most species in a state of nature. In the future we shall have to look to moral barriers to prevent indiscriminate interbreeding and its evil consequences. Nations, like individual men and women, must be allowed to work out their own salvation, each in its own way, without undue interference on the part of their neighbours. All the resources of nature can then be exploited by division of labour and co-operation in the interests of humanity as a whole.

In these concluding remarks I have endeavoured to indicate some of the points of contact between biology and the moral and political sciences. It is not the business of the biologist, as such, to follow up the lines of thought thus suggested beyond the boundaries of his own territory, and I fear I have already been guilty of trespassing to a certain extent upon the preserves of my neighbours.

Whether the joint efforts of biologists, moral philosophers, students of economics and politicians, will succeed in rescuing our present civilisation from its impending doom is an interesting question, but it is one that the future alone can answer. Even if we are convinced that the answer must be in the negative, and that the law of evolutionary progress must still take its course, there is no reason to despair so long as there are fresh and unspoiled offshoots of the human race to make a new start and carry on a little further. We need not trouble ourselves to look for them ; if they exist they will make their presence felt when their hour strikes. But the law of evolutionary progress is not revolutionary ; decadence and progress alike are slow and gradual processes, and even if much of the superstructure of our civilisation has to be sacrificed we may still hope that much that is of more permanent value may survive and serve as the foundation upon which future generations may build a more noble edifice.

THE WHITEFRIARS PRESS, LTD., LONDON AND TONBRIDGE.

HEREDITY AND EUGENICS.

By R. RUGGLES GATES, Ph.D., F.L.S., Professor of Botany in the University of London (King's College), sometime Associate Professor of Zoology, University of California. Demy 8vo. 21*s*. net.

The Lancet.—"This entertaining book should be closely read by all who are interested in human inheritance."

Glasgow Herald.—"Professor Ruggles Gates is especially qualified by his biological studies both in botany and zoology to write with authority on this subject, and his discussion will satisfy the student and replace much that has been erroneous in former teaching of the subject."

Scotsman.—"An exceptionally interesting and unbiased description on race inter-marriage is included in one of the chapters, and it would be well if the ardent advocates of wholesale birth control would realise the warning hinted at in a few paragraphs on present-day social conditions."

Nature.—"The book is well written and adequately illustrated: it will serve admirably as a guide to those who seek an honest statement of the present position of the principles on which the practice of eugenics is being built to-day."

SOCIAL LIFE AMONG THE INSECTS.

By WILLIAM MORTON WHEELER, Ph.D., Sc.D., Professor of Economic Entomology, Harvard University; Dean of the Bussy Institution; Honorary Fellow and Research Associate, American Museum of Natural History. Medium 8vo. With 116 Figures and Illustrations. 16*s*. net.

Professor Arthur Dendy, D.Sc., F.R.S., writes as follows:

"Professor Wheeler's delightful book, 'Social Life among the Insects,' should make a strong appeal to all lovers of nature. It is addressed to the general public rather than to professional students, and it makes excellent reading. At the same time, Professor Wheeler's high authority as an entomologist, and his great literary ability lift the book right out of the category of mere popularisations. Zoologists, and even sociologists, will find much in it that they ought to know, and that they will not easily find elsewhere."

Weekly Westminster.—"It is a work which reveals a wonderfully extensive and close knowledge of the social insects. It is designed for the scientific entomologist in the first instance, but has very many pages which may give pure delight to the general reader."

Morning Post.—"A remarkable book."

Glasgow Herald.—"On social beetles, wasps, bees, ants and termites . . . a solid contribution to biology . . . In the many excellent illustrations, the orderly presentation by the author and his touches of humour, there is strong attraction for the layman."