# EVOLUTION—FACT AND THEORY

BY

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The Third Volume in the *Science of Life* Series

WITH ILLUSTRATIONS BY

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AND OTHERS

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# PREFACE

BIOLOGY is the science of living things. It is a rapidly expanding science, which has now grown so large that it is beginning to divide itself into a number of daughter-sciences.

With this increasing subdivision there comes a tendency for the latest results in the various fields to be known only to specialists, although they may be full of interest and meaning for the lay reader. From each of the different branches he can gather something of consequence if the main results are made accessible to him by being shorn of confusing technical complications. From Systematic Zoology and Botany he can obtain a view of all the different kinds of living things, and of the relations which they bear to each other. From Anatomy and Physiology he can derive an understanding of his body. From a study of Embryology and Reproduction, he can understand his development and his relation to the stream of life. Genetics, a subject of comparatively recent growth, is emerging from a controversial period and is now able to present to him the main principles of heredity with considerable certainty. Evolutionary biology can trace the actual history of the various forms of life, and in so doing it explains much that is perplexing in their structure and working. Ecology, another recently developed field, is concerned with the different living species, not in isolation, but as interrelated parts of a single web of life; already it has produced results of great service to the breeder and cultivator. Medicine, once the study of diseases, is becoming the study of health. Psychology, in its widest sense, treats of the most fascinating problem of all—

it is just beginning to explain the working and evolution of mind, from its dim origins to its strange and often devious workings in the culminating human species. Any one of these sciences can be studied independently of the rest, but they all interact and illuminate each other.

This volume deals with one only of the many branches of biology. It is in all essentials complete in itself, and can be read as a single treatise.

But it also forms part of a more ambitious project—*The Science of Life*—which aims at presenting, for the lay reader, a complete survey of the main results of biological science. This work was originally published as a single volume. In preparing the present edition the text has been divided into nine separate volumes, each complete in itself and each dealing with one particular division of biology. The opportunity has been taken to correct errors in the text and to bring it up to date. Together the nine volumes form an integrated whole. Accordingly, here and there in this volume, the reader will find references to others. These cross references indicate passages in which the topic under review links on to other subjects. In no case are they essential to the understanding of the argument of the separate volume in which they occur. But the reader interested in heredity, for example, will find that the subject is intimately linked with evolution; while one who is studying the past history of life is likely to discover that this would become still more interesting if he were to have some knowledge of physiology and of animal behaviour. Those who desire to pursue such clues must do so in other volumes of the series.

We hope that this method of making volumes on separate subjects available singly, while at the same time providing the possibility of a more general view in the series as a whole, will prove satisfactory both to readers who propose to concentrate on a single field and to those who have the ambition to study the whole subject of biological science.

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# EVOLUTION—FACT AND THEORY

## CHAPTER I

## THE FACT TO BE PROVED

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### § 1

### *Evolution and Creation*

IN this volume we take up questions that have been the centres of great controversies. We have first to tell of the gradual recognition of a fundamental reality—the Evolution of Life. And having done that as clearly and plainly as we can we shall have to discuss in the chapters which follow certain theories about which opinion still varies widely, and at times violently.

Now, until a century or so ago it was commonly believed that the world as we know it to-day had begun suddenly. It had been created, with man and all the species of beings as we know them to-day. Great numbers of people, including most educated people, held to the view with great tenacity. They had adjusted their moral and religious ideas to that view, and they did not realize that these ideas were not inseparably dependent upon it. All of us are prone to resist changes in our fundamental ideas. We feel instinctively that it may mean a disturbance of our way of living and the abandonment and change of objectives; it is a threat to our peace of mind and our satisfaction with our lives. The idea of the earth's going round the sun was considered to be just as impious in its time of novelty as was the idea of Evolution by the Fundamentalist of the backward States to-day.

Then steadily and more and more abundantly came evidence to show that the existing forms of life were not all the forms of life, and that there had been a great variety of animals and plants which had passed away, a greater variety and multitude indeed than that which still exists. The science of geology became a new region of intellectual activity, and in the study of the earth's crust the traces of a past infinitely longer than men had hitherto suspected were unfolded. Varied and wonderful as was the present spectacle of life, the series of faunas and floras that had preceded it and passed away was found to be more wonderful. Life had a past, a stupendous past. So far from it being a thing of yesterday, the creation of a few thousand years ago, it had a history of enormous variety and infinite fascination. We can still imagine something of the excitement of our grandfathers when the fantastic and marvellous dinosaurs, the vegetation of the coal measures, the flying dragons of the Mesozoic Period were revealed to them. Continually now that once incredible catalogue is expanded. Every year the palæontologist, the seeker and student of fossils, adds fresh details to this history of living forms.

Faced with these marvels the Creationist at first denied and then, no longer able to deny, declared that these extinct forms of life had been created in the past, tried out for some unknown end, to be extinguished in favour of fresh creations. They were but the prelude of these later creations. They had no clear rational relationship to living things and living things had no clear rational relationship to them. But a bolder school of interpretation appeared. These ancient forms were not so strange and incredible as they seemed. Life had produced them on its way to its present state. Generation by generation it had changed from the wonder it was to the wonder it is. There had been no Creation since the beginning of life. Life had unfolded—or, to latinize unfold, it had been " evolved "—from some remote and very simple beginning.

What weighed with the Evolutionist in his denial of successive creations was this, that the abounding and continually accumulating record of past forms of life is not a disorderly multitude, not a confusion of inexplicable " wonders," but that it falls into shape, it has a plan, and every fresh discovery drops into place in that plan. *All* of these forms fall into the scheme of a common tree of descent. That is the plan of it. If there was no other evidence to sustain it, we should still have to believe that Evolution has occurred on the strength of the plan of the fossil record alone.

Let us be very clear here. We are telling the reader in this chapter that this later view is the sound one, that Evolution has occurred. But we are making no suggestion as yet as to how it has been brought about. We are simply declaring that life has come to its present variety through the modification year by year, and age by age, of simpler and less various ancestral species. In making this declaration we are denying a belief, formerly very prevalent, the belief that animal species, as they are now, came into being suddenly, through some abrupt act of Creation. That belief has now become impossible in the face of an assemblage of countless known and established facts. On the other hand, all these contributing facts build themselves up into the comprehensive vision of Evolution as the fact of facts, the quintessence of the whole display.

But we are not attempting any *explanation* of this fact of Evolution here. We are not attempting any account here of why species have changed. We will write later of the various theories by which an explanation of this central fact is attempted. We are not discussing here the Theory of Natural Selection, or the Theory of Creative Evolution or any theory at all of how Evolution has been carried on. First the facts and then these more stormy issues may be faced. Here we traverse ground upon which scientific men of every creed and school are now agreed.

We make this distinction between fact and theory here and, so to speak, underline it, because we know there is still a considerable confusion in the public mind between the fact of Evolution and the conflicting theories about how it works. Dishonest Creationists, narrow fanatics, and muddle-headed people attempt to confuse the very wide diversity of opinion among scientific men upon the questions of how and why with their assertion of established fact. Through this confusion it is suggested that the hated fact is still unproven. It is, on the contrary, proven up to the hilt, and here we shall unfold as much of the evidence as is necessary for conviction.

## § 2

## *The Nature of the Proof*

Before we go on to the evidence, however, let us consider what our evidence must show if Evolution is to be accepted as the general process of life.

First, then, all things living, or once living, must fall into a branching plan. Everything in the past must be reasonably shown to be either ancestral to a living thing or else without descendants; there must be no renewal of the process, nothing in the past must be plainly derived from some later form. Every mammal, for example, is held to be descended from a reptilian ancestor. Suppose in the early Coal Measures, before ever a reptile existed, we found the skull of a horse or a lion. Then the whole vision of Evolution would vanish. A single human tooth *in situ* in a coal seam would demolish the entire fabric of modern biology. But never do we find any such anachronisms. The order of descent is always observed.

Next there must be an orderly sequence in fossil forms, so far as they are found. We must see very distinctly that form passes into form In the days of Darwin such sequences were hard to find. In those days there were probably not a hundredth part of the present multitude of fossils that are now collected and arranged. The Creationists pointed triumphantly to a gapped and fragmentary story, sustained by hypothesis, broken up by " missing links." Darwin was challenged to show anywhere in the fossil record the steps by which one species has passed into another. It was then quite a difficult challenge. To-day we have an answer, a score of answers, to that challenge, beyond Darwin's utmost hopes.

Then if animals have been specially created just as they are to fit special conditions, it is reasonable to suppose they are perfectly and completely adjusted to those conditions. There is no reason why any animal should fail to have any structure that might be helpful in its way of life, or possess any structure it has no need for. If a cat lives on birds and a tiger on ground game, is there any reason why a cat should not have wings because a tiger has not? But if the diverse species have been evolved step by step, a certain disharmony is to be expected between inherited structure and reactions, and the full possibilities of the life a creature leads. The second section of our evidence then will be an examination of plant and animal structure to see how far animal and vegetable organs are special to their needs, and how far they have the air of being primarily an inheritance merely fitted to those needs and limited in that fitting by conditions of descent.

And then the way animals and plants are scattered over the world will not be haphazard if Evolution is really the truth of life. If we found a region where an animal might live abundantly and that animal is not there, but somewhere else in the world, then if we are to believe in Creation we have to find Creation very remiss upon the distributive side; but if we believe in Evolution, then it is quite reasonable to suppose that an animal evolved in one part of our planet may never get to another for all the fitness of conditions there. All that also we will illustrate and weigh.

Finally we will take up a question that was once a burning question and is still regarded as smouldering. Does man come into this process of Evolution or is he in some strange way outside general biology, following laws of his own? We will show that there is no exception in his case. We hope to show the reader convincingly that Evolution is the form of all life in time, man and his acts included. Evolution is, in fact, *the* life-process.

# CHAPTER II

# THE EVIDENCE OF THE ROCKS

§ 1. The Nature and Scale of the Record of the Rocks.
§ 2. Defects and Happy Finds in the Record.
§ 3. A Sample Section in the History of Life: the Evolution of Horses.
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## § 1

### *The Nature and Scale of the Record of the Rocks*

IN order to make the nature of the record of the rocks perfectly clear it is necessary to remind the reader of certain elementary geological facts. They will probably be familiar to him, but we do not want to have any "missing links" in our chain of argument. We warn him of this beforehand, so that if the note of the professional lecturer creeps into our discourse he will forgive it—for the sake of its explicitness.

It is only after decades of patient work, we must remember, that the fact of Evolution obtruded itself as a necessity in the face of the palæontologist. Right up to the end of the eighteenth century the comparatively few fossils then known were almost universally regarded as mere curiosities; many dismissed them as sports of Nature, freaks of the earth, and not really the remains of flesh-and-blood, while at most they got credit for being witnesses to the universal biblical Deluge. Nothing more could be expected until geology had made her profound advance of introducing time, and time on a vast scale, into our ideas about the earth's crust.

Let us recall how that extension of time dawned upon the human intelligence.

Everybody knows that flowing waters bring down sediment and deposit it in layers on the floor of seas and lakes, or on flood-plains. Sometimes the deposit reaches the surface, as in deltas. Consider the great tongue of the Mississippi delta, built out into the sea for sixty miles and more; the Mississippi brings down every year over four hundred million tons of sediment. At other times the deposit spreads over the bottom, as when a pond is gradually filled up, or an alluvial meadow built, layer upon layer, from the silt laid down by successive floods. Layers of material may be laid down in other ways; the great spit of Dungeness, on England's south coast, grows out to sea at the rate of over five feet a year, from shingle brought along the coast by the waves and currents. In moor country, deep layers of peat are formed by the successive death of the bottom parts of the bog plants. Currents and waves deposit stretches and banks of sand in quiet bays. After a volcanic eruption vast quantities of dust and pumice and rock fragments fall in the neighbouring sea and sink to the bottom. And from the surface layers of the ocean a constant rain of billions of skeletons of animals and plants, many of them microscopic, but as we have already shown, incredibly abundant, is always falling softly towards the depths.

In these and other ways new materials are to-day being accumulated in the form of sheets or layers of varying extent in innumerable regions of the globe, and they must obviously have been accumulating in the same sort of way through all the ages since liquid water has existed on our planet. These accumulations of slowly deposited layers are what we call sedimentary or *stratified rocks* [1] (as opposed to the *igneous*

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[1] By the geologist, all constituents of the earth's crust, except the actual soil, are called *rocks*, whether they are hard granite or limestone, friable chalk or sandstone, or soft clay or loess.

*rocks*, forced in among the other layers of the crust in a molten state from below, or belched out over the surface by volcanoes), and the sheets themselves are technically called by the Latin word for layers—*strata.*

In these stratified rocks fossils are often found entombed—the remains and traces of dead animals and plants which were often strikingly different from any creatures alive to-day. We need give but a couple of examples. If you happen to spend your holiday on the Dorset coast near Lyme Regis and search the crumbling cliffs near by (or, indeed, if you explore any clay quarry across from Dorset to Peterborough), you will be pretty sure to find some bi-concave bone discs, the vertebræ of some large animal. Persistent and lucky hunters have found whole skeletons containing such vertebræ. They are of giant reptiles, christened Ichthyosaurs, or "fish-lizards," wholly unlike anything existing to-day, obviously aquatic, for their limbs are converted into paddles.

In the same clay you will be likely to find other fossils, the spiral ammonites, often beautifully patterned. These, too, though their shells are to be found in millions embedded in various rocks, have never been discovered alive. But we know that these shells were inhabited by creatures not unlike the pearly nautilus of to-day, and more distantly resembling the cuttlefish and octopus.

It would not take much reflection, one might think, to realize that in any such sedimentary deposit, whether thick or thin, the lower layers must have been laid down before those above them. But such were our ancestors' prejudices and preconceptions, based for the most part upon the belief in the sudden creation of the world at a not very remote period, that it was not until the turn of the eighteenth century that this fundamental but elementary idea was properly put forward, to become from thenceforward the basis of geology. William Smith, an English surveyor, as his work took him from one part of the country to another, noted that a number of characteristic rocks, such as chalk, oolite limestone, red sandstone, or gault clay, occurred as layers which covered large areas of country. Moreover, wherever these layers occurred, they were always in the same order. The gault clay, for instance, was always close below the chalk, the greensand always immediately below the gault, the oolite limestone many layers below the chalk, the red sandstone several layers below the oolite, and so forth. And, a third point, each layer of rock was characterized not merely by the material of which it is made, but also by the fossils which it contains. This last was of vital importance; often two layers of clay or of sandstone may be nearly indistinguishable in their consistency and materials, but easily distinguished by their contained fossils. For instance, the London clay, over which London is built, lies above the chalk layer. It contains fossil fruits of palms and conifers, some nautilus shells, numerous characteristic sea-snails, and a few mammals. No ammonites or ichthyosaurs have ever been discovered in it. The gault clay, on the other hand, from below the chalk, has no plant fruits, but does contain ammonites, often uncoiled in a peculiar way instead of regularly spiral; while the Oxford clay, a thick layer close above the oolite limestone, has huge numbers of ammonites, almost all built as regular spirals.

Such facts as these obviously mean that we ought to be able to arrange all the sedimentary rocks of the world in a series, according to their age; and, this once accomplished, all the fossils in the earth's crust will fall into their time-sequence, too. The task has been accomplished for the great majority of layers. As a result, we can say that one kind of fossil belonged to an animal which lived and died before another kind of animal found fossilized in another layer; and the bewildering variety of life becomes more orderly through receiving an arrangement in time. To take merely the same examples we first mentioned, ammonites are found to be absent from all layers below the coal measures and from all above the chalk, but present in all congenial layers between these limits; while ichthyosaurs, though they also have the chalk as their upper limit, only extend downwards through about two-thirds of the layers in which ammonites are found.

This fundamental principle, that the different layers of the earth's crust can be arranged in a time-sequence, is the basis of that department of science known as palæontology. These sheets of inert matter are the pages of the book of our planet's history. They lie scattered over the globe, often torn, defaced, or crumpled. But patience and reason combined have been able to reconstruct whole chapters and sections of that great book. In it we can read not only the physical changes that the world has experienced—when the Rockies were built, or the Scottish Highlands worn down to mere stumps of their former grandeur, the date of great Ice Ages, æons before the last Ice Age, or of the appalling flow of lava which overwhelmed a quarter of a million square miles in North-Western India—but also the history of Life, printed on the pages of the book in the form of fossils, hieroglyphs which to persevering study reveal readily enough the secret of their picture-writing.

The principle is both fundamental and simple; but there are sometimes difficulties in applying it. Part of the record may have been destroyed or defaced till the life-story it contains becomes illegible; or a whole set of pages may have been crumpled or turned upside down into reverse order (as in the upthrust of some mountain ranges), so that their proper rearrangement is a matter of the greatest difficulty; or an isolated page or chapter from some out-of-the-way corner of the globe may be hard to place.

Happily such difficulties only concern parts of the record; whole chapters of it have the pages all tidily in order, the fossil-writing abundant and easy to interpret. In most cases these confusions have been analysed and overcome, and the result is that, with rare exceptions, the fossil-bearing rocks of the world can now be assigned to their proper position in the time-scale—their right place among the pages of the Book of Earth.

As a result, the earth's history has been divided up, as this book is divided into books, chapters, sections, and so forth, into sub-divisions of various grades. Two sets of terms are used, according as we are thinking in terms of geological time or in terms of layers of rock. The main divisions of geological time are usually called Eras; within each Era a number of Periods (or Epochs) are distinguished, and they are further divided into sub-periods.

When, on the other hand, we are speaking of rock-layers, we refer to a System as our main unit, roughly corresponding to the rocks laid down during one Period of time. The Systems are divided into Formations, and so on down to the narrow Zones, which may be likened to the paragraphs of a book. The Cretaceous System is thus an actual set of rock layers laid down during the time of the Cretaceous Period.

For our purpose, the Eras and Periods are all we need trouble about; when we need to go into further detail, we can specify sub-periods by simply using the words "upper," "middle," or "lower." For instance, the Carboniferous Period, during which the world's coal was deposited, is the fifth of the six Periods of the third main Era. The Upper Carboniferous, then, is its latest sub-period, for obviously the uppermost layer must have been the last deposited.

The names of the Periods are at present, unfortunately, unfamiliar to the majority of people. They should be as well known as the names of the continents and main countries of the world, or as the great dates of human history. We give a set of diagrams here, geological time-maps (Fig. 2), and we suggest that the reader make himself familiar with the divisions of these diagrams if he does not know them already. Very roughly the divisions of these diagrams are spaced out in the proportion of time assigned to each Period. We shall note later in this Book how the lengths of these Periods have been determined.

❦ Now, the fact of primary importance in the history of life displayed by these geological Periods is the orderly succession of living forms. They *progress*. They progress from simple beginnings to more complex and versatile types. At the bottom (earliest) of our rock series come rocks with barely a trace of life and then in succession life unfolds. Comes first the Archeozoic Era with the dawn of life. Then the Proterozoic Era, with creatures as highly organized as worms. Then the vast Paleozoic Era. There are no vertebrata at all and no evidence of land life in its opening period, the Cambrian. Then in a second period, the Ordovician, is the dawn of vertebrate life. Then comes the Silurian, in which fishes and some land plants and invertebrata appear. Then Devonian and Carboniferous, with an ever-increasing amount of land forms, and the whole of the era closes with Permian, in which reptiles first appear.

Above these comes the Mesozoic System of rocks, that gigantic volume which tells of the Era of mighty reptiles and coniferous and cycad-like plants. Its formations (which like the Periods of the Paleozoic derive their names either from the districts in which the rocks are well-developed or from well-defined physical characters) are the Triassic, the Jurassic, the Cretaceous.

Finally comes the Cenozoic Era, the age of modern life, of mammals, birds, grasses, flowering plants, and trees. And here we warn the reader of one of those exasperating indistinctnesses of nomenclature in which the scientific mind at its worst seems to delight. The Cenozoic Age is subdivided into the Eocene (dawn of recent life) and so onwards with progressive modernization of animals through the Oligocene (slightly recent), Miocene (less recent than the next division), the Pliocene (more recent), the Pleistocene (most nearly recent)—the Period of the last great Ice Age—and the "Recent" Period, since the retreat of the ice, in which we live. The use of local and mineral names for the formations is suddenly abandoned for these kindred confusable names. For some reason quite a number of slightly inattentive students get "mixed" with Miocene and Mesozoic, just as it is the commonest misapprehension in the world to substitute Paleolithic (a stage in human development) for Paleozoic. The scientific systematist has never grasped what

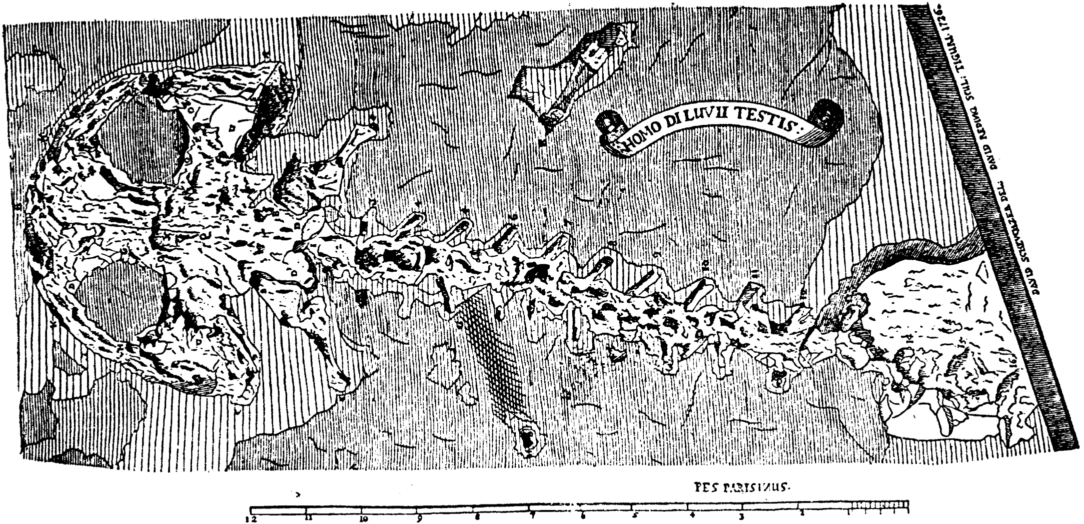


FIG. 1.—WHEN THE REMAINS HERE SHOWN WERE UNEARTHED IN 1726, THEY WERE DESCRIBED BY PROFESSOR SCHEUCHZER OF ZURICH, WHO PUBLISHED THIS FIGURE OF THEM, AS "THE DAMAGED SKELETON OF A POOR SINNER DROWNED IN THE DELUGE."

As a title to the picture is written "Homo Diluvii Testis"—man, witness of the Deluge. A century later Cuvier showed the remains to be those of a giant Salamander, now called Andrias scheuchzeri; it came from strata of Miocene Age (V C) in Baden.

any novelist can tell him, that names must be distinctive if they are to be remembered. How would he like to struggle through a story in which Tompkins, Tomlins, Tomkinson, Robert Thompson, Robins and Robinson were the names of the principal characters? Unhappily the present writers have no power to rechristen the geological formations, as they would gladly do, for the ease and comfort of their readers.

We will, however, attempt something that may be of service to those who find these names of Eras and Periods too clumsy a load to carry in their memories. We will attach numbers and letters to these Eras, Periods, and sub-periods, Roman numerals for the Eras, letters for the Periods, and Arabic numbers for sub-periods. These numbers we will append to the names as they crop up in what follows, and at the price of a certain typographical disfigurement the reader will be reminded of the position of each Age as it is named. Thus, Archeozoic is I, Proterozoic II, and the Paleozoic Era III. The two former we do not subdivide for our purposes. But III falls into divisions, Cambrian (III A), Ordovician (III B), Silurian (III C), Devonian (III D), Carboniferous (III E), and Permian (III F). Each of these can be further divided into Lower (1), Middle (2), and Upper (3). Upper Carboniferous, for example, is III E 3. IV stands for the great Era of the Mesozoic, with its divisions, Triassic (IV A), Jurassic (IV B), and Cretaceous (IV C). Finally, most modern of all, our present Era, the Cenozoic, is distinguished by V. That again sub-divides into Eocene (V A), Oligocene (V B), Miocene (V C), Pliocene (V D), Pleistocene (V E), and the current Period, the Recent (V F). With the help of the printer's reader these numbers shall as a rule appear after each repetition of these geological names.

We may add one further word of elucidation. In the earlier days of geology only three great Eras were distinguished instead of the five we recognize now. These were called Primary, Secondary, and Tertiary. Primary was our Archeozoic (I), Proterozoic (II), and Paleozoic (III) together,

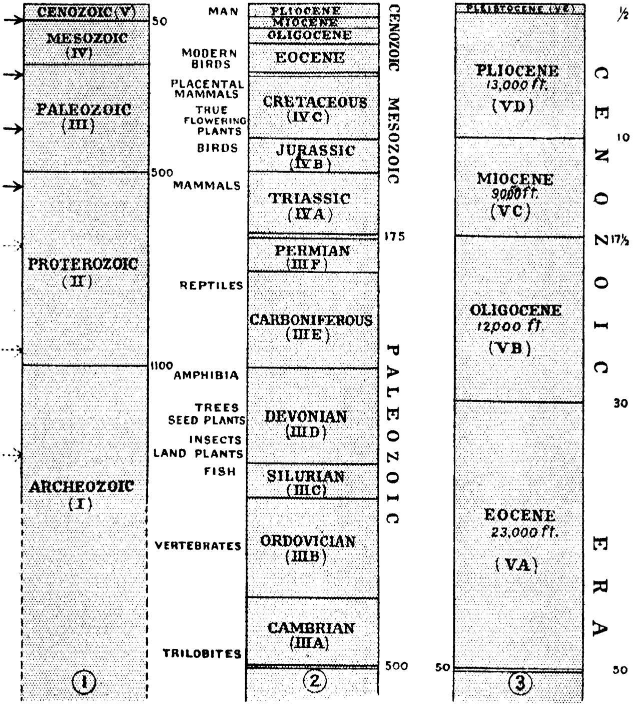


FIG. 2.—THE TIME-SCALE OF THE RECORD OF THE ROCKS.

The whole of Geological Time is represented in (1), except for the earlier Archeozoic (dotted), whose history is not yet known. The darker part of (1), from the first well-preserved fossils to the present day, is shown on a larger scale in (2). The relative lengths of the periods can only be approximate. The period of active Mammalian evolution, darkened in (2), is shown still larger in (3). Here the total thickness, in feet, of the strata laid down during the various periods, is added, to indicate the speed at which deposition occurs. The recent period since the last Ice Age is too short to be visible in a diagram of this scale; it is hidden by the printer's ink of the upper line. The figures to the right hand of the columns show the time-scale in millions of years, measured backwards from the present day. They are based on analyses of radioactive minerals. (Some authorities would make the Proterozoic of shorter duration.) The arrows in (1) indicate the great "revolutions" or times of violent mountain-building. The dates of the earliest of these disturbances (dotted) are not certainly known; it is generally assumed that they took place at about the same rhythm as the later ones. The first appearance as fossils of a few dominant groups of animals and plants is indicated to the left of column (2); but it should be remembered that in several cases the first stages in the evolution of a group have not yet been discovered.

Secondary was what we now call Mesozoic (IV), and Tertiary, the Cenozoic (V). Later a fourth term Quaternary was added to distinguish the most modern deposits—those now called Pleistocene (V E) and Recent (V F). The word Primary is now rarely used, but Secondary and Quaternary turn up at times, and Tertiary (because it is an easier word, perhaps) has more than held its ground against Cenozoic. The reader is likely to find us falling rather frequently into the use of that more familiar word.

In the third of our time-scale diagrams the maximum thickness of the layers is given, Period by Period. Of course, the total thickness, or anything like it, is not to be found piled up at any one spot of the earth's crust, but the total thickness gives a rough measure of the time taken to lay down these miles of rock, film upon film, year after year. The time must evidently have been prodigious; and when we look at the actual figures in years (which are determined by another method, later to be described, and which can now be taken as accurate within about ten per cent.) they are indeed staggering.

Archbishop Ussher, less than three hundred years ago, dated the creation of the world in 4004 B.C. (and gave the day and hour, too !), and his calculations still adorn the margin of the Authorized Version of the Bible. Though they are wrong, they are at least wrong on a grand scale, since the age of the earth is somewhere about half a million times greater than he supposed. Even to-day the average man tends to think the six-thousand-year antiquity of Babylon or Egypt enormous. But just as astronomy is teaching us to think of cosmic space on a wholly different scale from geography, to be measured in terms of " light-years " running into ten thousands of millions of miles, so geology is making it necessary to think of earth-history on a wholly different time-scale from human history, in terms of million-year periods, to which a decade bears almost the same proportion as an hour does to a century, and a century as a day does to a whole generation of human life.

To think in such magnitudes is not so difficult as many people imagine. The use of different scales is simply a matter of practice. We very soon get used to maps, though they are constructed on scales down to a hundred-millionth of natural size; we are used to switching over from thinking in terms of seconds and minutes to some other problem involving years and centuries; and to grasp geological time all that is needed is to stick tight to some magnitude which shall be the unit on the new and magnified scale—a million years is probably the most convenient—to grasp its meaning once and for all by an effort of imagination, and then to think of all passage of geological time in terms of this unit.

## § 2

## *Defects and Happy Finds in the Record*

The principles on which the geologist relies in his attempt to decipher the past history of the earth and the life upon it are clear and simple—so simple and so clear that at first sight it would seem that the task of the palæontologist, apart from the physical labour of finding and digging out fossils and the mental labour of studying them, should be easy. But Nature rarely reveals her secrets cheaply, and we have not yet told of the complications of the task.

In the first place, even when a large thickness of rock shows every evidence of having been laid down steadily and continuously, year after year, it may well change its character. For instance, clay, being composed of fine particles, will only be deposited farther out to sea or in quieter water than the more coarse-grained sandstone; but a layer deposited off a coast which happened to be slowly rising (as for instance Spitsbergen is rising to-day) may easily begin as mud and end as sand, the one deposit gradually hardening into clay, the other into sandstone. And if it change its character, the character of the animals and plants which live on and in it will change, too. Mud-dwellers will give place to sand-dwellers. If the change is too rapid for adaptation the fossils will not show a gradual evolution, but there will be an invasion of new creatures from other parts of the sea-bed as the conditions alter. The old forms are extinguished and drift off elsewhere, and the palæontologist is left with his story broken.

Still more frequently there is a break in deposition. The layer perhaps comes within the range of scouring currents, which prevent deposition; or it is shoved out of water by some upward movement of the crust of earth and has its newly deposited sheets removed. Later it sinks into favourable conditions and deposition begins again. But now, whether the new material be the same or quite different from that laid down before, there is a gap, during which life has bequeathed no record of itself. In general no widespread deposition will occur off-shore except when the coast is sinking, and very few animals will be preserved except when deposition is rapid.

Difficulties in some ways more serious confront us in studying the sequence of the rocks in many mountainous regions. Anyone who uses his eyes and opportunities on a railway journey through hilly or mountainous country will see that it is rare for the layers of rock exposed in the cuttings to be horizontal; they are usually tilted, and sometimes tilted at sharp angles. This tilting is due to movements of the earth's crust, such as its shrinkage and consequent bending and folding during periods of cooling. Over all of midland and south-eastern England the tilting is usually slight but definite. This was very favourable to William Smith, the British pioneer of geology, for, although it left no doubt as to which layer was above which, it caused new layer after new layer to come to the surface, open to investigation, as he passed across country upon his work of canal-making. His genius worked under the luckiest conditions.

But in mountain regions the disarrangement may be much more serious. In the Alps it is common enough to see layers of rock standing on edge, or even turned quite upside down;

and in some places, as in parts of the Scottish Highlands, the pressure has been so great that the rocks have been what we may call accordion-pleated—thrown into a whole series of deep folds, so that when seen in section on an exposed face they look like a fan. Not only that, but what the geologists call faulting may take place. Under the stresses and strains of mountain-building or of earthquake, great layers of rock may crack across, and one side slip down or be forced up and made to ride over the other side. At the time of the San Francisco earthquake a fault hundreds of miles long was produced, in which the whole country to one side of the crack fell suddenly from five to ten feet; but in mountain regions areas of rock may be faulted down hundreds of feet.

During these magnificent crumplings whole pages of the record have been made altogether illegible. Even when life has succeeded in writing its story on the rocks, the writing has too often been obliterated again. The rock-layers may be subjected to colossal pressures under great depths of newer deposits or scorched by contact with huge intruding lakes of molten material from below, so that any contained fossils are squeezed, distorted, or baked out of recognition or even out of existence. The rocks themselves change their very character. Such transformed rocks are called *metamorphic*; marble, for instance, is thus metamorphosed out of limestone, quartzite or gneiss out of sandstone, and so forth.

This difficulty becomes more serious as we go farther back in the record. For rain and wind and frost never stop their scouring and splitting and wearing, and the younger sediments must all be derived from the débris of the old. Whole mountain ranges, with their contained fossils, have been destroyed, worn down to level plateaus to furnish material for new layers, often hundreds or thousands of feet thick, which in their turn will be upheaved, and in their turn eroded away. Entire chapters of the Book of Earth have thus been pulped to furnish material for new pages. Luckily, however, the making of the book went on simultaneously in many regions, each one often of huge extent, and it is rare that all the records of a whole Age have perished.

Then we must remember that fossilization is the fate of very few animals and plants. Only one in a million makes its mark in the Book of Life. The great majority of dead things simply decay and disappear and their material is returned to the general circulation of Nature to be built up into the bodies of new organisms. But once in a while a corpse is preserved more permanently; it falls into mud or silt or some place where the bacteria of decay cannot get at it. Insects have been caught and sealed and preserved for countless years in the fossilized resin we call amber. The bodies of mammoths can be dug out of frozen mud-cliffs in Siberia with the skin and flesh still preserved. And even when the flesh decays away the bones may escape the dissolving action of rain or other waters and ultimately find their way into the palæontologist's cabinet.

But it should be remembered that these direct preservations of the material of extinct creatures are the rarest accidents. Most fossils (for any dug-up trace of an organic being is called a fossil) are not actual surviving bits of corpses at all, but bits of corpses which have been changed into rock by a slow translation and replacement. They are copies at second hand of the original writing. As the bones or other enduring fragments lie buried they slowly dissolve away and are replaced more or less completely by mineral substances. In a word they are "petrified." In this process, of course, they undergo varying degrees of distortion, although in one or two exceptional cases the translation is astonishingly accurate, each little difference of texture in the original being faithfully reflected in the mineralized fossil. The record may be even more indirect than that; it may be a dried footprint or the hollow impress of a bit of skin or a shell. From these scattered and accidental remains the palæontologist patiently reconstructs his picture of the world as it used to be.

Occasionally a lucky chance makes us realize how scanty our information really is.

In California, for instance, a pool of water with sticky margins impregnated with tar proved a death-trap to thousands of creatures as they came down to drink, and to hordes of carnivorous mammals, like wolves and sabre-toothed tigers, which endeavoured to catch the drinkers when they stuck fast. Now the palæontologist finds a hoard of treasure in that one pool. In France, in the drought of 1911, it was noted that all the fish in a pool burrowed into the mud when the water dried up, and were eventually baked hard in their hundreds. Unless the geologists of future ages happen to hit on such a patch of trapped life, they are not likely to find more than isolated bones of these kinds of fish.

Almost the only complete skeletons of the extraordinary giant reptile, Iguanodon, are those of a whole troop, twenty-nine of them, old and young, which were found in a Belgian cave, obviously entombed by some accident.

Fossil ants, we note, are often found in amber. Amber is the fossilized gum which once exuded as resin from long decayed pine-trees. Only an insignificant fraction of the ant population of the world gets trapped in resin; and only an insignificant fraction of the resin is hardened and preserved as amber; and yet almost all our knowledge of the ants of the past is derived from specimens in amber.

The amount of detail preserved to us is also very much a matter of luck. As a rule, nothing survives but the skeleton, and even that may be distorted and sometimes partly rotted. Now and again, however, happy accidents have caused traces of the softer parts to survive to our day. For example, one or two specimens of the strange, duck-billed dinosaur, trachodon, in the Upper Cretaceous (IV C 3), died and fell on a patch of soft mud. They decayed and the place where they had been became covered with sand. But the mud beneath held the impression of their skins with surprising fidelity—so that now we have the form of their skins preserved, with a mould in hardened mud and a cast in hardened sand. Some of the dolphin-like ichthyosaurs left records of their flesh and fins ; some even of their fæces, marked with a spiral twist by the folds of their intestine, and containing undigested remains of the fossil squid-like creatures called belemnites.

The very first known land beasts left footprints in the mud across which they lumbered ; the bird-reptile Archæopteryx stamped its feathers with astonishing detail in the fine-grained lithographic limestone of Solenhofen.

But there are even older happy chances than these. Some Devonian plants (III D) are so minutely petrified that we can study the precise shape of the microscopic hairs protruding from their leaves. And recently Walcott has discovered a wonderful array of invertebrates imprinted on Middle Cambrian shales (III A 2), nearly as clear to view as when they were swimming about, ages before the first fish, almost five hundred million years ago. The soft mud, now pressed hard, reveals to us the outlines of jelly-fish, annelid worms, with their appendages and bristles, small crustacea, with all their soft leaf-like appendages, even the outlines of their stomachs, and arrow-worms, just like those that swim in our modern seas, with their transparent fins. Walcott has also found swarms of bacteria from still earlier rocks. It is doubtful whether this is to be considered the most extraordinary case of fossilization ; it is certainly rivalled by some Paleozoic (III) fishes (to be seen in New York) which have been so delicately petrified that thin slices of their muscles, ground down to transparency, and looked at under a high power of the microscope, show the cross-sections of the muscle-fibres as clearly as a fresh-made preparation from a modern dog-fish. How the microscopic structure of living tissue came to be thus translated into stone we do not fully understand ; but at least the rarity of such lucky finds brings home to us the multiplicity of what is lost for ever.

The various difficulties thus put in the way of palæontologists are of two main kinds. There are those which lead to gaps and imperfections in the fossil record, whether through the fewness of animals and plants which became fossilized, the washing away of large sections of the crust when brought above water, for wind, rain, and frost to destroy, or the destruction of fossils by the heat and pressure of metamorphosis. And there are those which make it difficult to arrange what fossils we have in the right order, whether the difficulty springs from the turning of layers topsy-turvy and from faulting, or from the fact that two contemporaneous layers might show quite different fossils, either because they were laid down in quite different situations, or because, though comparable in the environment they provide, they were situated far apart on the earth's surface.

The imperfection of the record is unfortunate, but nothing more. It makes the labours of fossil-hunters greater, and should warn us against clamouring for the immediate discovery of this or that " missing link." But patience and the exploration of more and more of the earth's surface are bringing their own reward. Every year the record becomes less scrappy, and in many groups of animals, what fifty years ago seemed impossible to hope for has been achieved, and an unbroken series discovered, leading through ages of time from simple to highly developed types. The difficulty is not one of principle.

But the other difficulty seems at first sight more serious, and the opponents of Evolution, anxious to find any stick to beat a dog with, have tried to make out that it is a defect of principle. The Evolutionist, they say, pretends that he dates his fossils by the order of the rock-layers in which they are found; but in reality he very often dates his rock-layers by the fossils found in them—when, for instance, they are distorted in mountains, or when only a single fossil-bearing layer can be found, or when new quarters of the globe are explored for fossils; and this, they proclaim, is arguing in a vicious circle.

As a matter of fact, however, the palæontologist does not fake his results with the naïveté which these assertions ascribe to him. He first of all examines the earth's crust in some region, like the south-eastern half of England, or the Bad Lands of Wyoming, where the strata lie plainly one above the other and are not crumpled or distorted. He collects series of fossils from as many as possible of such undisturbed layers, examines them, determines to what group they belong, and whether there exist any others of exactly the same species from other layers. By so doing he can provide for each main layer and for each kind of deposit—sandstone, shale, clay, or limestone—within each main layer, a list of fossil species which are not found in any other layers, and of others which are especially abundant in the layer, or very scarce or absent therein. It is only after he has thus dated his fossils by reference to an undisturbed succession of deposits that he uses them to help him in dating layers whose age cannot be determined by these straight-forward methods.

The only really serious difficulty in dating rocks is the problem of relating the rock-systems of distant regions of the globe. The succession of rocks in China may be known, and also the succession in Western Europe ; but the evidence may be lacking which enables us to say exactly how the one should be fitted against the other. This may lead to uncertainty in points of detail ; but even in such cases it is always possible to date within geologically moderate limits, and every scrap of new knowledge helps to narrow those limits down. Here again the difficulty is not one of principle.

The essential fact is this : fossils are not used to date rocks of doubtful age until they themselves have been dated by their position in rocks whose order is not doubtful but obvious. And the proof of the correctness of the method is that its results are coherent and intelligible. We do not find ammonites appearing haphazard in the earth's crust, but in a definite set of its layers ; mammals do not appear and disappear sporadically through geological time, but come on the scene when they are expected, and from then onwards show a steady development ; four-toed and one-toed horses are never found in the same stratum, and so forth. If each fossil is a word in the Book of Life's history, then a century ago these words made only a few scattered but promising sentences; to-day, thanks to unceasing exploration, they have fallen into place, and have told man a new and clearer story of life's past and life's destiny.

## § 3

## *A Sample Section in the History of Life: the Evolution of Horses*

And now let us take one of the better preserved sections from this vast, confused autobiography which life has written in the rocks. It is a section of which we shall give a considerable amount of detail and rather a bothersome multiplicity of generic names. The reader is under no obligation to remember these names, but they have to be "produced in court" for the purposes of our proof.

It is loudly argued by many Creationists and semi-Creationists that there is no fully-worked-out pedigree of any existing forms of life, and that there is nothing to dispose of the view that at irregular intervals creative forces intervene in the evoluting process and make life take a convulsive stride forward. This, however, is not the case. So far from there being no well-worked-out pedigree, in which the successive forms in some group of animals are seen visibly modified and differentiated, there are now several such family trees in existence. We are giving here the past record of the existing horses. They have been evolved from a small, four-toed Eocene mammal, and every step in the process is traceable. (Let us warn the reader that the time diagram —Fig. 2—is necessary to the reading of what follows.)

It is worth noting that the earliest known three-toed fossil horse was described as recently as 1860, the year after Darwin published the *Origin of Species*, and that it was not till about 1870 that any serious attempt was or could be made to establish the horse's ancestry from fossils. Many startling finds were made in the 'seventies and 'eighties presenting the story in rough outline. But it has been the patient accumulation of specimens since then which has filled in the details and made it convincing. As the fossil-bearing rocks have been more intensively explored, link after link has been brought to light, until now we are able to reconstruct an almost unbroken chain of change extending for over forty million years.

The existing horses constitute a very distinct family of animals. No other vertebrates have but one toe to each foot; and no other animals have quite similar teeth. The family now comprises one genus only, called *Equus* and including seven species—two Asiatic wild asses (the onager and kiang), one African wild ass, the little Przevalsky's horse from Asia, and three kinds of zebra from Africa. A fourth kind of zebra, the quagga, has recently been exterminated. In addition, there are, of course, the many varieties of domestic horse and donkey, brought into being by man's selective breeding. Now all these wild horses and asses and zebras live in much the same way. They run swiftly over hard, level plains (wild asses in the Mongolian desert have been timed doing their forty miles per hour), and they feed on a food that is difficult to chew—on the tough leaves and stems of grasses, which are often hardened by a certain amount of flinty matter. And corresponding with this hardness of ground and of food, we find special provisions in their feet and teeth.

The single toe of a horse's foot corresponds to the third or middle toe of the more ordinary five-toed foot. Only the last joint of the toe touches the ground; the hoof in which this last joint is encased in the exact equivalent of an overgrown toe-nail. The horse's wrist and ankle are far above the ground, forming the joints commonly called "knee" and "hock"; the true knee is what is styled the stifle. The region corresponding to our palm or sole contains the single elongated cannon-bone. But the other fingers or toes are not completely absent, for attached to the hinder angles of this cannon-bone are two little splint-bones: and that these are the remains of the second and fourth fingers and toes is amply proved not merely by their position, and by the fact that one or both of them occasionally develop the missing joints and a miniature hoof, but also, as we shall soon see, by their development in the embryo.

The horse's limb, then, is a specially modified limb; it is a limb in which one toe is enormous and strong, and in which the others have dwindled more or less completely away. It is a limb devoted to a special function. On open, grassy plains the best means of escape from enemies lies in speed; and it is for speed on comparatively level and hard ground that the legs of the horse are suited. Everything else has been sacrificed to that. The elongation of the actual foot-region gives a better leverage; the concentration of all the limb-muscles in the upper part of the legs allows for rapid swing; a limb which consists of a single pillar, jointed so as to move only fore-and-aft, transmitting all the weight downwards to a single expanded hoof, is stronger than one which can be moved in all directions, or than one in which the lower arm or leg contains two bones (as in ourselves), and there is less " give " than in a limb ending in several toes. Accordingly the horse, though it can only execute a very few kinds of movements with its limb, though it sinks in soft ground owing to lack of spreading toes, though it is not well adapted to broken country, triumphs in speed on dry and rolling plains (Fig. 3).

Incidentally, length of leg makes length of neck a necessity; without that the horse could not reach down to its food.

The grinding teeth of a horse are beautifully and elaborately adapted for dealing with the tough grasses that he consumes. They are peculiar in three ways. First, they are all alike, instead of the true molars being more complex than the premolars as is usual. The premolars, we may remark in passing, are those grinding teeth which have predecessors in the milk dentition; the molars have not. Secondly, these quite similar molars and premolars of the horse all have an extremely complicated surface pattern. Before they cut the jaw-bone they are covered with hard, glossy enamel, rising up in ridges round a couple of deep cavities. These cavities later get filled up with cement, a substance not quite so hard as enamel, which is secreted by special glands as the tooth

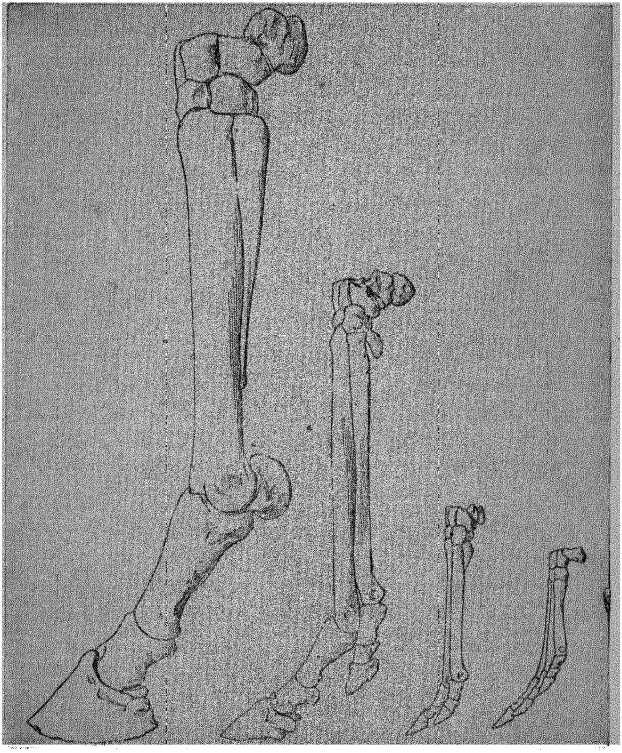


FIG. 3.—STAGES IN THE EVOLUTION OF THE HORSE'S HOOF; A SERIES OF LEFT FORE-FEET.

On the right, Eohippus with three of its four toes visible—the fifth, fourth, and third. Next to it, Mesohippus with fifth digit reduced to a splint-bone, and considerable lengthening of the toes. Then Merychippus with fifth digit small and lifted off the ground, and enlarged central digit. On the left, the modern horse, Equus, with big central hoof, fifth digit quite disappeared, and second and fourth digits reduced to splint bones.

breaks through the gum. Under the enamel is the softer dentine. Use soon grinds off the top of the teeth, with the result that their tops become nearly flat; but as the three materials wear down at different rates, sharp edges of enamel stand up a little beyond the cement, and a little higher above the dentine. The whole forms a remarkably effective miniature millstone, with the advantage over our millstones that it keeps its grinding-ridges sharp as it is worn down (Fig. 4).

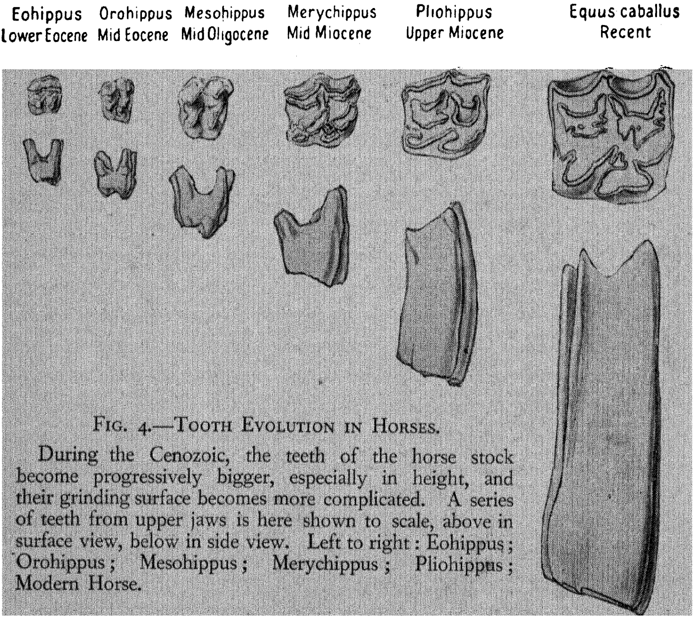


FIG. 4.—TOOTH EVOLUTION IN HORSES.

During the Cenozoic, the teeth of the horse stock become progressively bigger, especially in height, and their grinding surface becomes more complicated. A series of teeth from upper jaws is here shown to scale, above in surface view, below in side view. Left to right: Eohippus; Orohippus; Mesohippus; Merychippus; Pliohippus; Modern Horse.

The third point about the teeth is that they are of remarkable depth, and that during the first eight years of life they have no closed roots, but go on growing from below, like a rabbit's front teeth, as they are worn away above. After this roots are formed, new growth ceases, and the teeth are simply pushed up to compensate for the wear at the surface till they are all worn away, and the animal dies because it cannot chew its food. Our own teeth, and most mammalian teeth, are finished and complete as soon as they have erupted, but in a horse completion is delayed for eight years to give a longer working life.

The horse's teeth, then, are admirably adapted for chewing up grasses ; and the size and peculiar shape of his head is due to the need for finding room for these powerful and deep-rooted living millstones, and for the muscles to work them.

Now, when we look back to the fossils of the Eocene (V A), the earliest period of the Cenozoic, we find nothing resembling a horse. We find no mammal so specialized as a horse. In the earliest Eocene, almost all the mammals were small, they all had either four or five toes to each foot, and their teeth were short, low-crowned, and provided with more or less rounded or conical cusps, never with grinding ridges. Obvious carnivores with teeth for slicing and cutting, like those of lion or wolf, did not exist, nor obvious herbivores, with grinding and chewing teeth like those of cow or elephant. In the later stages of the Eocene Period, definite carnivores and herbivores can be recognized, together with other well-marked types ; but these early forms are all extremely different from any living animals. When Owen in 1856 described Hyracotherium—for that is the first name in our history—he never even guessed at the relationship between it and the horse ; now not only do we know that the one is ancestral to the other, but we can fill up all the gaps between the two.

If we go back stage by stage through the rocks of the whole Cenozoic Period (V), we find that the horse has recorded its pedigree in fossils. There are four main stages. In the last, the fossil horses resemble the living forms in all essentials of teeth and feet, differing only in details of proportion. They are all grass-plain animals.

In the stage before this there are no one-hoofed horses. Instead we find smaller creatures, of obviously horse-like type, but with three hoofs on each foot ; the two outer hoofs, however, are small and must have been useless in running, since they did not reach the ground, but hung in the air like the dew-claws of deer and other animals. The teeth had a less elaborate grinding system, and were much shorter. Fossil bones of these—shall we call them the fathers of the horses?—are not uncommon in China, and (with others) are dug up to be sold to apothecaries as "dragons' teeth," that essential ingredient in the Chinese pharmacopœia. Professor Watson tells us that even the Chinese labourers employed to dig them up recognize the skulls as like those of their donkeys.

In the next, and still older, assemblage of forms, the grandparents, so to speak, the ancestral horses were no larger than a large dog or a small Shetland pony. They also were three-toed; but all three hoofs touched the ground, and in addition they possessed on the forefoot the trace of a fourth toe, in the form of a little splint against the cannon-bone; the tooth-pattern again was less elaborate, the whole tooth shorter, and there was no trace of the cement which in all later forms filled up the valleys between the ridges of enamel and dentine, and so ensured a flat grinding surface throughout. Yet one can easily recognize the skeletons even of this stage as those of horses—three-toed and rather lumpish horses, but horses.

Finally, in the earliest stage, the far ancestors, in which we can still definitely detect the tendencies which culminated in the modern horse, none of the animals were bigger than a medium-sized terrier; there were four little hoofs on the fore-foot and three on the hind; sometimes the hind-foot also showed two splint-bones representing the missing first and fifth digits; the teeth were very short, with only indications of the system of grinding ridges, and the premolars were not so large nor of so complicated a pattern as the molars.

Besides the teeth and toes, other characters, too, show steady parallel changes as we go back through time. The earlier forms had shorter necks and faces, less tightly fitted wrists and ankles, two separate bones instead of one in the lower arm and leg. In a word, as we go back we find horses less and less efficiently adapted for swift running and for grinding hard vegetable food, and more and more like the other generalized mammals of the early Eocene (V A I).

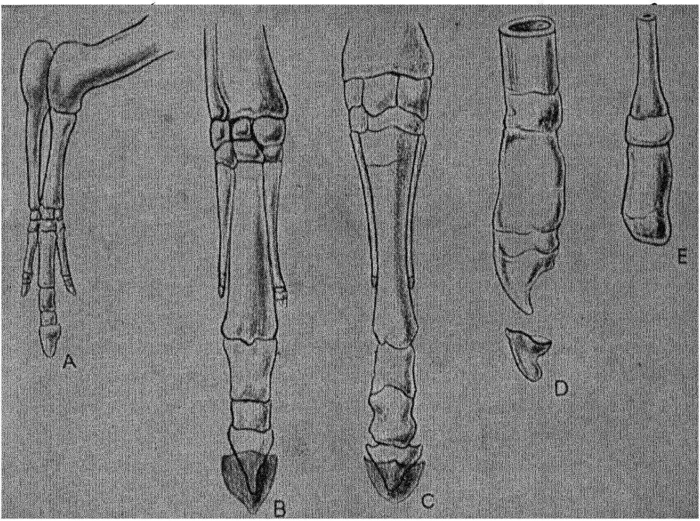


FIG. 5.—THE MODERN HORSE RECAPITULATES ITS OWN EVOLUTION.

(A) The skeleton of the limb of an embryo horse six weeks old, showing three toes. (B) The same, eight weeks old, showing the side toes much reduced relative to the middle toe, on which the hoof is forming. (C) The same in a five-months embryo, showing side toes reduced to splints. (D) The end of a side toe of (C), much enlarged, showing its rudimentary hoof. (E) The end of a side toe at birth; the various bones are still separate, not joined as in adult horses. (Modified from drawings by Professor Cossar Ewart.)

The existence of these three-toed horses in the past acquires a double significance when we remember that every individual one-toed horse of to-day actually passes through a three-toed stage in its embryonic development. In a six-weeks embryo the limbs are short; two separate bones are present to make the skeleton of the forearm; the wrist and foot are short, and the middle toe is flanked by two other smaller but perfectly formed toes, each complete with the same number of joints as the centre toe. At eight weeks the two side toes are on the way to become mere splints, but they still show the full number of joints. They eventually develop a cross between a nail and a hoof at their tip, and this later grows into a regular hoof. Not until some weeks after birth do the separate joint-surfaces disappear, and the three end joints coalesce with each other and with the elongated first joint to form the little buttons that tip the splint-bones (Fig 5).

Thus the three-toed state occurs twice, in two different ways, in the history of horses. It occurred as a stage in the past history of the race; and it occurs as a stage in the development of every modern one-toed individual: the current stage recapitulates the three-toed past in its own embryo person.

All this in broad outline was known more than half a century ago, when isolated representatives of all our four main stages had already been described, and the general trend of horse evolution correctly deduced from them. But to-day we have more than the broad outline; we are able to fill in the details. It is amazing how fine the detail has now become.

The amount of material at our disposal is enormous. In this single horse-stock, beginning with the little four-toed creatures from the Eocene (V A) and ending with the forms alive to-day, a total of over two hundred and sixty species have now been distinguished and named. It is, of course, true that in a continuously changing life-flow like this, species, genera, and families become merely arbitrary, since no sharp lines can be drawn. But even a continuous melody is divided up into bars: and the naming of two hundred and sixty species of fossil horses means roughly that we may chop up the continuously written record into two hundred and sixty pieces, making the difference between each piece and the next about equal to that found between forms recognized as species in an average abundant and variable family living to-day. Actually, however, in many cases the species and genera of fossil horses which were readily separated in early days have simply blended into each other as new material came to light. Sharp breaks in fossil history appear always to be the result of poverty of finds. Furthermore, not only are there these hundreds of types, but of many single types hundreds or even thousands of specimens have been unearthed. Occasionally the specimens are complete, but more often they are fragmentary, the skull (and especially the lower jaw) being perhaps most commonly found. All together, the specimens of evolving horses now in the museums of the world run into several tens of thousands. Even of the Lower Pliocene (V D 1) three-toed forms alone, at least ten thousand have been collected; and though they come from many localities in Europe, North Africa, Asia Minor, India, Persia, Mongolia, China, and North America, all of them agree with one another in their testimony with regard to the evolution of teeth and feet.

There are two complications of the horse's history. First, though the main trend is always on towards the modern horse, many of the fossil types represent side twigs which have died out sooner or later, leaving only the central branch to grow on to culmination. Second, the horses, being a very mobile species which can travel great distances rapidly, have a wide arena for their development. The earliest forms so far found are from the Western United States; but from North America they soon invaded the Old World across a land connection where is now Behring Strait; and the living tide flowed back and forth between the Old World and the New, or was dammed back, according as this bridge emerged or was sunk under the waters; it invaded Africa, and flowed down into South America, when the Central American connection came into existence, in the late Miocene Period (V C 3). Thus, as climate changed and barriers were bridged, the various types of horse would move from place to place of this wide scene, so that sometimes quite new types suddenly appear in the local record—invaders which were evolved in some other locality where perhaps fossils have not yet been discovered. But in spite of these obscuring factors the story has been clearly worked out; the fossils are so numerous that it can be construed without any doubt at all.

It will repay our trouble if we try to penetrate a little deeper into this representative chapter of life's history. First, we may ask what could have been the reasons for this steady evolution in one direction. The answer appears to lie largely in a climatic change. The evidence of fossil plants makes it clear that during the Cenozoic, from Eocene (V A) to Pliocene (V D), the climate of the north temperate and subtropical regions became progressively drier, and that over much of North America and Eurasia forest gradually gave place to glades, and these to open plains, on which the newly evolved grasses flourished and spread. It was but natural that a few of the animals from the already crowded forests ventured out to try their luck in the new world that thus presented itself. It was a new, exacting life; the new plants of the plains were wiry and hard to chew, and in a plain, since effective concealment is difficult, one has to run fast. Some of the adventurers chewed well enough and fled fast enough to survive; the pursuing carnivores had yet to achieve the speed of the wolf. The earliest four-toed horses were forest-dwellers; they must have lived as their closest surviving relations the tapirs live to-day, moving slowly and warily over soft ground and eating comparatively soft vegetation; but the three-toed forms had for the most part taken to the grazing life of the plains. The progressive spread of the plains during the rest of the Cenozoic up to the Glacial Epoch (V E) put a premium upon continued improvement in the same direction. Thus the early horses increased and flourished. Their more conservative forest-dwelling cousins dwindled in numbers as their range was restricted, and in most cases became altogether extinct, while the primitive wolf and the primitive horse were teaching each other speed.

The various stages of this main line of evolution have been classified into ten genera, of which we append the following thumb-nail sketches. Number one is Eohippus from the American Lower Eocene (V A 1), the earliest known four-toed horse; of this genus thirteen species are now known, ranging in size from a cat to a medium-sized terrier. It represents the more primitive type of the earliest of our four main stages, still with rudiments of the first and fifth toes on the hind-foot. There are also three or four European species of the same age and general character, but with even more primitive teeth, which have been given the name of Hyracotherium. Orohippus comes second, from the Middle Eocene (V A 2), with ten known species. This lacks the rudimentary hind-toes, and its premolar teeth gradually become more molar-like as we pass up in the rock layers from species to species. In both these types the lower arm and leg contained two separate bones, and the fore-limb could still be twisted and turned about in a way impossible for the modern horse. Number three, Epihippus, with only two species hitherto described, is from the Upper Eocene (V A 3). It is still four-toed, but the fourth toe is smaller, the central toes larger, and two of the three premolar teeth are just like the true grinders. There is no real break between it and Orohippus.

That closes our Main Stage I. Mesohippus is the first type of Main Stage II, the horses with three usable toes. Between it and Epihippus there is a slight gap, during which the final stages in the reduction of the fourth front toe to the merest splint must have been run through, and during which there was also a considerable increase in size. Thousands of specimens of the genus have been found, the earliest from the Lower Oligocene (V B 1), but running on through Middle into Upper; these can be separated into no less than eighteen species. All three of the actively-grinding premolars are now like the molars, and in the fore-arm and lower leg one of the two bones is enlarged to take nearly all the weight, while the other is on the way to disappearance.

The fifth genus is called Miohippus. It is first found in the Upper Oligocene (V B 3) and is scarcely to be separated from Mesohippus, save by its rather larger size (up to that of a sheep) and the better mechanical construction of the skeleton of its wrist and ankle. It also is abundant and variable, with seventeen known species. Parahippus, first found in the next higher rock formation, the Lower Miocene, is a real connecting link between Main Stage II and Main Stage III. The earlier of the eighteen species so far discovered are on the whole very like Miohippus, while some of the later forms have the outer two hoofs and digits so much reduced as to be useless. The teeth, too, are interesting; the cement filling appears for the first time, but only in some of the later species is it anything but a very thin coating.

Parahippus runs on right through the Miocene; but already by the Middle Miocene (V C 2) a more progressive type had appeared, which is called Merychippus. This type, abundant and wide-ranging, with some twenty-five species, definitely initiates our Main Stage III, for its side toes never touch the ground. But it makes a greater advance in the depth of the teeth. In the earliest species of Merychippus the grinders are only as high as wide; in some of the latest, the height is two and a half times the width. The cement is always abundant, though it was not deposited until just before the tooth emerged from its bone socket, instead of some time before, as in the living horse. The ulna, the dwindling second bone in the lower fore-limb, is a separate splint in colts of Merychippus, but in the adults is fused with the main bone or radius, as it is from birth onwards in modern horses: here we get a second glimpse of recapitulation, that wide-spread phenomenon of which the three-toed embryos of modern horses have already given us an example. Much increase in size also took place within the group before it faded out in the early Pliocene (V D 1), the later forms being often as big as small ponies.

Our eighth genus, Pliohippus, grades back insensibly into some of the Merychippus forms, first emerging distinctly towards the very end of the Miocene (V C 3) and continuing through the Lower Pliocene (V D 1). As regards feet, Pliohippus bridges the gap between Main Stages III and IV, some of its seventeen species possessing tiny but perfect side toes complete with miniature but useless hoofs, while in others they were reduced to single splints as in modern horses. The chief point of progress again concerns the teeth. In earlier genera, the molars led the way; then their more elaborate pattern was gradually adopted by the premolars too. However, this applied to the permanent premolars; their milk-teeth predecessors in the colt were always of simpler pattern. But in Pliohippus the elaborate pattern has been thrown back into the milk-tooth stage, and from now onwards all the grinders at every stage of life share equally in every advance made in the grinding machinery.

The ninth genus is Plesippus, which comes definitely into the last of our four main stages. So far, only one species has been discovered, from the Upper Pliocene (V D 3), but of this one species the anatomy is known in full detail. These creatures were very much like a smallish horse, but the hoofs, as in Pliohippus, were still much smaller than in a modern horse, and the teeth show but little advance on those of Pliohippus. The splint-bones representing the outer toes are very interesting, for they are longer than those of living horses and more expanded at the tip. The fifth digit of the fore-foot, which, as we saw, became useless in Mesohippus, hung on for a long time as a remnant, and was apparently loth to disappear, for it is still represented in Plesippus by a tiny nodule of bone. Indeed, in living horses, though usually wholly absent, it is still to be found in a few individuals as a still smaller nodule. The shape of the skull is like that of our modern horses.

From this type to Equus, the true horse, is but a small step, which was taken at the turn from Pliocene to Pleistocene (V E). Even among the various species of Equus, however, evolution can be seen at work, for many of the earlier species are both smaller and more primitive in tooth-pattern than

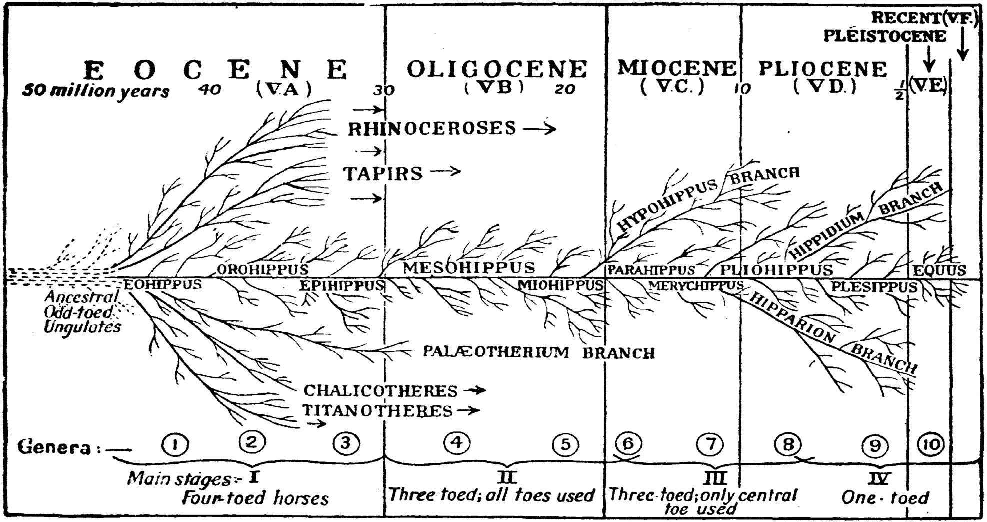


FIG. 6.—THE EVOLUTION OF HORSES.

The different geological periods are all represented on the same time-scale, except for the Pleistocene and Recent Periods, whose scales have been magnified five and twenty-five times respectively. In the early Eocene the various stocks of odd-toed Ungulates are scarcely to be distinguished, but soon the separate stocks (Rhinoceroses, Tapirs, Horses, etc.) diverge and become markedly distinct. The horse stock alone is here followed throughout. The names of its ten successive genera mentioned in the text are given, with (below) the numbers corresponding to them. Below this again the duration of the four main stages is indicated. The initial stock is all the time throwing off side branches which become extinct; most are short and unimportant, but some produced distinct types of horses, such as Hypohippus and Hipparion.

any existing modern horses. On the other hand, one or two recently extinct forms considerably exceeded any living wild species in size, and were probably even larger than our domestic draught-horses; their size is perhaps to be correlated with their living in an interglacial period when the world was warmer and richer in vegetation than it is nowadays. As many as forty-five fossil species have been unearthed and described, so that less than a sixth of the total known variety of the genus Equus is in existence to-day.

Thus has the change been brought about, from the tiny, furtive, forest-haunting, browsing Eohippus to the swift, strong, grazing Equus of the open country. But the study would not be complete without a mention of certain side branches which grew out, turning aside from the main trend of horse evolution and sooner or later came to nothing. We have this evolution of their extinction, step by step.

The first of these branches started in the early Eocene (V A 1). Some of the Old World, four-toed forms wandered off on their own, but became extinguished in the Lower Oligocene (V B 1) after advancing a certain way parallel with the main horse-stock. Palæotherium, three-toed but somewhat heavy and tapir-like, was the best known, but others were lighter and better adapted to swift running. Over twenty species are known to have been evolved in these sidelines; what brought their career to a close is uncertain.

The next divergent branch began at the close of the Miocene (V C). Its peculiarity consisted in its retaining three good toes on each foot, very much splayed out, and teeth less well adapted for grinding grass, but suitable for browsing leaves. While some species of Miohippus form a connecting bridge to Parahippus and the rest of the main horse-stock, others connect equally insensibly with the base of this side-branch. The tendency, first revealed in them, runs its course through a couple of genera, culminating in the early Pliocene (V D 1) in Hypohippus. In this branch, with at least ten known species, we can trace a progressive adaptation to forest life, the animals apparently eating more juicy food and supporting themselves on softer ground by the aid of their spreading toes. Here we have, so to speak, a line of quitters, of animals which shirked the more arduous life of the open plains that was the goal of their race and turned back into the woods. For a time they throve, but only for a time. It was not in this direction that the horse-stock was destined to win through.

In the late Pliocene (V D 3) the horse-stock invaded South America, and here was evolved the Hippidium branch, possessing extremely short legs and a strangely-constructed nose-region. These creatures were a group of three genera, of which only four species have as yet been unearthed, only extinguished within the last million years. Their short legs probably indicate that they were adapted to mountain life. The origin of this aberrant line is traceable through Protohippus, a group of thirteen somewhat earlier species.

The fourth and largest side-line is the Hipparion branch. It came off from Merychippus in the late Miocene and ran on to the close of the Pliocene, when it was extinguished, but not before it had given rise to some thirty-five species. It is interesting as retaining the two outer toes, though not touching the ground, long after the main-line had reduced them to splints; while, on the other hand, some of its species improved their teeth beyond anything known even in present-day horses, the grinding pattern being more complex in some, the height of the teeth greater in others. It is likely that this increased specialization of teeth was an adaptation to a desert life, where the hard, dry vegetation needs more grinding. It may be that these horses fell out of the battle for life because of this too exclusive dependence on the special virtues of their teeth and were caught by a change of circumstances that made speed of greater importance.

That is a condensed summary of the story of the horse and its ancestors and vanished cousins as we know it to-day. It is a tale of adventure and arduous conquest, of steady and successful adaptation of a race to new surroundings. But it is more interesting as a part of a vaster drama. It displays one streak of the process of Evolution very completely and convincingly. Step by step, variety by variety, the progressive changes can be traced. . One can hardly say where one species ends and another begins. Doubtless our knowledge of fossil horses will be further filled in and rounded off in the future, as new specimens turn up; but new discoveries can do no more now than fill in a little gap here, correct a minor error there. The essential facts are already before us in their fullness. In one long gallery one might assemble all these stages. We have here in a crushing multitude of steadily progressing specimens just that complete, continuous exhibition of Evolution in action the Creationist has demanded. He is answered.

## § 4

## *The Continuity of Evolution as Shown by Sea-urchins*

One great merit of the horse's evolutionary record is that the animal is familiar and that we can readily understand the biological meaning of the main trends in its long, ancestral development. Its only defect as a demonstration is that the record is nowhere continuous *in one single locality*.

If we could find a considerable thickness of rock, all deposited under approximately the same conditions, we should expect to find an absolutely unbroken sequence, a still more unbreakable evolutionary chain, in the fossils which it contains. Such large thicknesses of one kind of deposit are naturally, though unfortunately, rare; for usually, as deposits pile up they are brought nearer to the surface of the sea by the mainland rising, or by their own gradual accumulation, or they are submerged deeper by the land's sinking. In either case the character of the sediment, and therefore of the animals which can live at the bottom, will change, since, for instance, sand particles will sink before fine mud, and future sandstones therefore be laid down nearer inshore and in less quiet waters than future clays.

But the chalk of the Mesozoic Epoch (IV) happily serves our purpose. Up to a thousand feet of it were continuously laid down in large but shallow seas, originally as a limy mud, largely formed of the tiny skeletons of single-celled animals rained softly down from the waters above. This went on during much of the Upper Cretaceous Period (IV C 3), for at least ten million years; and through much of this time conditions of life on the bottom of the chalk-depositing sea continued so similar that many of the same kinds of animals are found in every layer.

Among the most abundant and the best studied of the chalk fossils are the sea-urchins known as Micraster. These are found, and found abundantly, throughout most of the lower half of the chalk. In Southern England, for instance, they persist through 450 to 500 feet of chalk, the total thickness of the deposit varying from nearly 1,300 to nearly 1,500 feet. Translated into time, this means thirty-five per cent. to forty per cent. of the total chalk period, certainly over four million years.

Throughout this long period the fossil Micrasters are so abundant that hundreds of thousands can be collected and a gradual evolution can be traced as we pass upwards. The changes are apparently trivial. There is a slow alteration of shape from rather flattened to rather arched, and from rather elongated to about as broad as long. The mouth creeps steadily forward, its distance from the front border of the lower surface decreasing from about a third of the body-length in the early types to a sixth in the latest, on a total length of fifty to seventy millimetres. A low ridge, totally absent at first, appears and grows slowly higher along the hinder part of the upper surface. The grooves from which the tube-feet emerge grow longer, and their surface, smooth at first, becomes sculptured. The mouth gets more and more overhung by a protruding lip of the hard skeleton; the little knobs on the skeleton become in some regions gradually more prominent. There are other changes, but these are the most obvious.

Opinions differ as to the number of separate species into which Micraster should be divided during this period. Since the series is continuous this question can only receive an arbitrary answer; but the most conservative estimate is half a dozen.

The changes are infinitesimal, both in extent and biological meaning, compared with those in the horses. The explanation doubtless lies in the fact that at the beginning of the chalk period the sea-urchins were already an old and well-differentiated stock. Even the earliest Micrasters were highly specialized for life in sand or mud, and there was neither need nor room for any radical improvements. The mammals, on the other hand, were one and all primitive and small in early Cenozoic times; there was obvious necessity and opportunity for their improvement, and the horses shared in the great evolutionary movement which completely remodelled the whole mammalian stock between Eocene (V A) and Pliocene (V D).

Steadfast as it is, Micraster answers our present purpose, for though the changes involved are small, they are absolutely continuous, the urchins found at one level grading quite imperceptibly into those of the rest; a single specimen, indeed, may show characters of one " species " in some of its tube-feet grooves, characters of another in the rest. There is no question but that the Cretaceous sea persisted without any notable change in its conditions throughout the whole time, and that our urchins lived, died, and reproduced upon its bed in a continuous succession, so that the fossils from the lower layers were actually the parents of those embedded higher up. Slowly the race modified itself; by almost imperceptible degrees Micraster changed its shape. The evolutionary movement which Micraster demonstrates to us is only small and sluggish, but the demonstration is complete, with not a chink or loophole in it.

## § 5

### "*Missing Links*"

It would be possible to give a number of other evolutionary series, almost or quite as perfect as those we have described in detail. The Titanotheres, strange, horned, extinct mammals, rival the horses in fulness of record. So do the camels. The tapir and rhinoceros branches are not far behind. An extraordinary parallel to the later development of the horse-stock is afforded by the evolution of the Litopterna, a group of South American animals, all now extinct. Although many characters prove that they were not horses, and not even closely related to horses, they responded to the world-wide change of vegetation in the same way as the horses did. Evolving from a different five-toed ancestor, they gradually increased in size, lengthened their legs, reduced their outer digits and from three-toed became one-toed. They grew regular hoofs and their teeth became progressively longer and longer and of more complicated pattern. It is interesting that while their side toes were finally reduced farther than in any horse, to mere stubs of bone, their teeth remained less efficient, and never formed cement. Grassy plains developed in South as in North America, and since for long before the Pliocene (V D) the southern continent was wholly cut off from North America, no true horses could then invade it; but the Litopterna developed along a parallel line to fill the same niche in Nature.

The elephants, too, provide us with a fine evolutionary series, which is peculiar in that its trend was first towards the development of a four-tusked creature, with long, lower jaw. Later, however, with increasing bulk, the further elongation needed, if the animals were to continue rooting in the ground with their lower jaw, became mechanically impossible; and at the same time the head, with its great tusks, was too heavy to be borne on any but a stout and short neck. Accordingly, evolution changed its direction and pushed forwards towards a short, tuskless lower jaw, while the development of a trunk kept the animal in touch with the ground. And other series almost equally perfect can be found among various groups of carnivores. In reptiles, the fossil crocodiles gradually shift the internal openings of their air-passages farther and farther back along the palate, making it easier for the animal to breathe while holding prey under water in wide-open jaws. Moreover, series of smaller scope but greater continuity, like that of Micraster, are now available for certain starfishes, lamp-shells, ammonites, pond-snails and other invertebrate forms.

Sometimes the fossil record is not so complete, but yet discoveries, though isolated, may be of startling

FIG. 7.—A RECONSTRUCTION OF ARCHÆOPTERYX IN THE JURASSIC WOODS. It must have used its wing-claws to scramble among the branches.

interest as supplying the "missing links," as our grandfathers called them, between hitherto isolated groups. Typical of such linking types is the primeval bird, Archæopteryx. Two almost perfect skeletons of this creature are known, both from the Jurassic Period (IV B) in the middle of the Age of

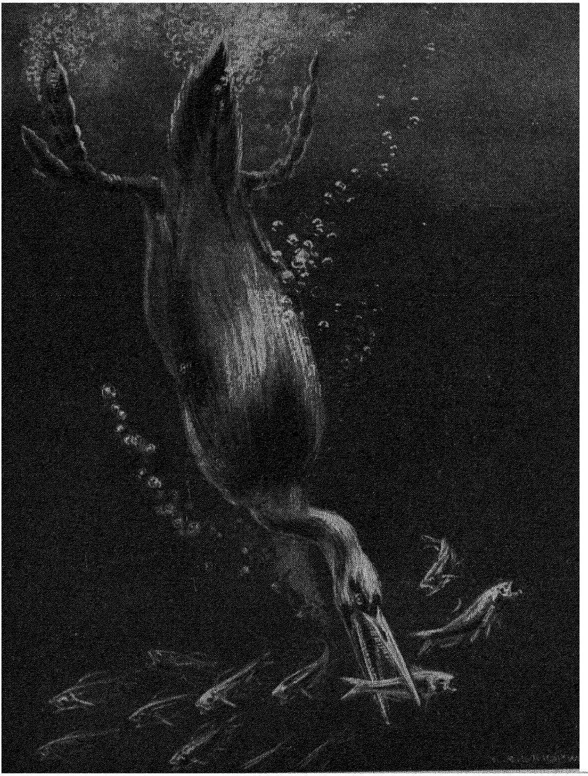


FIG. 8.—A BIRD WITH TEETH LIKE A REPTILE. THE EXTINCT DIVING-BIRD, HESPERORNIS, AS IT PROBABLY APPEARED IN LIFE.

Its remains are found in rocks of the Cretaceous Age (IV C). It was over five feet in length.

Reptiles. The rock in which their form is preserved, at Solenhofen, in Bavaria, is so fine-grained that it is used for lithographic stone and has retained the smallest details down to those of the delicate feathers.

Birds, as was suspected even before the discovery of this missing link, are descended from reptiles; they are reptiles which have been specialized for an aerial life.

In Archæopteryx we see the specialization in progress, incomplete. In a modern flying bird, for example, the reptilian fore-legs are turned sideways to serve as wings, and this has necessitated profound changes in their structure. Several originally distinct bones are welded together for rigidity, and the claws are lost (except in the young South American Hoatzin, which uses its wings to clamber about in the bushes). But in Archæopteryx, although the fore-limb is very certainly a wing, the welding of bones had not yet been brought about and there were still three well-developed and movable clawed fingers protruding from the wing, used presumably in climbing. Again, in a modern bird the tail-skeleton is short, a stumpy little support for the fan of tail-feathers, but Archæopteryx had a long lizard tail with twenty vertebræ or more, and a row of large feathers on each side along its whole length. And instead of the horny, toothless beak of a modern bird, this winged, feathered lizard had ordinary reptilian jaws with a fine array of socketed teeth. Had it not been for the happy accident by which the feathers were preserved, it is doubtful whether the skeleton alone would have warranted us in definitely calling the creature a bird. As it is, Archæopteryx is in its general construction a perfect link between the two great groups of birds and reptiles, though more than half-way to modern birds.

Its wings were too small to sustain its whole weight, and so the hind part of the body had to be supported (as in almost all aeroplanes to-day) by a large tail-plane. Archæopteryx must have lacked the power of rapid, controlled flight; that came only with stronger arm-skeleton and larger wings which allowed the tail to be reduced and so permitted the bird to turn, check, and drop suddenly, instead of planing along and coming to grief below a certain speed as an ordinary aeroplane will do.

But there are other linking fossil forms in the bird stock. In the Cretaceous Period (IV C) birds have been discovered which were essentially similar to living birds in wings and tail, but still had teeth on the jaws (Fig. 8). Before the Middle Eocene (V A 2) these toothed birds had disappeared, and from thenceforward all bird fossils are of modern type. A somewhat similar example comes from reptiles. All modern tortoises and turtles are toothless and beaked like modern birds; but far back in the Permian Period (III F) there lived a tortoise, Eunotosaurus, with well-formed teeth like the majority of reptiles.

The mammals, too, are now linked by fossils with their reptilian ancestors. We knew already that mammals must have sprung from reptiles. Apart from all other lines of evidence, the discovery of those "living fossils," the Platypus and the Echidna, clinched the matter. Had we nothing but the skeletons of these animals, it would be very doubtful whether we should call them reptiles in the last stage of becoming mammals, or mammals which had just ceased being reptiles. But the fact that they nourish their young by a milky secretion, possess a coat of hair, and have a more or less constant temperature, stamps them as true mammals, even though their egg-laying habits and many other peculiarities show by how little they have crossed the boundary.

This is convincing proof; but all the same it is only indirect. However, in the Permian (III F) and Triassic (IV A), as the Age of Reptiles was dawning, a group of creatures existed whose name of Theromorphs implies a likeness to mammals. Their teeth were already beginning to differentiate into incisors, dog-teeth, premolars and molars, and the whole form of the skull was approaching the mammal. They did not crouch on their belly, but ran with body lifted off the ground. But they still retained the little hole in the

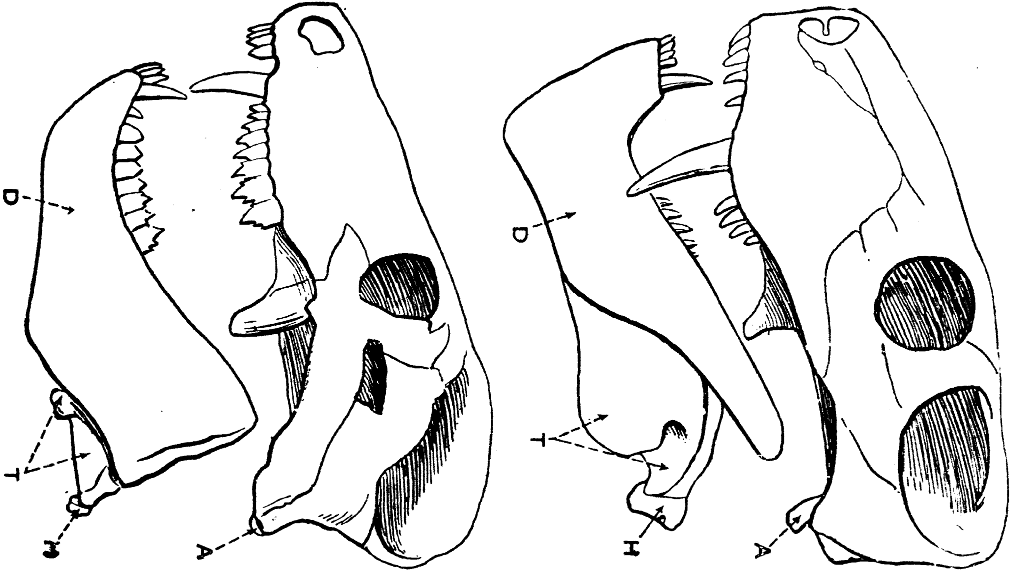


FIG. 9.—STEPS IN THE EVOLUTION OF EAR-BONES FROM JAW-BONES IN THE MAMMAL-LIKE THEROMORPH REPTILES.

Top, skull of Scymnognathus from the Upper Permian (III F 3). Bottom, Cynognathus from the Lower Triassic (IV A 1). (D): the bone which forms the jaw in mammals. (A) and (H): bones which in most reptiles form the joint between upper and lower jaws, and in mammals become the little Anvil- and Hammer-bones in the ear. (T): the bone on which, in mammals, the ear-drum is stretched.

top of the head, the pineal foramen, below which, in many modern reptiles, the third or pineal eye is still to be found; this has been lost in all known mammals, with the transformation of the third eye into the pineal gland.

And they link reptiles with mammals in yet another way. One of the most important differences between existing mammals and all other vertebrates is the fact that in mammals the lower jaw consists of but one bone on each side, instead of several distinct bones stuck together. At the same time, there are three little bones in the mammal's middle-ear, transmitting the vibrations of its ear-drum to its organ of hearing, while in all other land vertebrates there is but one. It had been suspected for a long time that these two extra bones, the so-called "hammer" and "anvil," correspond to the two bones which in a reptile make the hinge-joint of upper with lower jaw; for in a mammal embryo before they are built into the machinery of the ear they are actually nipped off from this very region of the developing jaws. And the tympanic bone, on which the ear-drum is stretched, can similarly be homologized with another of the multiple bones of the reptile's lower jaw. Now, in the Theromorphs most of the steps in this process can actually be traced. In the earliest fossils, the arrangement is like that of other reptiles. But as we go forward in time, the two hinging bones of the jaws gradually release themselves from this duty, grow smaller and are to be found in the region of the ear; from this condition, only a small step would be needed to convert them into ear-ossicles. Meanwhile the future tympanic bone also was becoming less concerned with biting and more with hearing (Fig. 9). Archæopteryx had just raised itself to bird status; the Theromorphs were still reptiles but were on the verge of climbing out into a higher stratum of biological society.

If we want an example of such a transition among the invertebrates, we can go to the brittle-stars. These Echinoderms are very like starfishes, but their central body or disc is much more sharply marked off from their wriggling arms.

FIG. 10.—A VEGETABLE MISSING LINK. LYGINOPTERIS, ONE OF THE PTERIDOSPERMS OR SEED-FERNS, FROM THE CARBONIFEROUS PERIOD (III E).

A plant is shown bearing seeds on one of its fronds. Three fronds are expanded, the others still curled up. Below, on the left, a bit of a frond bearing seeds is shown enlarged; on the right, a young, unexpanded frond. The reconstruction was made by Miss J. Robertson.

*(From " Extinct Plants and Problems of Evolution," by Dr. D. H. Scott. Courtesy of Macmillan & Co., Ltd.)*

In all living brittle-stars the grooves along the lower surface of the arms, so prominent in starfishes with the tube-feet arranged along them, have disappeared below the surface, roofed over to form tunnels; further, the main skeleton of each arm is a chain of little ossicles, beautifully jointed together. But in the Silurian (III C) and Devonian (III D) Periods there existed obvious brittle-stars which possessed open arm-grooves and arm-skeletons of much less elaborate construction: in both these ways they link the existing brittle-stars with the true starfishes. They were starfishes becoming brittle.

There are plant missing links as well as animal ones. The Pteridosperms, or " seedferns " which flourished during the latter half of the Paleozoic Era (III), are linking types of rather a different description. They appear not to provide a *direct* connection between seed-bearing plants and the true ferns, seedless and spore-producing; but rather to be a side-branch (like the Hipparion branch of the horse stock), which while progressive in respect of seed-evolution, remained primitive in its general fern-like form and growth. But if the true link between ferns and seed plants must be sought in some type ancestral to both modern ferns and seed-ferns, none the less the seed-ferns decrease the gap (Fig. 10).

Once more, examples could be multiplied; but these suffice, since all we are concerned with here is to show that missing links turn up in the most diverse groups of animals and plants, and from all periods of the earth's long history. Steadily the gaps are filled and the ramifications of the tree of life mapped out with ever-increasing confidence and precision.

# CHAPTER III

# THE EVIDENCE FROM PLANT AND ANIMAL STRUCTURE

§ 1. Structural Plans, Visible and Invisible.
§ 2. Vestiges: the Evidence of the Useless.
§ 3. The Evidence of the Embryo

## § 1

## *Structural Plans, Visible and Invisible*

IN the previous chapter we have reviewed the geological facts which constitute the direct evidence for Evolution. They have shown us Evolution as actually taking place among living things; they have demonstrated that it has needed enormous lapses of time for its operations; that it is a gradual, steady process; and that it operates to produce, not merely progressive change, but also divergence and variety.

But although this transformation made visible in the past history of life is by itself sufficient to establish the fact of Evolution and to intimate something of its *modus operandi*, yet the indirect evidence must not be passed over. For one thing, it is impressive to see how each line of evidence confirms the same story; and for another, the indirect evidence throws light upon many of the facts and methods of Evolution which the direct evidence does not touch.

The first line of indirect evidence is comparative anatomy. This is often very similar to the direct evidence derived from fossil forms; in a number of cases the linking forms between groups are not wholly extinct, but a few of them linger on to the present day. We have already seen how the mammals and reptiles are linked by the duck-billed Platypus and its allies; worms and arthropods by the grub-like Peripatus; vertebrates and sea-urchins by Balanoglossus. So also the dog-faced but tree-living lemurs link monkeys with insectivorous mammals, the tailless apes are half-way in structure between monkeys and man, the lungfish help bridge the gap between fish and terrestrial vertebrates.

But the chief evidence from comparative anatomy comes from the broad study of structural plan. In *Patterns of Life* we saw that each of the great phyla of animals and plants is characterized by a common plan that underlies the construction of its members. That is fact. But why should it be fact? What is the sense of flying bat, swimming whale, burrowing mole, and jumping jerboa, all being built on one plan, while a wholly different plan runs through flying butterfly, swimming water-boatman, burrowing mole-cricket and jumping grasshopper?

Long before the time of Darwin, naturalists had recognized these underlying similarities of plan; Cuvier endeavoured to explain them by asserting that each main plan, or archetype as he called it, corresponded to an idea in the mind of God, who had rung changes on it in the process of creation. It is difficult to understand why only a small, definite number of archetypal ideas should have been thus divinely conceived. Why should God be limited in his ideas? And, further, as we shall see, the facts of embryology make that conception unacceptable. In any case, the idea of Evolution provides a more natural and much simpler presentation of the reality. If bats, whales, moles, jerboas, and the rest of the mammals were all descended from some common stock, then it would be *expected* that they should all show the same general plan, that they would start with that and vary from that to meet the demands of their distinctive ways of life.

What could be more different at first sight than whale's flipper, human arm, horse's foreleg, and bat's wing? Yet the skeleton of each is very plainly built on the same plan—

a plan originally comprising one long bone in the upper arm, two in the lower, ten little knobbly ones in the wrist, and five jointed fingers to end up with.

This original model is distorted, cut about, modified. Sometimes one or two parts are enormously enlarged, like the two bones of the horse's fore-arm ; sometimes parts are shortened and broadened, like the humerus, radius, and ulna of whales ; sometimes they shrink almost to nothing, like the second and fourth toes of the horses, or wholly disappear, like their first and fifth toes ; but the general plan remains as the common point of departure (Figs. 11, 14).

Even in limbs all serving the same function, the plan may be treated very differently and yet survive ; in the wing of a bird, the bones of wrist and palm are fused into one solid mass, and only three tiny fingers are retained ; the bat enlarges all the fingers except the first ; while pterodactyls, the extinct flying reptiles, enlarged only the " little " finger ; or again, the flippers of some among the ichthyosaurs, though at first sight very like those of a whale, achieved their paddle-like shape by a new kind of variation on the original plan ; they broadened themselves by adding to the original number of fingers until these numbered seven or even eight. If all higher vertebrates, from Amphibia up, are descended from one common stock with a five-fingered hand, all these curious details are illuminatingly sane ; if otherwise, they are incomprehensible (Fig. 12).

In precisely the same way, the jaws and mouth-parts of all insects conform to a single plan—the piercing, blood-sucking tube of the mosquito, the butterfly's coiled miniature trunk for sipping nectar, the house-fly's licking proboscis with its expanded lobes, the stag-beetle's formidable weapons of attack, the ant's chewing apparatus—all can be reduced to a simple plan such as is most clearly seen in a grasshopper or cockroach, with an upper lip, one pair of strong mandibles, and two pairs of weaker maxillæ, the second pair united to make a single lower lip (Fig. 13). Once more, if all insects are blood-relations, with bodies basically similar but special-

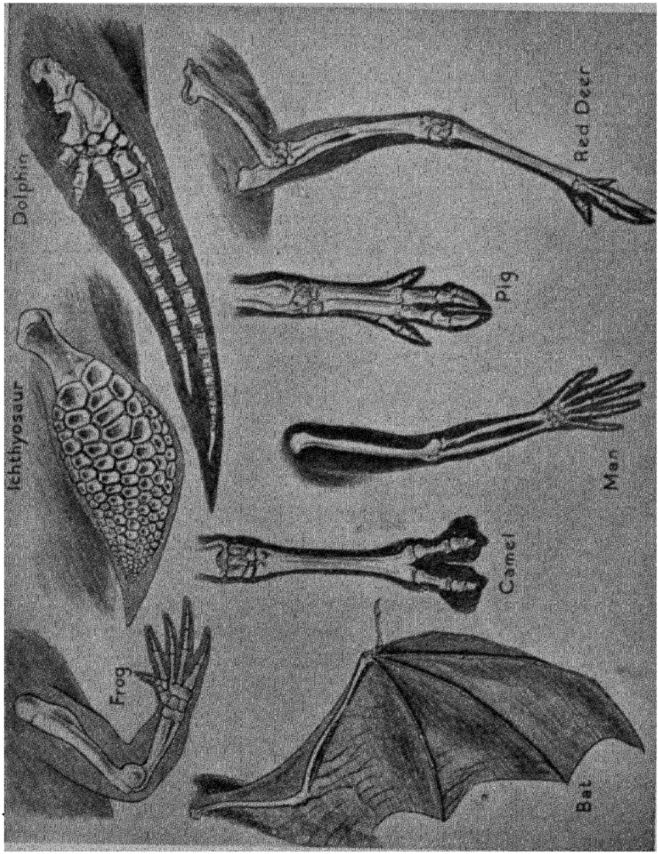


FIG. 11.—THE STRUCTURAL PLAN OF THE VERTEBRATE'S FORE-LIMB IS EXEMPLIFIED BY THAT OF MAN.

The general plan remains the same throughout the vertebrates, from amphibians up, though the details may be altered. In the Frog, the two bones of the lower arm are fused. In the Ichthyosaur, they are extremely shortened, and extra rows of finger-bones are added. In the Dolphin, two of the fingers are elongated; in the Bat, four. In the Pig, the thumb has vanished. In the Red Deer the second and fifth fingers are on the way to disappearance, and in the Camel only the third and fourth are left.

ized in divers ways to suit their diverse habits, the common plan of their jaw parts is easy to understand; if they are all separate creations, then only the supposition of a monstrous pedantry in creation seems to afford a glimmer of elucidation.

Examples could be multiplied almost *ad infinitum*—the appendages of lobsters, crabs, and other crustaceans; the teeth of mammals; the skull or the brain through the whole vertebrate series—all tell the same story.

A handful of different flowers gathered in a country walk would suffice for demonstration, if looked at searchingly with the eye that can pierce below the surface; for, as T. H. Huxley wrote, " Flowers are the primers of the morphologist; those who run may read in them uniformity of type amidst endless diversity of plan with complex multiplicity of detail. As a musician might say, every natural group of flowering plants is a sort of visible fugue, wandering about a central theme which is never forsaken, however it may, momentarily, cease to be apparent." Only descent seems able to explain that unity.

Of recent years fresh support for the evolutionary idea has been forthcoming from a new quarter in the proof of the chemical resemblances and differences between animals and plants. This is really evidence of the same kind which we have just been examining, save that the witness speaks a different language. The evidence still concerns resemblances in construction, but they are the invisible resemblances of chemical structure instead of the visible ones of anatomy.

Let us be a little more explicit about this new line of evidence. Many of the triumphs of modern medicine, as the reader probably knows, such as the antitoxin treatment of diphtheria, or preventive inoculation against typhoid and paratyphoid fevers, are based upon the fundamental principle that when any foreign substance belonging to the chemical group of proteins gets into the circulation, the body manufactures an " antibody "—a substance which in some way neutralizes the foreign protein or puts it out of action; and the antibody acts with full force only against the particular

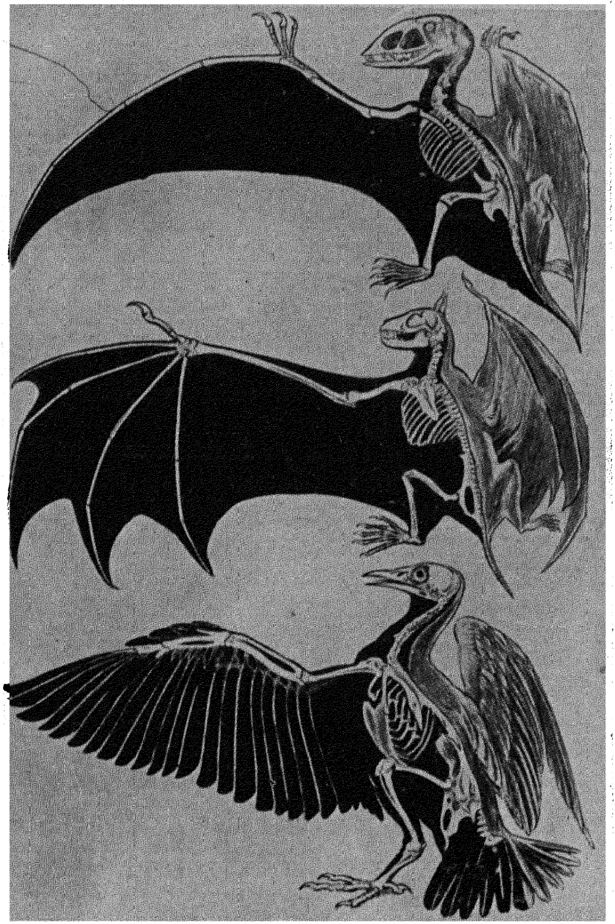


FIG. 12.—The FORE-LIMBS OF THREE FLYING VERTEBRATES, SHOWING DIFFERENT MODIFICATIONS OF THE SAME STRUCTURAL PLAN.

Above, a Pterodactyl. The wing-membrane is stretched on the enormous "little" finger, three other fingers are left as claws. In the centre, a Bat. Only the thumb is left as a claw; the other four fingers are used to spread the wing on. Below, a Bird. The thumb is a mere vestige, and besides this only the second and third digits remain.

protein introduced, with less force against proteins of similar chemical structure, and not at all against the rest.

Now, one of the chief ways in which the foreign protein may be put out of action is by precipitating it in solid form. If, for example, a rabbit be poisoned by a few injections of horse's blood it produces an antibody which gives its own blood the power of precipitating the blood of horses. If measured quantities of the bloods of treated rabbit and of a horse be mixed in a test-tube, a cloud appears and settles to the bottom—the horse-proteins have been eliminated.

If, however, the same amount of the treated rabbit's blood had been mixed with blood from a hen, there would have been no precipitate, not even a trace of cloudiness. The rabbit antibody which was efficacious with horse-proteins would be totally ineffective with hen-proteins. But if it had been mixed with donkey's blood, there would have been a precipitate—only not quite so much as if horse's blood had been used; while cow's or sheep's blood would have given a definite, but very much smaller precipitate. It is obvious from general structural considerations that a donkey is more nearly related to a horse than a cow, or a cow than a hen. Here we find that this relationship extends to the chemistry of the proteins. In brief, after animal X (a rabbit is generally used for this purpose) has been treated with the blood of a second kind of animal A, then the amount of precipitate which its blood gives with the blood of A and of other kinds of animals B, C, D, is found to be proportional, so to speak, to the closeness of relationship of these latter to A, as measured by anatomical likeness. A great amount of work has been done on this subject, much of it summarized in Nuttall's book, *Blood-Immunity and Blood-relationship*, and it is of great technical interest.

Wherever the evidence from comparative anatomy is clear, this new chemical evidence is in agreement with it. The anatomist, for instance, tells us that seals and sea-lions are carnivores which have taken to life in the sea: and their blood-proteins are chemically more like that of dogs, cats,

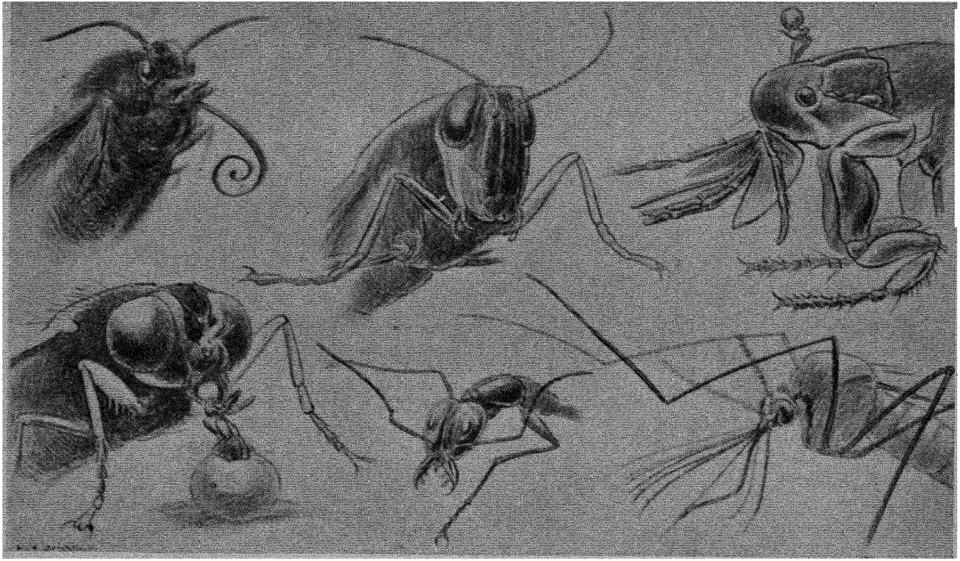


FIG. 13.—SIX INSECT FACES.

Above: A Moth (Poplar Hawk Moth); a Locust; a Flea. Below: A House-fly, sucking a drop of liquid; an Ant; with a female Malarial Mosquito, with the parts of its proboscis separated. The mouth-parts, whether built for sucking, licking, chewing, biting, or piercing, are all built on the same general plan—unpaired upper lip and three pairs of jaw-appendages. The last two pairs usually bear little feelers or palps, as shown in the locust; one pair of these is seen in moth and fly.

and bears than of any other creatures. The anatomist puts man in the same group with the apes and monkeys, and tells us that he is more like apes than tailed monkeys, more like tailed monkeys than lemurs, and more like any of these than he is to all the rest of the mammals. His very blood-proteins reinforce this conclusion. The blood of a rabbit previously inoculated with human blood gives a heavy precipitate when tested with chimpanzee's blood, less with a baboon or an organ-grinder's monkey, still less with a South American spider-monkey, but next to nothing with any animal from other mammal groups.

Occasionally anatomy gives a dubious verdict; and then the blood-test may throw fresh light. The whales, for instance, have points of resemblance both to carnivores and to ungulates, and anatomists have hesitated between the two alternatives. Blood-tests seem to show that they are more akin to the ungulates—a valuable classificatory indication.

We have spoken so far only of animals; but antibodies are produced equally as well against plant-proteins, and the method can be, and has been, successfully used with plants. The rabbit can be injected with an extract of some plant tissue, and its blood later mixed with similar extracts from other plants. The results, from plants equally with animals, can be summed up in a sentence: likeness of chemical plan goes hand-in-hand with likeness in anatomical plan. Likeness is intrinsic and touches every aspect of the living thing. Living things resemble or differ from each other in thread and texture as in plan and form. This falls in with the idea of Evolution, but it is reasonless on any other assumption.

## § 2

## *Vestiges: the Evidence of the Useless*

There are certain facts of anatomy which have proved not merely difficult, but impossible to explain on any other assumption than that of Evolution. These are what are

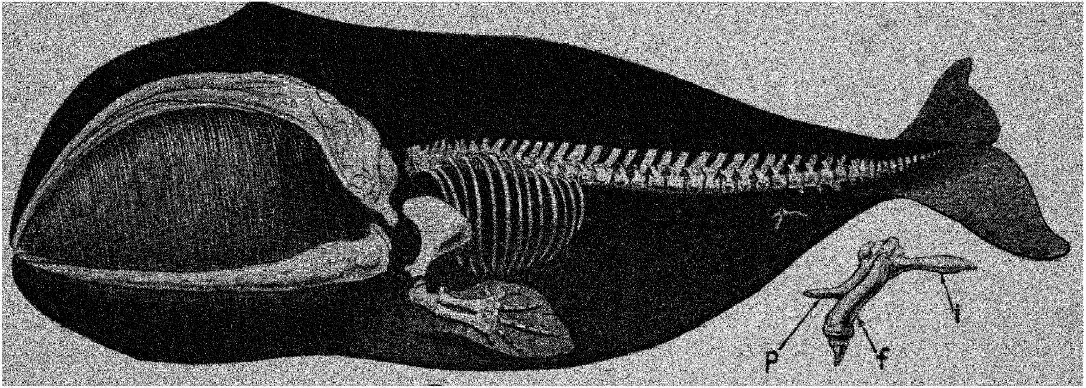


FIG. 14.—A VESTIGIAL LEG.

The outline and skeleton of a Greenland Right Whale. It has no hind-fin, but the useless remains of a limb-skeleton show that it is descended from four-footed creatures.

Below, the vestiges are drawn enlarged. (P), (*i*), parts of the hip-girdle; (*f*), thigh-bone with a vestige of the lower leg attached to its tip. Note also the skeleton of the five fingers concealed within the flipper; the huge jaws carrying whalebone plates; and the tail, set horizontally instead of vertically as in a fish.

called vestiges—organs which are useless to their possessor, but resemble and correspond to useful organs in other creatures. Such organs are often loosely called rudimentary organs; however, since they seem definitely not to be the beginnings of something better, but rather to represent the ruins of past usefulness, it is better to style them vestigial.

Perhaps the most striking vestigial organs are the legs of whales. Whales have, in their flippers, well-developed fore-limbs; but externally they show no trace of hind-limbs. However, if they are dissected, one or two little bones are to be found embedded in the flesh in the region of the hind-limb. In some whales, a pair of long rods is all that remains, representing the vestige of the limb-skeleton, while the limb is altogether gone; in others, the vestige of the hip-girdle has a vestige of a thigh-bone attached. These bones are wholly useless—there is no trace of limbs for them to support, and they have not been turned to other uses. If we believe in the special creation of each kind of whale, or even of whales as a group, we must confess that these limb-vestiges spell nonsense. But if whales have evolved from land mammals, their presence is not only natural but full of significance. Leviathan we realize is not a perfect, immaculate whale, made as a whale and as nothing else, but the descendant of a land animal doing its best to swim.

Very similar vestiges of limbs are found in some snakes. No snake has any trace of a fore-limb, and most lack hind-limbs, too. But in the boas, pythons, and one or two others, vestiges of hip-girdle and hind-limbs are to be found. Sometimes these seem to be wholly useless, while in other cases, although they have no use as limbs, they protrude as two claws, which doubtless serve some new if minor function. If, as their general anatomy indicates, snakes have evolved from lizards, these vestiges make sense; without the background of Evolution, they are inexplicable.

The Duckbill Platypus has no teeth; like a bird, it uses a horny bill instead. But it is a mammal, and on evolutionary principles must have descended from toothed forbears. We look for evidence on this point—and there the evidence is, carried about by the baby Platypus in the shape of teeth which, though they are complete with dentine and enamel, never cut the gum. They have no function whatever, save that of reassuring the Evolutionist: and the same is true of the whalebone whales, for here also the embryo develops teeth and then changes its mind and absorbs them again, all before it is born.

The vestiges of toes preserved to us in the horse's splint-bones have no sense save an evolutionary one; and here the fossil record clinches the matter by showing that this sense is the true sense.

In the common Vapourer moth, which of recent years has become such a pest to trees in London parks, the females are wingless. Where they burst out of their cocoons, there they stay, and are there sought out and fertilized by the winged males. Most moths, of course, are winged in both sexes; thus on the theory of Evolution we should expect that the wingless female Vapourer had arisen from winged ancestors. That she has done so is shown by the fact that she still bears the vestiges of wings—mere buds, wholly useless for any purpose; and, interestingly enough, in the chrysalis stage the wing-rudiments are actually larger than in the adult moth.

Another very pretty example of a vestigial organ is to be seen in the African Swallowtail butterfly, *Papilio dardanus*. The "tails" of Swallowtails are prolongations of the hind wings; and in order to make room for these during the resting stage between caterpillar and butterfly, their chrysalis-cases possess special little pockets into which the tail-rudiments project. Now, *Papilio dardanus* differs from most Swallowtails in being tailless in the female sex; for the females, in shape, colour and pattern, mimic other butterflies which happen to enjoy immunity from attack by most enemies. But the chrysalis-cases of the females possess tail-pockets just like those of the males, although they are obviously useless and not to be explained unless we suppose

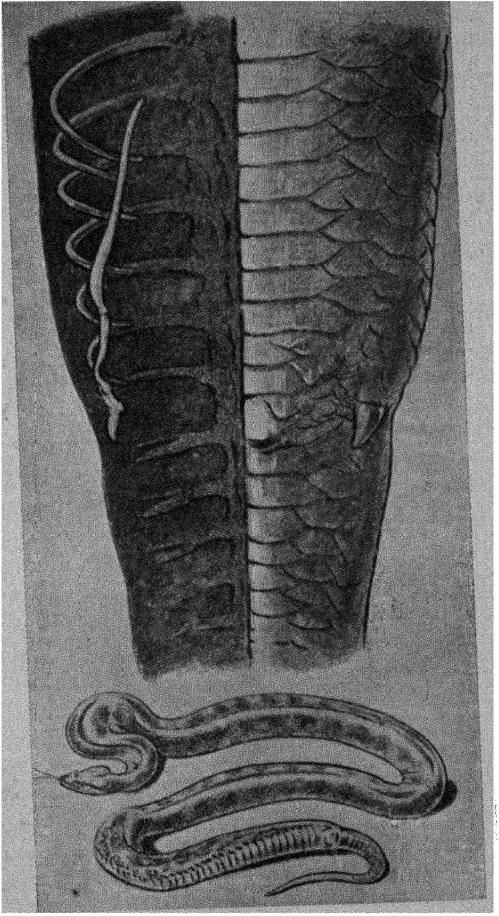


FIG. 15.—ANOTHER EXAMPLE OF A VESTIGIAL HIND-LIMB IN VERTEBRATES.

Below, an Anaconda. Above, a view of the region of its vent from beneath. On the right the surface is shown, with a single protruding claw, sole external remnant of the hind-limb. On the left the skeleton is drawn, with the vestigial skeleton of the hip-girdle and hind-limb lying outside the ribs, and not connected with the backbone.

that *dardanus* is descended from an ordinary Swallowtail with tails in both sexes.

Sometimes one only of a pair of organs becomes vestigial. Female birds have only one ovary and oviduct—the left—doubtless to provide against the accidents that might occur if two large and brittle eggs were to knock about simultaneously in their insides; but the right ovary and oviduct are always present as miniature and useless vestiges. The reptiles, from which birds undoubtedly have evolved, possess a pair of functional ovaries and oviducts: so that the presence of the vestigial right set of organs is perfectly intelligible to the Evolutionist.

Vestiges may, of course, also occur in plants. The well-known Butcher's Broom (*Ruscus*) gives us an example. In this plant, what appear to be the leaves are really flattened-out stems, as is shown by the fact that on them are born the flowers and by other anatomical details. This curious arrangement is an adaptation to a dry soil; the leaf-like stems are flattened vertically, instead of horizontally like ordinary leaves, and are accordingly not so much heated as leaves would be, and so lose less water from their pores. However, leaves are not absent in the Butcher's Broom; they are still to be found, but only in the form of vestiges, mere scale-like organs below the leaf-like stems and the flower-stalks. These contain very little chlorophyll, and in any case soon wither and fall off, so that they are quite useless for the leaf's prime function of food-manufacture.

Very similar vestiges of leaves, though often still more reduced in size, are to be found in many of the cactuses and prickly pears, which, too, have taken on the function of food-manufacture by their thickened stems, and for the same reason of economizing water.

In flowers, too, vestigial organs may be found. The flower of the common figwort, *Scrophularia*, has changed from its original five-rayed symmetry, so common among flowers, to a bilateral arrangement. And, of its five stamens, four are grouped in two pairs, and the odd fifth never develops any pollen; it is purely vestigial, and quite useless. In the related *Gratiola*, only two of the stamens produce pollen, one has been entirely lost, and two have been reduced to vestiges.

These flowers have lost their original, perfect, five-rayed symmetry; and in the process some of the stamens have become useless. But instead of being discarded they sometimes linger on as vestiges to help the botanist unravel the plant's past evolution.

And so we might proceed. There are the sightless vestiges of eyes in many cave-fishes and cave-shrimps; the feeble vestiges of wings in kiwi and dodo, and in many flightless insects; the poor useless limbs of Proteus, and other newt-like creatures, which have preferred swimming to crawling, and of some lizards which have taken to a burrowing life; and there are a host of examples which man carries about with him in his own person. But we are reserving for a later section that museum of evolutionary biology, the human body.

## § 3

## *The Evidence of the Embryo*

Vestigial organs, actually so diminutive, swell in their theoretical aspect to mountainous proportions, forming impossible barriers to the attacks of the Anti-Evolutionist. But obstacles almost or quite as formidable await him in the facts of embryology.

About a hundred years ago, von Baer, the great embryologist, omitted to label some specimens of embryos which he had put away in spirit. When he came to examine them later he found——but we will quote his own words: "I am quite unable to say to what class they belong. They may be lizards, or small birds, or very young mammals, so complete is the similarity in the mode of formation . . . of all these animals." Thinking over this he came to formulate a general law—that animals resembled each other more and more the farther back we pursued them in development. This law in general holds good, and this resemblance of embryos or larvæ is a very striking fact, very difficult to explain save on evolutionary lines. A child of two can tell a pig from a man, a hen from a monkey, an elephant from a snake. But these animals are only easy to tell apart in the later stages of their development. When they were early embryos, they were all so alike that not merely the average man but the average biologist would not be able to distinguish them, and even a specialist in embryology might be pardoned a mistake (Fig. 16).

But this is by no means all. The embryos of different animals, in addition to being more like each other as development is traced backwards, show also a widening contrast with their parents and their adult destiny. They become unlike their adult selves, but at the same time and in the same respects their construction comes to resemble that of quite other types of animals. To go back to von Baer's unlabelled specimens, not only are the early embryos of man, cat, hen, and snake so alike that they are hard to tell apart, but one of the ways in which they are alike is in having their heart, main arteries, and neck-region built on the same plan as in fish. Their heart is not divided, wholly or partly, into right and left halves, but it is a single series of pumping chambers, just like the heart of a fish; on the side of the neck is a series of clefts in just the position of a fish's gill-slits; there is a series of arteries running down between the clefts just as in fish; and, indeed, the whole arrangement of blood-vessels and nerves and their relation to the clefts is piscine, and not in the least indicative of the arrangement they themselves will show later. These clefts never bear gills; the resemblance is not complete; the reader must not run away with the idea that the human embryo ever has the "gill-slits of a fish." But it has a transitory rude passage through that type of structure. It is not, so to speak, a reproduction; it is an imperfect memory.

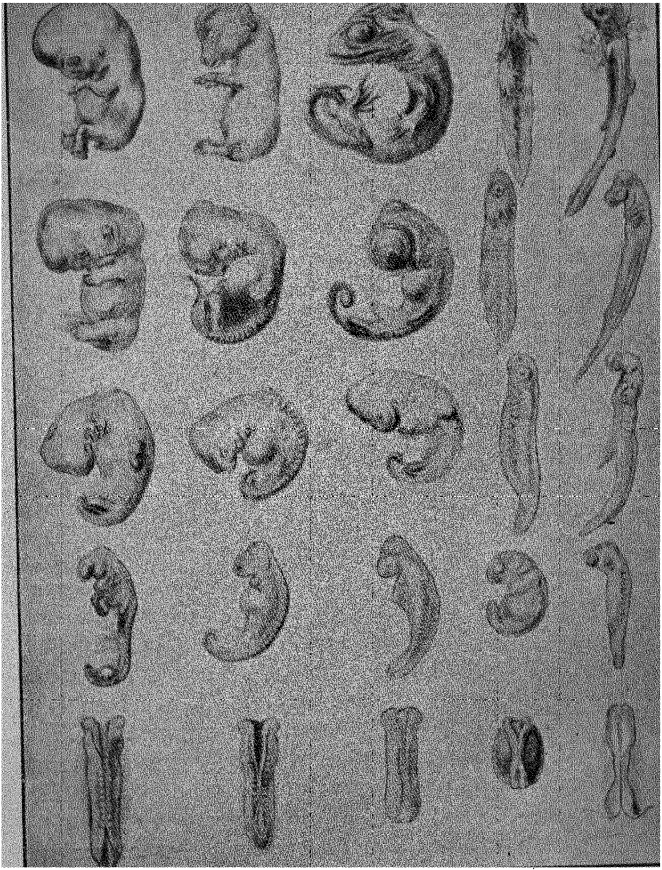


FIG. 16.—A COLLECTION OF VERTEBRATE EMBRYOS.

Each upright column represents the development of a single type—left to right, Man, Rabbit, Lizard, Newt, and Dogfish—the earliest embryos being below and the latest above. Note that the early stages are very like each other, and that the animals diverge as they develop. In the first stage the nerve-folds are closing in to form the brain. Then the gill-clefts appear. In the land animals these close later; in the newt and dogfish feathery gills appear. The human tail and its gradual shortening are clearly seen.

Once more this means nothing—indeed, makes nonsense—if we are to believe that land animals were created as land animals. But it at once becomes pregnant with meaning if we accept the fact of Evolution, for then we can understand that snakes and hens and human beings and all other air-breathing vertebrates are fundamentally fishlike, that they start on the fishward road and turn away from it towards their higher structural achievement. When they reproduce the old disposition asserts itself; they start towards the old water-way and turn aside towards the uplands. Because of that recurrent urge each individual animal repeats within its individual cycle of life these uneffaced tendencies from the remote part of its race. In Amphibia the recapitulation is much more thoroughgoing; they have not only the clefts but the gills, and most of them actually do breathe by means of gills in their early tadpole stages, and physiologically are indeed fish.

Nearly half a century later, Haeckel, looking at the facts of embryology in the light of evolutionary ideas, broadened and reformulated and perhaps rather exaggerated von Baer's law. Haeckel's revision was this, that every animal in the course of its individual development tends to recapitulate the development of the race; and from this time onwards the facts on which the law is based have been called the facts of recapitulation. But it is a general and not a complete recapitulation. Evolution can affect every part of a life-cycle, and if a stage wastes much time or energy, Nature, who is no historian, will abbreviate it or cut it out quite ruthlessly.

Exactly how far Haeckel's law takes us—what are its limitations; whether recapitulation ever shows us an animal's adult ancestors; whether present development ever does more than recapitulate ancestral development; what is the cause of recapitulation; and why some of the characters and structures are regularly recapitulated in development, others only occasionally or not at all—all this we cannot here discuss. What we are here concerned with are the positive, visible facts. Tens of thousands of animals do recapitulate the past during their development—do, without any apparent advantage in so doing, show organs and constructions which occur elsewhere in the adults of less specialized creatures: and in none of these tens of thousands of cases is this departure intelligible save on the view that in so doing they are repeating phases that were once final forms in the earlier evolution of the race.

There is probably no single case of development among many-celled animals which does not show some recapitulatory feature. Even the origin of all sexually produced individuals in a single cell, the fertilized egg, in a certain sense recapitulates the origin of many-celled from single-celled forms. But there are plenty of more definite examples. Every human being and every other vertebrate at a certain stage of his or her development has an unjointed notochord in place of the future jointed backbone, even though in all save the lampreys and certain fish this notochord-rod vanishes entirely. And the most primitive chordate, Amphioxus, has a notochord all its life long and never develops a backbone.

We have already spoken of the extraordinary transformation that overtakes the young sea-squirt. Here the sedentary adult animal, bearing only faintest indications of its real relationship, passes its early life in a tadpole-like form which shows all the salient points of the chordate plan—the notochord, the tubular nervous system along the back, and the gill-slits. If the gelatinous sea-squirt is not a degenerate chordate, why should its larval form be so entirely chordate? What creative idea is served by this hesitation in development?

A much less all-pervading example, but none the less a very pretty one, we have already cited in the early horse-stock. The three-toed Merychippus had an elaborate grinding pattern on its permanent premolar teeth; but the pattern of the milk-teeth was simpler, like the pattern of the permanent teeth in geologically earlier and more primitive horse-ancestors. Here we can actually put side by side the adult ancestral form and its young descendant recapitulating it before passing on to the more highly evolved structure.

A beautiful example of recapitulation comes in the life-history of the common feather-star. This is an echinoderm belonging to the crinoid class. The great majority of the class spend their adult lives rooted to the bottom; they are the stalked sea-lilies which wave their graceful, branching arms far down in the abyss, and in the past they were so abundant as to have built up whole layers of rock with their skeletons. From such forms as these the freely swimming feather-stars have evolved. But the feather-star, too, begins its adult existence with a fixed stage. For some weeks it lives and grows rooted to the bottom like a sea-lily. Only later does it abandon this sea-lily guise, break off from its stalk (which is left to die) and become a free-creeping feather-star (Fig. 17).

An interesting case among plants of the preservation of phases of the ancestral life-cycle which are now unnecessary is that of the maidenhair tree or ginkgo. This lovely tree, with its leaves like little fans, is extinct in the wild state, but has been preserved to us by being cultivated as a sacred tree in the gardens of Chinese temples. It is a naked-seeded plant, related to the pines and firs. As in all other seed-plants, its fertilization is effected by means of pollen. The pollen-grain, as we have already explained in *Patterns of Life*, if it alight on the pistil of a female flower, sends down a long tube towards the egg-cell embedded in the ovary. From its original single nucleus, three nuclei are produced by division; two of these nuclei act as male gametes, either of them capable of fertilizing the egg. In almost all seed-plants these male gametes are merely more or less ordinary nuclei which pass down the tube to the ovum; but in the ginkgo and the cycads the nuclei, associating themselves with some of the surrounding protoplasm, become transformed into two actively swimming, ciliated sperms, like the sperms of fern, moss, or seaweed, which swim on within the tube to fertilize the egg (Fig. 46 in *Patterns of Life*). They would get there just as surely, we judge from the higher plants, if they had no cilia. These tiny sperms are as revealing as the gill-slits in our own embryonic neck. They show that once upon a time, a very remote time, the ancestors of seed-plants lived in the water, where free-swimming sperms provide the natural method of achieving fertilization. And here, long after the pollen-tube had been evolved to provide a dry method of fertilization for dry-land plants, the motile character

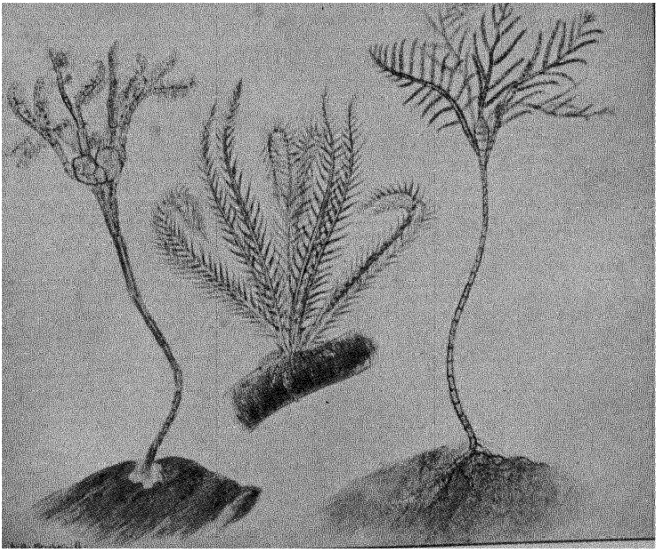
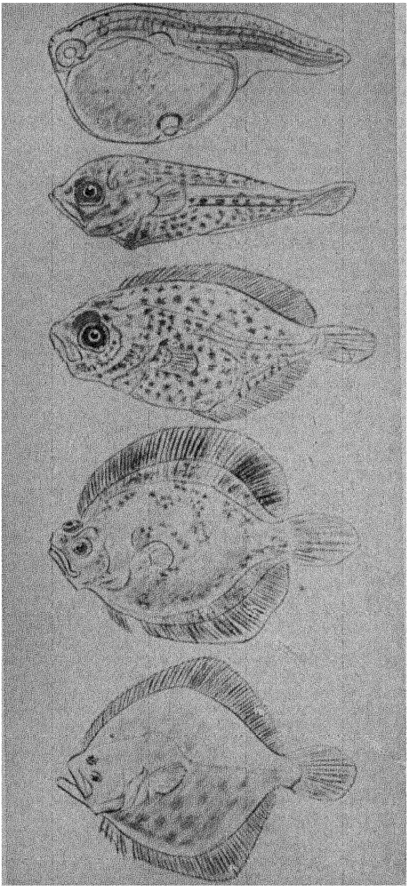


FIG. 17.—ANCESTRAL REMINISCENCE IN THE FEATHER-STAR'S LIFE-HISTORY.

The adult Feather-star (Antedon) can swim from place to place by waving its arms, or anchor itself temporarily by a set of jointed claws, as the specimen in the centre is doing. On the right is an adult Sea-lily (Rhizocrinus), from a depth of about a hundred fathoms in the North Sea. This animal is permanently fixed by a stalk which ends in a root-like tuft. On the left, a young Feather-star in the stalked stage. After growing for some time in this form, the animal breaks off and swims away, leaving its stalk behind. Thus the Feather-star passes through a fixed stage which is like the final form of its more primitive relatives, the sea-lilies.



of these transitory sperms survives to recall the watery past. Even in some much more modern plants, like the sunflower, though cilia are no longer formed, the fertilizing male nuclei still assume corkscrew shapes in recapitulation of the coiled, swimming sperms of many lower plants.

Two final examples we may note, one from fish, the other from Crustacea. Everybody knows what soles and plaice and other flat-fish look like, and a great many people are aware of their peculiarity in having both their eyes on the one side of their twisted head and in lying flat, not on their belly but on one side, the oppo-

FIG. 18.—A TURBOT RECAPITULATES ITS SYMMETRICAL PAST.

Above, a newly hatched larva, symmetrical, with organs incompletely developed, and a large yolk-sac. Next, about one eighth of an inch long, symmetrical, independent, swimming upright. Next, one-fifth of an inch long; the right eye is beginning to shift upwards. Last but one, four-fifths of an inch long; the right eye has grown nearly round to the left side, the animal swims almost flat instead of upright. Below, fully transposed; the fish spends most of its time lying on the bottom.

site side to the eyes. But not so many know that when they hatch out of the egg, flat-fish are symmetrical like other fish, swim about in the ordinary upright position, and have their two eyes on different sides of their head like any ordinary vertebrate. It is only after several weeks that a symmetrical growth distorts the head and eyes and the animal gradually settles down to its sideways existence. This is natural enough in the case of a fish which was once free-swimming like other fishes but which, generation by generation and age by age, has taken to life upon the bottom, but it is fantastic if we suppose that the plaice and soles were specially created as they are now. Why should they not spawn themselves in miniature?

The most startling example has been reserved to the end. Portunion is the name given to a repulsive parasite found in the gill-cavities of crustaceans, where it devotes all its energies to sucking its host's blood and maturing its own reproductive cells. In the female sex especially this creature looks much less like a whole animal than like a detached piece of somebody else's internal anatomy. There is nothing to show what sort of a creature it really is, from what kind of animal it has degenerated. But in its development it lets the cat out of the bag—or perhaps we should say it lets the sea-woodlouse out of the bag; for when young it is obviously a crustacean the details of whose anatomy place it at once in the order which contains the familiar slaters and woodlice. In *Patterns of Life*, Chapter III, we traced a similar story in the parasite Sacculina, which is shown by its larva to be a curiously disguised and degenerate barnacle.

The evidence of the fossils in the rocks is direct evidence for Evolution. But the evidence of embryology, though indirect, is more immediate. You can watch the individual animal indulge in these amazing reminiscences, and pass almost before your eyes from ancestral primitiveness to adult modernity. All the facts have a simple and straightforward meaning if Evolution be a fact, while a denial of Evolution leaves them unexplained and apparently inexplicable. It is plainly essential to a parasite like Sacculina that it should have a free-swimming larva, but it is hard to see why that larva should be built so exactly upon the crustacean plan if Sacculina has no crustacean ancestry. And a colt, safe in its mother's womb until it is born a well-nigh complete miniature of its parents, has no sort of advantages in preceding its backbone by a notochord or producing and reabsorbing gill-arches. Nor is it some mysterious widespread harmony which requires this rhythm of repetition, because the amount of recapitulation varies with different animals and the story is often blurred and abbreviated. Recapitulation occurs like something done under a powerful and unavoidable inertia of tradition, like something deep in the nature of living creatures. They recapitulate because they reproduce and because they have been evolved through an infinite series of reproductions from simpler things.

## CHAPTER IV

# THE EVIDENCE FROM THE VARIATION AND DISTRIBUTION OF LIVING THINGS

### § 1

### *The Variability of Living Things*

THE rocks tell us that the forms of living things have changed slowly but steadily in the past; careful comparison of the structure and mode of development of creatures living to-day is in accordance with this fact. We will now open up a new series of facts that harmonize and complement those that have gone before. If Evolution is the form of life's process, it must still rule life. Life must still be evolving to-day. Is that so? We do not see striking metamorphoses happening; Evolution is an extremely slow process, its changes in the case of the slower-breeding organisms take hundreds of thousands of years to accomplish, and it would be strange indeed if any profound alteration in the form of a living thing had occurred in the couple of hundred years during which animals and plants have been carefully and systematically observed. To expect rapid changes of this kind is like expecting visible movement in the hour-hand of a clock. Nevertheless, we can detect slight changes in progress, sufficient to convince us that Evolution still continues.

One of the clearest and most striking proofs of the plasticity of living things is the extraordinary variability they display under domestication. Consider, for example, the dog. Here we have an enormous assemblage of forms, the extremes differing from each other far more strikingly than many natural species, ranging in size from the St. Bernard and the Great Dane to the toy Lapdogs, in proportion of parts from the slender-limbed greyhound to the low-hung Dachshund, from the long-nosed Collie to the snuffling Pekinese, and showing an enormous variety of colours and coat-patterns. Yet they seem to be all of one kind; they recognize each other as like creatures, and if the physical disparity between them is not too great they breed freely together. In a word they are all dogs. They show to what an extent a living form may vary.

There are plenty of similar instances among domesticated animals. Compare, for example, a cart-horse, a race-horse, and a Shetland pony; a carrier-pigeon, a tumbler and a pouter, or the multitudinous fancy breeds of rabbits and guinea-pigs and mice. And consider also the enormous richness of varieties that is found in cultivated plants—in roses or primulas or cereals.

It is unfortunate from the point of view of evolutionary science that the mode of origin of most of those special domesticated breeds has not been recorded. They are in many cases very ancient. There were domesticated dogs in the Bronze Age cave and lake-dwellings of Central Europe; in Egypt there were several distinct breeds, including a greyhound, as early as 3000 B.C.; a dog very like the St. Bernard appears on Assyrian bas-reliefs. Nevertheless, it is clear that man has been the primary cause of this extraordinary divergence. He has kept and bred from those animals which best suited his fancy, and he has drowned or starved or given away the others. So he has gradually moulded the breeds.

There are plenty of cases in which the gradual changes have been recorded. The greyhound of to-day is more slender-legged than the greyhound that appears in Egyptian paintings; a specialist in hunting hares, he is smaller and lighter even than his Elizabethan ancestor, which was sent after deer and all sorts of game. And the bulldog has been modelled about almost like a lump of plasticine. He was bred first for the special purpose of bull-baiting—hence his short, stocky build, which enabled him to dodge the swing of the bull's horns, his underhung jaw and strong gape, and his method of attack, which is to come boldly from the front to seize the muzzle and hold on instead of dancing in from the rear and slashing after the manner of deerhounds and other elegant dogs. When bull-baiting was made illegal in England the breed was kept on as a curiosity and was changed from a fighter into a caricature; its face became so short that it could hardly breathe through the nose, its legs were absurdly bowed and twisted, while its general physique and stamina deteriorated. To a large extent this change for the worse was due to selective breeding, although that process was assisted by such tricks as keeping the puppies in cages so low that they could barely stand up, to exaggerate the curve of the legs, and keeping them in harnesses to hollow their backs. Recently there has been a reaction in the other direction, and the bulldog is becoming less grotesque. Thus, now in one direction and now in another, the form of the breed has been moulded.

Presumably all of the domesticated animals and plants have been derived by the selective breeding of wild species. The various sorts of domesticated pigeons have all been evolved from the wild rock pigeon *Columba livia*; and an astonishing diversity in form and colour of domesticated forms has been produced. But it is not true that in all cases the races of a domesticated animal spring from a single wild ancestor. In dogs it is probable that more than one ancestral species have been involved. There are several kinds of wolves and jackals, which will breed freely with our dogs, and many of these can be tamed. It is rather the rule than the exception that the tame dogs of any region carry an obvious dash of blood from their local wild kindred. The highly civilized countries are exceptional in this respect, for we select and mould our dogs to an extraordinary degree and we destroy our strays. But from Central Europe, across Asia, and down through Africa the common dogs of the people show evident resemblances to the local kinds of wolves and jackals; and it is the same in America, for the Eskimo dog is like the North American wolf and the Hare-Indian dog is like the coyote.

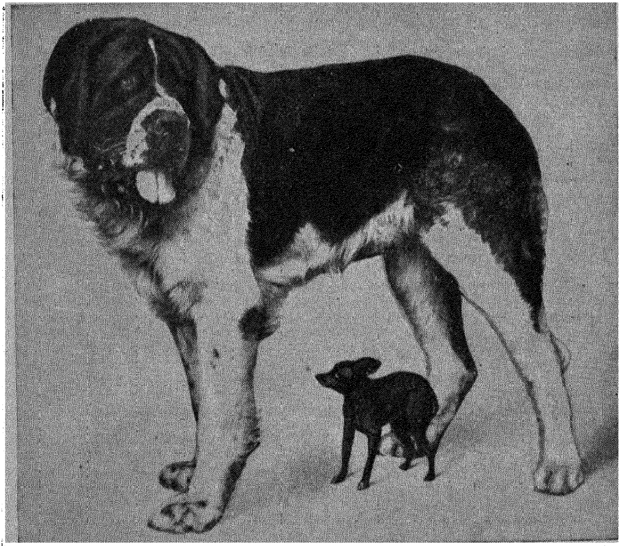


FIG. 19.—TWO FULLY ADULT DOGS, A SAINT BERNARD AND A TOY BLACK-AND-TAN TERRIER, AFFORDING AN EXTREME INSTANCE OF VARIATION WITHIN AN INTERBREEDING GROUP OF ANIMALS.

Apparently the habit of domesticating dogs is ancient and widespread and it has entangled a number of different species into one interbreeding complex.

But whether a domesticated race involve one species or many, the essential fact is this—that divergence of form has been brought about by the selection of variations and that such variations do occur in the wild forms from which our tamed or cultivated races have been derived. Indeed, it is not possible to study intensively any single group of animals without finding abundant variations of type. Living tissue is always groping about in search of improvements. Naturally enough we do not find such *outré* creatures in the wild as we do in our kennels or farmyards or gardens : we do not find pug-dogs wheezing through the woods after their prey or ravenous cart-horses scouring the plains for grass to build up muscles quite unnecessarily large for their own needs. These are creatures fitted to man's special requirements, for his amusement or for his service, and they would be unable to survive or breed in a wild state. But we find plenty of variations among wild species all the same.

For example, our common European squirrel exists in two varieties, red and black. In some regions only one kind is found, in others only the other, while in the intermediate zone both black and red young may appear in a single litter. Similarly in the case of the common American opossum. Among the usual greys a small proportion of black specimens (up to ten per cent. in some regions) is to be found ; while in other regions a small percentage of cinnamon-coloured animals regularly occurs. The valuable fox skins are a further example of the same thing. The Arctic fox is usually brown in summer, white in winter ; but a considerable proportion of the species is bluish all the year round, providing the blue fox skins of commerce. The more southerly red fox also has, as a comparatively rare variety, the silver fox, with black, silver-tipped hair, and the less uncommon cross fox with a cross mark on the shoulders. Members of the different types may be found in a single litter. The same holds for the white and grey varieties of some kinds of herons.

Many plants habitually exist in two or three such varieties. The common milkwort (*Polygalum*) may have white or red or bright blue flowers, and the comfrey (*Symphytum*) is not in the least particular whether it shall be purple or white.

Besides such sharply marked varieties, between which no blends occur, there may be gradual variation leading insen-

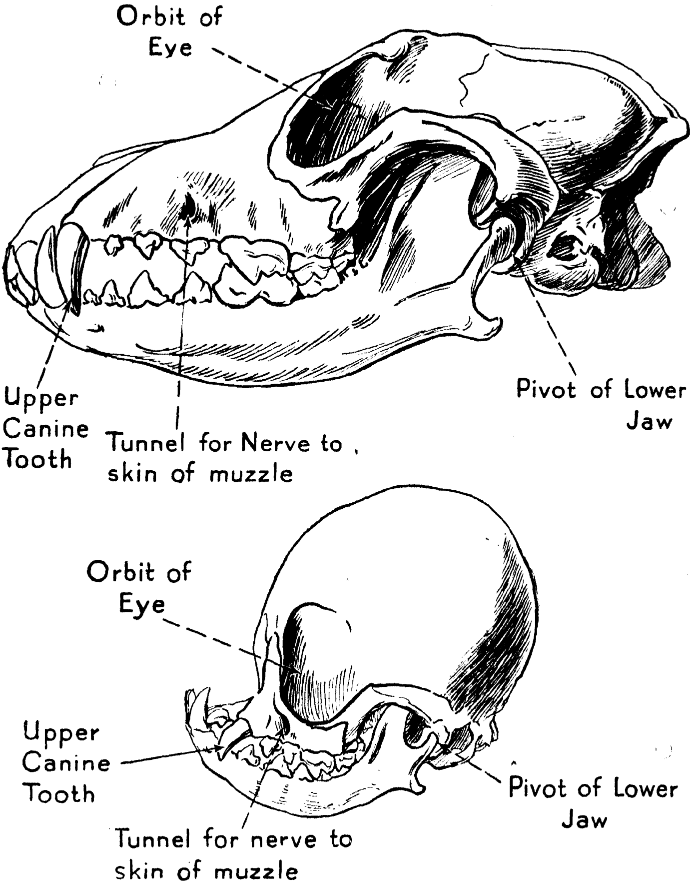


FIG. 20.—THE SKULL OF A KING CHARLES' SPANIEL (BELOW), CONTRASTED WITH THAT OF A PRIMITIVE, WOLF-LIKE PARIAH DOG (ABOVE).

Both are drawn from the left side and to the same scale. One or two points are labelled correspondingly in the two skulls to bring out more clearly how the nose of the fancy breed is shortened.

sibly from one extreme type to another. The common skua or jaeger may be wholly white below, or wholly dark; and between these two types all intermediates occur, through dark-waistcoated to broad-collared birds and so to narrow collars and finally to no collar at all.

Examples of variation in wild animals and plants might be multiplied *ad infinitum.* And although because of their conspicuousness we have confined ourselves here to colour-varieties, equally marked variations are found in other points, in shape and size, in the internal organs, even in such invisible physiological characters as disease-resistance or longevity. All kinds of living things vary; the differences are merely a matter of more or less, some varying more strikingly than others.

## § 2

### *What is a Species?*

In the foregoing chapters we have made frequent use of the accepted classification of living things; it is a chart that shows us our way about the Animal and Vegetable Kingdoms and the intermediate zone between them. But we have said nothing about the way in which that chart has been drawn. The classification of living things is a laborious task; it involves the collection of great numbers of specimens from all parts of the world, and their careful, indexed accumulation in central museums where they can be examined and compared; it involves the full-time labour of collectors and of museum experts in the various groups. It will be worth our while to glance for a moment at the work of these systematists, as they are called, because the way in which living things resemble and differ from each other is in itself a strong piece of evidence in favour of Evolution.

Naturally we cannot examine the drawing-up of the whole map; we shall have to confine our attention to a corner of it. We shall speak only of animals in what follows, although the classification of plants is based on similar principles and entails similar difficulties, and we shall begin with one particular group of animals, the wild dogs.

Running wild and hunting over almost the whole land surface of the globe—excepting only New Zealand, Madagascar, the ice-caps at the Poles, and those intensively civilized regions that man has made wholly his own—there is a tribe of closely related animals, the wolves, jackals, and foxes —in biological language, the family *Canidæ*. The appearance of a wild dog, such as a wolf, is well known enough. He has a bushy tail, erect ears, a pointed muzzle, a shrewd expression, and sharp, cruel teeth. He is lightly built; the dogs are a family of swift runners with exceptional powers of endurance. In general they are carnivorous, i.e., they kill and devour living prey, and for the most part they run their prey down and do not pounce upon it after the manner of cats. But dogs are by no means particular in their diet; when fresh meat is scarce they are willing to take invertebrate animals, vegetable food, or carrion.

Now, there are a number of kinds of wild dog; they vary in size, colour, and proportions of the parts, in habits (some hunting by night and others by day, some hunting singly and others in packs), and so on. And they have to be classified. Their popular names—wolf, jackal, fox, and the like—are unsatisfactory because they rest on the superficial appearance of the creatures and do not give any idea of their true relationships. It is the business of the systematist to classify these different kinds of dogs properly; he has to examine them and note how they resemble and differ from each other and give them unambiguous names which will define as clearly as possible their true relationships. How then does he proceed? We can most clearly understand the process by first giving a somewhat idealized account, and then noting some of the difficulties that stand in his way.

The unit of biological classification is the *species*. If we find a number of animals, resembling each other and differing distinctly from all other animals, breeding freely and fruit-fully together and recognizing each other as kin, then those animals constitute a species. In Britain, for example, the common fox is one species and the wolf, which was exterminated a few centuries ago, is another; in North America the coyote, the timber wolf, the common fox are examples of separate species. In this manner all the known Canidæ are grouped into species.

Now, just as individuals may be grouped into species by considering their resemblances and differences, so may the species be grouped into assemblies of a higher order. There is, for example, a large group of species—the wolves and jackals—that are obviously very like each other; there is another group—the foxes—which also resemble each other, but which differ in a number of respects from the members of the first. Each of these species-groups is called a *genus* (plural *genera*). The wolf and jackal genus is called *Canis* and the fox genus is called *Vulpes*. Sometimes a single species is so strikingly different from all other kinds of dog that it is put in a genus by itself; thus the long-legged, foxy-red " maned wolf " of Brazil and Paraguay constitutes the genus *Chrysocyon*. Usually, however, a genus contains a number of species.

In speaking of animals, the zoologist finds it convenient to give both the generic and specific names—very much as, in speaking of human individuals, we often give both Christian and family names. In order to avoid confusion, certain conventions are adopted; the name of the genus is put before the name of the species; the name of the genus is written with a capital letter, that of the species with a small letter. Thus the common European wolf is called *Canis lupus*, the Indian jackal is *Canis aureus*, the common fox *Vulpes vulpes*, the long-eared fennec fox *Vulpes zerda*, the maned wolf *Chrysocyon jubatus*, and so on.

Carrying the classifying process a step farther, we group the genera of dogs together to form a family, the *Canidæ*. This is brigaded with a number of other families, with cats and bears and hyænas and weasels and seals and a host of others, to form an order, the *Carnivora* ; this, with a number of other orders, forms a sub-class, the placental mammals, and so on, as we have already seen.

So much for the ideal. Now for the difficulties.

We noted in the last section that the individuals composing a species are never exactly like each other. Even in the clearest, most sharply defined species the individuals show slight variations in their colour, size, instincts, and so on. In the common European wolf, *Canis lupus*, for example, animals from different localities vary in length of fur, the coat being thicker in northern wolves, and there is a tendency for the latter to grow to a larger size than the southern individuals. This particular case does not present a very puzzling problem to the systematist. There is no question of dividing the European wolf into two or more species, for the extreme types are connected together by a grading series of intermediate forms, all breeding freely together. They are simply variations within the limits of a single species.

But when we take into consideration all the wolves in the world, the problem of variation becomes more serious. The true wolf ranges over the whole of the northern hemisphere from the Arctic Circle to south temperate latitudes, and apart from such " sports " as complete blackness, which may turn up anywhere, the characters of wolves vary in accordance with the climate of the particular region they inhabit. Northern wolves, for example, are on the average larger than the southern and have a thicker and whiter coat, and in temperate zones the wolves inhabiting comparatively dry country are on the whole paler in tint than those from districts where the rainfall is heavy. And there are variations in build and proportion. Now, sometimes these differences are considerable enough to make it doubtful whether the forms should be grouped in the same species or not. There are, for example, the American timber-wolf, the pale wolves of North-Western India, the small, short-legged Japanese wolf, the little red wolf of Texas—these and many others, all fairly distinct from the common wolf of Europe, but just similar enough to leave us in doubt whether they should be separated or left together. Confronted with this problem, the experts differ among themselves. Some prefer to distinguish these various kinds as separate species; some include them all within the species *Canis lupus* and distinguish them as local races or sub-species. Moreover, this variation is not a canine peculiarity; the foxes show it, too, and, indeed, nearly every wide-ranging kind of animal or plant has its local varieties and therefore its problems for the systematist.

This sort of difficulty is not confined to the first step in classification. It attends also the formation of groups of higher grades. It is often very hard to tell whether species are sufficiently like each other to be put in the same genus, or whether genera are sufficiently like each other to be put in the same family.

It will make the point clearer if we take another example, not this time from the dogs but from their cousins the cats. As is well known, the lion, tiger, leopard, lynx, and the rest are all plainly related to the smaller cats, and until recently they have always been called different species of one genus; the lion, for example, was *Felis leo*, the tiger *Felis tigris*, the leopard *Felis pardus*, the tame cat *Felis catus*, and so on. But, as a matter of fact, the group is divisible into two subdivisions, on the one hand the lion, tiger, leopard, and jaguar, and on the other the puma, lynx, and all of the smaller cats; their most striking distinction is that while only the former group can roar, only the latter can purr (limitations which have an anatomical basis). Here arises the first difference of opinion: Some authorities call the two groups sub-genera, while others call them genera with the names *Panthera* and *Felis* respectively. Now each of the commonly accepted species shows considerable variation, and here the second difference arises. The tiger, for instance, is big and long-haired at the northern end of its range, smaller and short-haired in India, very small indeed in Sumatra, unusually closely striped in Turkestan. Some authorities regard the various forms as local varieties or sub-species of the species tiger and denote them by adding a third name, the sub-species name, to the already elaborate titles—thus the Manchurian tiger is *Panthera tigris longipilis*, the Sumatran tiger is *Panthera tigris sondaica*, and so on. Others, however, consider that they are distinct enough to be called so many species, in which case the old tiger species is made a genus, the different kinds becoming *Tigris longipilis*, *Tigris sondaica*, and so on.

These differences of opinion, be it noted, are not signs of incompetence on the part of the systematists; they result from the nature of the facts, *which do not admit of categorical classification.* It is written that Noah collected "every beast after its kind, and all the cattle after their kind, and every creeping thing that creepeth upon the earth after its kind, and every fowl after its kind, every bird of every sort," and even nowadays most people share the delusion implicit in this passage—that if we could assemble together every individual beast and creeping thing and fowl that live in the world to-day, and if we could examine and compare them all, it would be possible to group them with neatness and precision into definite kinds, or species. But that is a myth. What has been said of dogs and cats is true of other animals—and of plants and microscopic creatures as well. There exists every conceivable grade of difference between organisms. There are animals which are very much alike, so much alike that they are obviously members of the same species. There are animals which are so different that they are obviously not members of the same species. And there are animals just different enough to make one wonder whether they should be called different species or not—and this is where the nice problems arise. Authorities vary widely in the freedom with which they erect new species; some group animals together whenever there is any doubt at all, while others put two specimens in separate species almost whenever they can see a noticeable difference between them. In an extreme instance, the British brambles and roses have been classified as sixty-two species by one authority and as two by another of equal eminence.

For there is no absolute criterion of species, no feature that will stamp living things definitely as the same or different. It used to be thought that there was a distinction between creatures which would breed together and produce fertile offspring and creatures which would not; the former were members of the same species and the latter were not. But in fact there is every conceivable stage, in some organism or other, between mutual fertility and complete mutual sterility. At one extreme the males and females breed freely together, and their offspring are fertile; in this case they are generally called the same species—mankind will serve as an example. At the other extreme the male and female do not recognize each other as similar creatures; a lion and a cow will illustrate this. But in between those two extremes there are various links; there are cases where a male and a female are friendly together but show no desire to breed, cases where they come together but are completely sterile, cases where they produce a few weakly or abnormal offspring, cases where they produce healthy but sterile offspring, cases where their offspring are healthy and fertile but their grandchildren are weak and unhealthy. Where in this series are we to draw the line? Which of the graded stages are sufficiently fertile to be called members of the same species?

Indeed, there are plenty of examples of animals and plants which are considered to be different species interbreeding freely in Nature. The case of the carrion crow and hooded crow is classical. These birds inhabit the greater part of Northern Europe and Asia, but the two species divide this vast area between them. The carrion crow (or common crow) is found in England and South-Western Europe and also in the eastern half of Siberia. The hooded crow is found in North-Eastern Europe and from thence across to the middle of Siberia and down as far as Egypt. There are therefore two lines along which the species meet: the western boundary runs through Scotland, Denmark and the Elbe Valley to Northern Italy, while the eastern boundary runs down through Siberia. In these boundary zones the two species frequently breed together and produce every possible intermediate stage between the coal-black carrion crow and the hooded crow with its grey body and black head, wings, and tail. A case with specimens of the two species and their intermediates may be seen in the Natural History Museum, London. A similar example is afforded by the flicker, a common North American woodpecker. There are two perfectly distinct kinds of flicker, the common flicker on the eastern side and the western flicker on the west; they differ conspicuously in a number of points in their coloration. But along a broad zone running from British Columbia to Galveston the two kinds mix and interbreed freely, and in this boundary region every conceivable kind of intermediate is found. One could multiply similar examples indefinitely; one more must suffice. In East Africa there are two species of antelopes of the hartebeest kind which, until recently, inhabited different districts and also were always perfectly distinct in such points as the shape of their horns; but a few years ago they spread towards each other and began to interbreed—presumably some sort of barrier that had been keeping them apart broke down—and now there are all sorts of intermediates between the two. So that the old fertility-criterion of species can no longer be said to work.

All of this was very perplexing to biologists in the days when they believed living things to have been created in a fixed number of immutable kinds in the garden of Eden. The Creator, they thought, had made so many different species, and it was the business of the systematist to recognize and identify those species and to base his classification upon them. The great Linnæus, for instance, laid down as biological dogma that " the number of species is as many as the different forms created in the beginning." Even in the nineteenth century Cuvier, as Professor J. W. Gregory remarks, " believed that species are as distinct as the different makes of boots sent out from a factory."

But it came to be realized that in many cases it was extra-

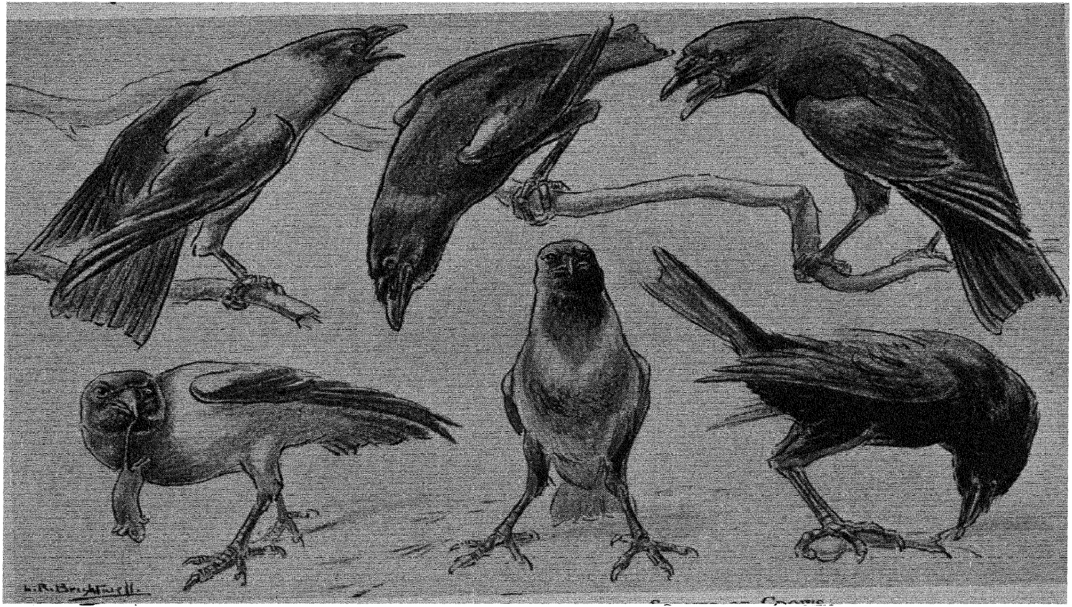


FIG. 21.—TWO FREELY INTERBREEDING SPECIES OF CROWS.

The Hooded Crow, Corvus cornix, is above on the left; the Carrion Crow, Corvus corone, is above on the right. The other birds are hybrids showing the hooded pattern more or less distinctly.

ordinarily difficult to recognize absolute distinctions of this sort; to tell, for example, whether there were both Sumatran and Manchurian tigers in Eden or whether there was one tiger which begat them both. The early systematists blamed their own incompetence. They believed in species, even where they could not recognize them, and they spent an enormous amount of time and energy in the quest of universal diagnostics of species (such as the test of mutual fertility that we have just discussed) and to devising definitions of species which would apply to every case. But the nineteenth century saw the passing of the idea of separately created "kinds." When the fact of Evolution was clearly stated and gained general acceptance, the confusion and difficulty of systematic work suddenly became luminously intelligible. It is precisely what one would expect. It is in itself evidence that Evolution is taking place. Our ideas of species have undergone a change and it is important to realize just how profound that change has been.

We have already spoken of life, seen as a whole in time, as a tree; the vertical height of the tree represents the time-dimension, and its branches, forking and multiplying from a common trunk, represent the various lines along which living things have evolved, diverging and spreading away from some common ancestral form. The horizontal distance between any two twigs represents the difference between two races, the degree to which they have diverged from their common stem. Clearly, the spectacle which life presents at any particular time—the present, for example—will be represented by a horizontal slice through the tree at an appropriate level. Now, what would such a slice reveal? It would pass through a great number of separate twigs; they would appear on the section as circles, and in our analogy they represent those species that are sharply marked off and distinct—such for example as the so-called Maned Wolf of South America. Some would be close together—if they had recently branched from a common stem—and others would be far apart; the former are closely

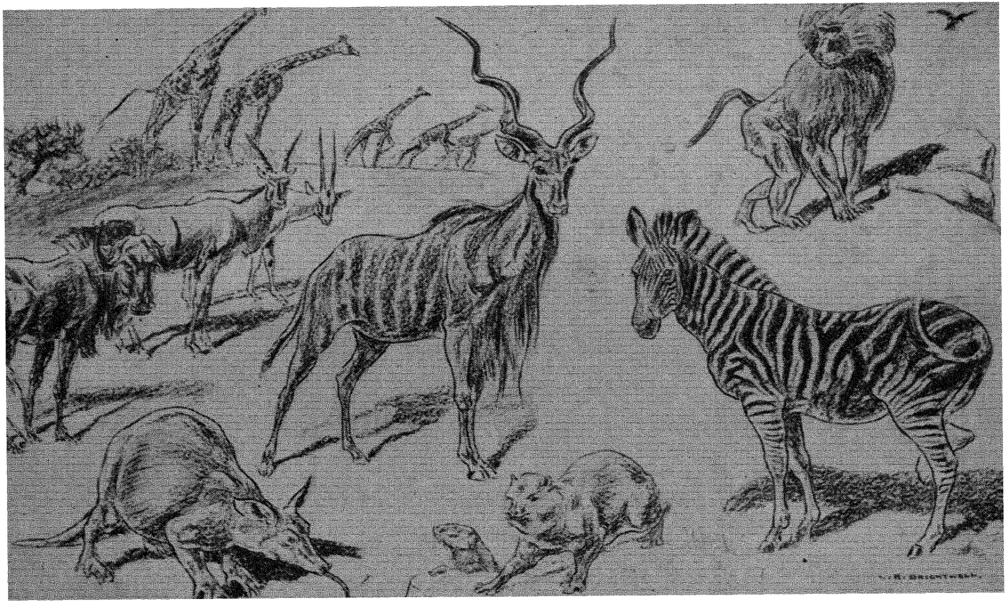


FIG. 22.—SOME TYPICAL AFRICAN MAMMALS.

Top left: Giraffes. Top right: Baboon. Centre (from left to right): Four kinds of Antelope—White-tailed Gnu, Eland, Oryx, Greater Kudu. Below (left to right): Aard-Vark; Cape Hyrax (Coney); Burchell's Zebra.

related, the latter distantly related species. But here and there our section would pass through an actual fork—it would appear as an ellipse, or a figure of eight, or two circles just touching each other—and these correspond to the doubtful cases, the border-line cases, like the case of the tigers, that may with equal justice be regarded as several species or as one. In a word, the twigs in our section would show every sort of relation to each other, every conceivable grade from twigs that are just branching to twigs that lie far apart. And that is how living things present themselves to-day.

Note the importance of this idea from the point of view of the systematist. In ancient, pre-Evolution days it was believed that living things had been created in definite "kinds" according to divine, but nevertheless presumably intelligible plan. It was our business in classifying living things to detect that plan; one started by assuming that species existed and then tried to find out what they were. Nowadays, on the other hand, we know that living things are a slice through a tree, showing every imaginable degree of cousinship, and not falling tidily and infallibly into "kinds." We know that their forms are not constant but changing. And in classifying this assembly, in trying to reduce it to some sort of order and describe it in unambiguous terms, we may choose what conventions we please. Phylum, class, order, family, genus, species, variety—these are words used by general consent to denote the *degree of relatedness* between forms; they are not clearly and categorically distinct from each other, but merge together, arbitrary divisions of what is really a continuous series. It is like saying of our tree-section: "If two twigs are over an inch apart we will put them in different families; if they are over two inches apart in different orders; if they are over three inches apart in different classes." And a species, in particular, is no longer a unit created by God, nor is it a natural unit at all like an atom, or a quantum; it is an arbitrarily defined grouping set up by Man for his own convenience.

From time to time many definitions of species have been

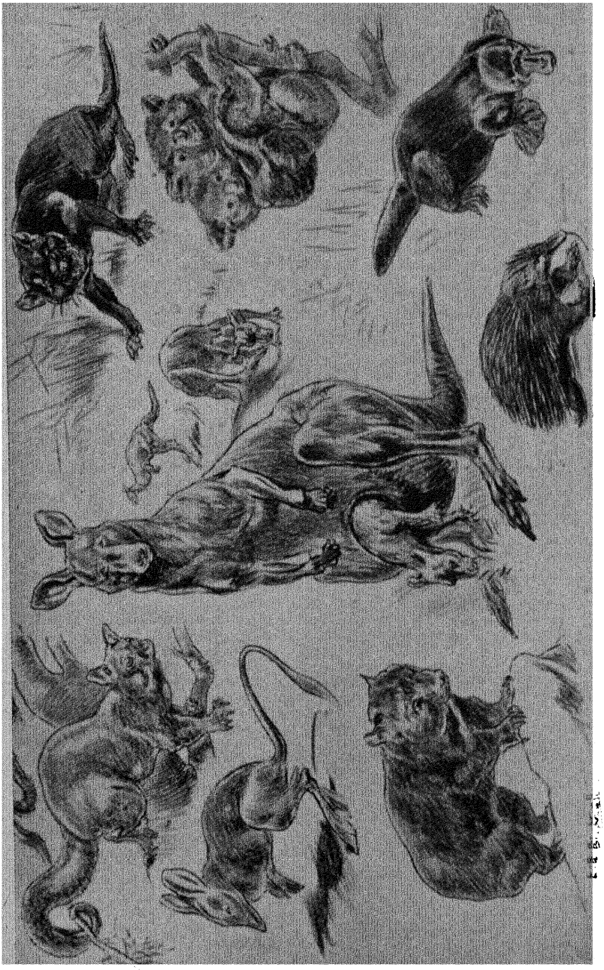


FIG. 23.—SOME PRIMITIVE MAMMALS FROM THE AUSTRALIAN AREA.

Left, from above downwards: Vulpine Phalanger; Rabbit-eared Bandicoot; Wombat (see also Fig. 27). Centre: Kangaroos. (Below): Spiny Ant-eater (Echidna). Right, from above downwards: Tasmanian Devil; Koala, or Native Bear; Duckbill (Platypus).

put forward, tested and rejected. One only is unassailable. It was proposed by Dr. Tate Regan at a recent meeting of the British Association, and it runs: "*A species is a group of animals that has been defined as a species by a competent systematist.*" Taken in conjunction with what we have said that definition is perfectly sound. It brings out two essential points—first, that a species is an arbitrary convenience; second, that an enormous amount of toil on huge numbers of specimens is necessary before a judgment of any value can be reached on a question of classification.

## § 3

### *The Distribution of Living Things*

Everybody knows that different animals come from different countries—the platypus from Australia and Tasmania, the zebra from Africa, the marmoset from South America, the musk ox from Greenland and Arctic Canada, and so on; and the same is, of course, true for plants. But it is not always grasped that different regions differ in respect of whole groups of their animal and plant inhabitants. Contrast the three southern continents: Africa south of the Sahara (that sea of sand which is as much a barrier to life as any sea of water), South America, and Australia. All comprise both temperate and tropical regions; all have their mountains, forests, and open plains. But their animal populations are extremely unlike. If, for the sake of brevity, we restrict ourselves to the mammal population, we find that Africa is characterized by an abundance of antelopes of many kinds, by rhinoceroses, giraffes, elephants, wart-hogs, zebras, lions, leopards, baboons, and buffaloes, and, in the rain-forests, by gorillas and chimpanzees, okapi and many kinds of monkeys. Farther south the coneys or hyraxes and the extraordinary aard-varks are very characteristic. The whole giraffe family, with both giraffe and okapi, is found in no other region, nor is the aard-vark family.

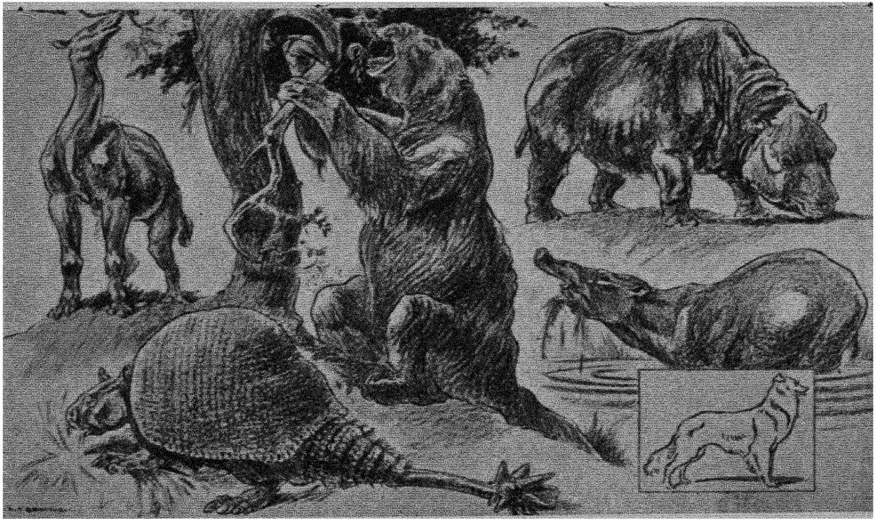


FIG. 24.—SOME EXTINCT SOUTH AMERICAN MAMMALS OF THE LATER CENOZOIC PERIOD (V), AS THEY PROBABLY LOOKED WHEN ALIVE.

Top left: Macrauchenia, one of the Litopterns. Unlike most of its relatives, which took to a horse-like life, this animal was bulky and tall, and probably browsed on the branches of trees. Top centre: Megatherium, the Giant Ground Sloth. This creature closely resembled the existing sloths in its anatomy, but lived on the ground and must have weighed over a ton. Top right: Toxodon, a large herbivore of a unique type. Bottom right: Pyrotherium, representative of another exclusively South American group of herbivores. Bottom left: A form of Glyptodont, very similar in construction to a large armadillo, but with carapace all in one piece, and a knob of heavy spikes on the end of its tail, which it doubtless used as a club. Lower right-hand corner: Outline of a collie dog, to give the scale.

Just as characteristic as the presences are the absences. There are no deer, no beavers, no field-mice or voles, no shrews, no bears, and scarcely any goats or sheep (we are, of course, speaking only of animals found wild).

Contrast this assemblage of mammals with that found in South America. Here live llamas and their relatives, edentates like the sloths, the true ant-eaters and the armadillos, primitive monkeys with prehensile tails, vampire bats, peccaries, tapirs, guinea-pigs, vizcachas and agoutis, opossums. None of these occur in Africa; and most of them are either wholly restricted to South America, or at the most penetrate a little way into Central or North America. The whole order of the true edentates is confined to this region (Fig. 25).

Finally, Australia (with which for our present purpose we must include the neighbouring islands of Tasmania and New Guinea) is more peculiar still. Before the advent of white men, it contained none of the higher placental mammals whatever, with the exception of bats, whose wings, of course, give them facilities for spreading denied to mere land forms, with a few ubiquitous mice and the dingo dog, both probably introduced by the early human immigrants of the country. But by way of compensation Australia possesses a unique menagerie (now, alas, rapidly dwindling, with many species in danger of extermination if protective measures are not introduced) of the two lower sub-classes of mammals, the pouched marsupials and the egg-laying monotremes.

In point of fact, no egg-laying mammals occur outside this area, and no marsupials, except the American group of opossums, and one curious little creature called Cœnolestes, with teeth in some ways recalling those of kangaroos, from South America. All the rest are Australian—kangaroos and wallabys, cuscuses and phalangers, wombats and bandicoots, marsupial wolf and Tasmanian devil, pouched ant-eaters and pouched moles and pouched mice—some forty genera, with hundreds of species. Add to this the platypus and its egg-laying confrères, the spiny ant-eaters, and you have indeed a strange zoo.

Now, it might naturally be supposed, and in the past often was assumed, that each species and each group lived in the region best suited to it. But such is demonstrably and obviously not the case. New Zealand has no native mammals save a bat or two and possibly one species of rat—and yet introduced mammals thrive and multiply. Rabbits, for instance, have run wild over large areas, and red deer introduced from Scotland have not only thriven, but have grown much larger than they ever do in their native land. Then the house-sparrow has spread and the starling is spreading over the whole of North America, in spite of the competition of the hundreds of kinds of native birds. The few horses introduced by the Spanish conquerors of South America multiplied and ran wild in huge herds over the pampas. Far from the native Australian birds and animals being especially well adapted to Australian conditions, they are no match for the species that have been introduced from other regions. The mere mention of rabbits will make an Australian farmer cross. And when we come to plants we find that one of the gravest problems of agriculture in various countries, notably New Zealand and Australia, is to prevent introduced species like the prickly pear and blackberry from overrunning the country and ousting not only the native plants, but man and his agricultural efforts as well.

Why then are whole groups of related animals tied down to limited regions of the world? What meaning is there in the restriction of the giraffe family to Africa, the whole of the edentate order of sloths and armadillos and ant-eaters to Southern America, all the monotreme sub-class and almost all the marsupials to Australia?

The answer is to be found in the past, in the history of evolving life in relation to the history of the seas and continents. Through fossils we are able to discover not only the past development of existing groups, but also their past distribution in each epoch. Geology, on the other hand, can tell us a great deal about the extent of the sea and land in past periods. It can do this by studying where in each

FIG. 25.—SOME CHARACTERISTIC ANIMALS FROM SOUTH AMERICA.

Top row: Tamandua (Tree Ant-eater, an animal probably subsisting in the main upon tree-living Termites); Humboldt's Woolly Monkey (with prehensile tail, like most New World monkeys); Great Ant-eater (with huge claws for tearing down the cement-like walls of the nests of ground-living Termites). Centre: Huanaco (related to the Llama); Three-toed Sloth (an animal which spends most of its life hanging upside down from the higher branches of trees; it resembles its surroundings by being coloured green through the growth of a species of single-celled green plant in special crevices in its hairs); Marmoset (one of the smallest and most primitive of New World monkeys). Bottom row: Nine-banded Armadillo (a type which has spread from South America to the southern United States); Opossum (a species in which the young are not carried about in the pouch, but anchored by their tails to the tail of their mother); Vizcacha (a large rodent).

epoch marine deposits were laid down, where there were deserts, or evaporating inland seas which produced beds of salt, where the invading ocean had carved beaches, where ice-sheets had passed or mountain-ranges had been elevated. Through such evidence, geology is able to say definitely that the present distribution of land and water is in no way permanent. In the past, the main land-masses of the world have been connected and disjoined in many other ways ; and geology can often tell us just when and where the connections and partings were made, and what was the distribution of seas and continents during a particular geological period.

Animals such as land-mammals can and do migrate slowly until they are spread over the whole of a land-mass. But there are barriers which they cannot cross. The sea is the most formidable of such barriers, ice-sheets are another, and broad deserts may be nearly as bad. Thus, the distribution of any group of land-animals will depend upon three factors —first, upon the region where the group happened to originate ; second, upon the connections which this region then and later happened to have with other land-masses ; and third, upon the fate of the group in the different regions to which it obtained access.

If mammals first evolved after New Zealand had been cut off by a barrier of ocean from all the continents, we should not expect to find any land-mammals in New Zealand. If lung-fish were once widely distributed all over the world, but later were all but extinguished in the struggle for existence, we should expect to find the few existing lung-fish scattered in isolated regions which happened to favour their survival ; it is along such lines that our reasoning must run.

The key to the present distribution lies in past distribution. When palæontology and geology are able to provide us with evidence, the distribution of animals and plants ceases to be a puzzle and becomes a simple matter of history. In the same way the distribution of human races, often so puzzling at first sight, clears up directly we know the history of their movements. The Mongol Turks in Asia Minor, or the fair-haired Lombards in Northern Italy, are at first sight anomalies; but with a knowledge of their migrations, the problem disappears. The only difference with animals and plants is that the periods of time involved are so huge that transformation as well as mere migration of stocks comes into play.

With these ideas in mind, we can turn back to the three

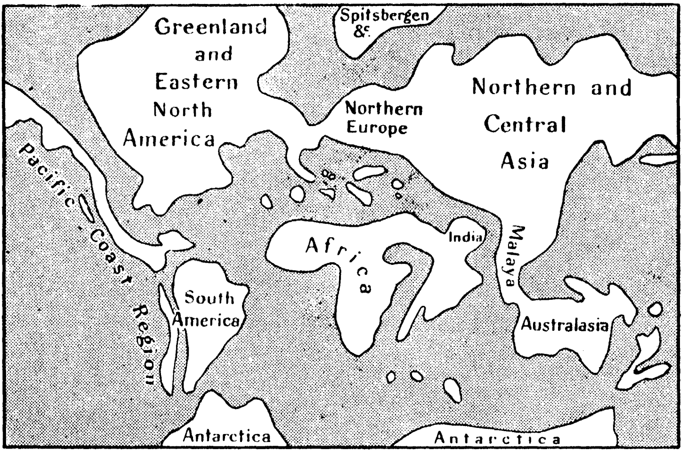


FIG. 26.—HOW THE MARSUPIALS COLONIZED AUSTRALIA.

The probable distribution of land and sea about half-way through the Cretaceous Period (IV C). In the shallow seas extending over what are now Western America and much of Europe, chalk was being deposited. Not only was the main block of North America connected with Europe, but the Cretaceous marsupials were able to pass across from the Eurasiatic land-mass to Australia. This land-bridge was soon afterwards broken, and Australia isolated. (Modified from Schuchert.)

southern continents and their three wholly different sets of animal inhabitants. First comes Australia and its marsupial menagerie. During most of the late Mesozoic Era (IV), Australia was connected with the rest of the world. Whether there existed a land-bridge to Asia, or, as many are inclined to believe, to Antarctica and thence again up to Cape Horn, or whether, as Wegener thinks, it once formed a part of a great southern continent which was later broken up, we must leave to the geologists to settle; in any case it is immaterial to us. We know that true placentals did not appear on earth before the later Cretaceous (IV C), that the earlier, Mesozoic (IV), mammals were akin to monotremes and to marsupials, though mostly even more primitive in type, and occurred all over Europe and North America. All of them, however, were very small, and they showed little variety in their ways of life. Some time in the Cretaceous (IV C) these primitive marsupial and monotreme mammals penetrated into Australia; the land-connection between it and the rest of the world was broken, before any placentals could enter. Australia thus became the marsupial's Ark—with the important difference that they did not stay merely a year and ten days in it like the animals in Noah's Ark, but over fifty million years. Indeed, it was to them like a combination of Ark and Promised Land. For during that long time they flourished and were able to give rise to new and varied forms of life not found in any other region of the world. These possibilities of the pouched mammal were never realized elsewhere, since in all other regions the marsupials were kept from rising or exterminated by the competition of the placental hordes, biologically more efficient in the protection of their unborn young and in the construction of their brains.

Now that modern man has introduced placentals into Australia, the marsupials are no match for them, and are dying out. The development of the varied marsupial life of Australia was due to biological Protection. Competing imports were barred. Home industries flourished, but their products never came up to those resulting from a more rigorous competition.

South America, on the other hand, was open to the North in early Eocene times (V A 1), but only for a short time. This allowed representatives of some, but not all, of the early placental mammals to enter, and the connection was then broken, not to be re-established till the close of the Miocene (V C 3), perhaps thirty million years later. Thus the inhabitants of South America, like those of Australia, were for long preserved from the full stress of competition; the difference lying in the fact that it was not marsupials, but early and primitive placentals, which there found an Ark.

Similar results followed in both regions—the development of creatures elsewhere unknown, the flowering denied to primitive types in more strenuous regions.

The chief factor contributing to this local evolution of South American types was the total absence of carnivores and of true ungulates. The only flesh-eating mammals were primitive marsupial types, all now extinct. The absence of more specialized beasts of prey permitted a great number of sluggish, large, and inoffensive creatures to come into existence, such as armadillos and their allies, sloths, big rodents like the tree-porcupines and vizcachas, opossums, and ant-eaters; while the absence of those best-developed of herbivorous running machines, the true ungulates, permitted other stocks more or less adequately to fill the gap thus left in life's economy.

We have already mentioned the remarkable if slightly inferior imitation of horse-evolution achieved by what we may call the pseudo-horses, the Litopterna. Among other remarkable ungulates not found elsewhere were the ponderous Toxodonts, with their peculiar incisor teeth, many of them outdoing the rhinoceros in bulk; the equally ponderous Typotheres, with almost rodent-like chisel-edged front teeth; other great herbivores with toes retractile like a cat's; the Astrapotheres, with two pairs of enormous tusks like exaggerated boar's tusks, and very stumpy limbs and neck. Finally, we have the extraordinary Pyrotheres, which not only grew as large as elephants, but paralleled certain features of the elephant stock in their huge teeth and their projecting tusks; they were unlike all other mammals in having the fore-arm and lower leg disproportionately short, scarcely more than half the length of the upper part of the limb, which must have given them a very grotesque appearance.

These were all flourishing, with many other groups such as the sloths and armadillos, when in the late Miocene (V C 3) the corridor was again opened to the north. It let in dogs and foxes, cats great and small, sabre-tooths, tigers, and bears, together with horses and deer, peccaries and llamas, mice and squirrels.

From this time on there was competition between the two sets of animals, the old and the new. The old types were not beaten at once, for many of them did not attain their maximum size or abundance until later. But the final result was decisive, and the great majority of them perished wholly from the face of the earth.

It is interesting to remember that it was perhaps the South American fossils which first turned Darwin's thoughts to the idea of Evolution. When he was going round the world on the *Beagle*, and occupying himself with everything from coral islands to the problems of structural geology and from the habits of savages to the structure of extinct animals, he excavated a number of the abundant fossils found in the wide-spreading Pleistocene beds of the South American pampas.

Among the skeletons there preserved are those of such remarkable creatures as the gigantic Megatherium—bulky as an elephant—whose construction made it able to pull down the branches of trees to browse on, and the eight-foot Glyptodon, a veritable animal tank, protected by a dome-shaped cuirass of heavy bone. As soon as their structure is examined it becomes obvious that the Megatherium was a sloth adapted to ground life, and that the Glyptodon was simply a giant armadillo which could not roll up.

What struck Darwin's imagination was the fact that, while these and other fossils belonged to the characteristically South American group of edentates, they were different from any living edentate. If the edentates had from of old been confined to South America and there had been able to evolve into many different types, some of which were extinguished to leave their bones as fossils, the facts would be understandable. Otherwise the existence of fossils similar in all general points, but dissimiliar in detail to the living animals, and the fact that all are found in one region of the world and one only, become very difficult to understand.

About the same time, though quite unknown to Darwin, a precisely similar story was being unfolded in Australia. Clift and Jameson had been collecting and studying the fossils of Australian caves and breccia beds dating from the Pleistocene (V E); and these creatures, often now wholly extinct, all revealed in their structure that they belonged to the marsupials, and only to those groups of marsupials still living in Australia. We may mention here the Thylacoleo, as big as a leopard, which is a phalanger adapted to a flesh diet; and the gigantic Diprotodon, almost as large as the Megatherium, which was closely akin to the kangaroos, though far too big to hop. Clearly the facts are parallel to those which impressed Darwin on the pampas. The marsupial stock which we find in Australia to-day (V F) must have been there for long periods, and it has evolved and changed its composition since Pleistocene (V E) times.

Africa is characterized by no such primitive types of animals as either South America or Australia. It seems to have been cut off from the main centres of mammalian evolution by the Sahara for a long time. It received its first land-mammals in the Oligocene (V B), after marsupials and the first clumsy Eocene (V A) placentals had disappeared from Asia and Europe. After this first irruption the way was again closed, to open again (probably on the eastern side of the Sahara, across to Asia by Arabia and Syria) only in the Pliocene (V D). The second and larger irruption which then followed gave Africa the bulk of its existing animal types; since then there has been evolution in many details, but no great changes. The door was then again closed, or at most left ajar, so that Africa thus became an Ark for a large sample of the Pliocene Old World mammals. Some, like deer and bears, had failed to find the door before it shut again, and there are none of them in Africa; but the rest throve and multiplied in the broad, equatorial stretches, while the drought and cold of the Ice Age dealt hardly with their congeners who had stayed in the north.

Just as stretches of sea act as barriers to purely terrestrial animals, so stretches of land bar the migrations of the inhabitants of the waters. The upheaval which in Miocene times (V C) created the Isthmus of Panama and the land-bridge between the two Americas, put an impassable barrier between the marine animals of Atlantic and Pacific, at least between those which could not face the cold of southern seas. As a result, no fewer than six hundred cases are known of pairs of fish-species from the coasts of Panama, one member of each pair from its Pacific, the other from its Atlantic shores, the two closely related, but different in some trivial but constant character. Original identity explains the similarities; independent evolution for some twenty million years has produced the differences.

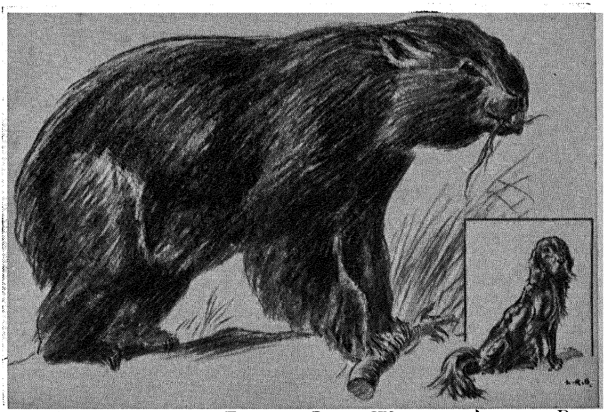


FIG. 27.—DIPROTODON, THE EXTINCT GIANT WOMBAT, FROM THE PLEISTOCENE (V E) OF AUSTRALIA, AS IT PROBABLY APPEARED IN LIFE.

Like so many large animals in different parts of the world, this creature died out during the last Ice Age. Inset, a small spaniel, to give the scale.

Another example, very similar in its watery way to the case of the Australian land-masses, is provided by Lake Baikal, the great, isolated sheet of fresh water that lies in

Southern Siberia. Since it was formed, possibly in the Mesozoic Era (IV), certainly before the earlier part of the Cenozoic (V), it has been without any close connection with any other large body of water, fresh or salt. The huge lake, over 400 miles long and in some places nearly 5,000 feet deep, holds out the most varied opportunities to water-living animals; but most of the kinds of animals which elsewhere take advantage of similar opportunities were absent in it from the start. As a result, other types, which elsewhere remain monotonous and feebly developed, have here blossomed out in extraordinary variety and fill the most important places in the economy of the lake.

This is so with certain kinds of fish, but pre-eminently so with a particular crustacean family, the Gammarids. To this belongs the familiar sand-hopper which swarms under moist seaweed on our sandy beaches, together with a goodly number of other types, freshwater as well as marine. Members of this group were in Baikal from its beginnings. Finding there what was denied them in all other parts of the world, a large and friendly home where there was no competition from more developed crustacean types, such as crayfish and crabs, and shrimps and prawns, they have done their best to take the place of higher Crustacea. In this single sheet of water they have evolved into over three hundred different species—more than as many as are to be found in all the rest of the world—and many of them belonging to purely Baikalian genera. They have launched out into the most varied occupations. There are deep-water Gammarids, blind but with long feelers to compensate for the loss of sight, living at 300 fathoms; there are Gammarids which swim all their life in the open water deep below the surface, and are transparent as any jellyfish; there are large shore-living Gammarids, four inches long—sand-hoppers doing their best to be lobsters; and so on. Here again, freedom from competition has allowed the surprising evolution of a group which elsewhere has had to keep its potentialities locked up, unrealized.

Isolation of a piece of land or a body of water from the rest of the world always permits its animal and plant inhabitants to evolve along their own peculiar lines. This is not only true for large groups, like the sand-hoppers in Baikal or the marsupials in Australia, but also for genera and species and varieties. We shall have more to say on this subject when we come to discuss the machinery of Evolution. Here we will content ourselves with but two examples, one of which, however, is of considerable historical interest. Those who are interested in the subject can pursue it in Wallace's famous book *Island Life.*

If a find of fossil animals on a large continent first put Evolution as a seed of thought into the fertile soil of Darwin's mind, the germination of that seed was brought about by a problem of present-day distribution on an isolated archipelago. The *Beagle* visited the Galapagos Archipelago, a collection of some fifteen volcanic islands, separated from each other by distances ranging from a mile or so up to nearly 100 miles, lying on the equator in the Pacific. The nearest mainland is the west coast of South America, 600 miles away. The account Darwin gave of them has been supplemented, though not supplanted, by Dr. Beebe's beautifully illustrated book, *Galapagos.* These islands, as Darwin pointed out, resemble the Cape Verde Archipelago, off the African coast, in soil, climate, height and size of the islands. In a world deliberately planned and created they would be populated by the same kinds of creature; what suits one suits the other. But they are not. Their animal and plant inhabitants are totally different. The inhabitants of the Cape Verde Islands are related to those of Africa, those of the Galapagos to those of America. On the Galapagos "there are twenty-six land-birds; of these twenty-one, or perhaps twenty-three, are ranked as district species, and would commonly be assumed [when Darwin published this passage, in 1859 !] to have been here created; yet the close affinity of most of these species to American species is manifested in every character, in their habits, gestures, and tones of voice"

—and so with the other animals and plants of both archipelagos—they are closely related to, though often slightly different from, those of the nearest mainland.

Thus, here we have the same fact, of difference in species but resemblance in general type, which emerged from the fossils of the other side of the South American continent, only now the differences and resemblances concern two sets of creatures separated in space instead of in time.

Such facts at once receive an explanation in terms of Evolution. Chance immigration of storm-pressed birds, wind-blown seeds, tortoises or their eggs drifted in logs or brushwood, would people the archipelago from the continent; this, followed by new evolution in the new and isolated home, would account both for the resemblances and the differences between the inhabitants of the archipelago and those of the neighbouring mainland. But in terms of the Creationist view, there is no explanation.

As our second example we choose St. Helena. St. Helena is perhaps the most isolated spot on the globe, the most insular of all islands. Well over half of its two hundred species of insects are to be found in no other region, and three-quarters of its thirty snails, and four-fifths of its flowering plants: and it boasts no mammals, no land-birds, no reptiles, no amphibia, no fresh-water fish and no fresh-water plants. In other words, animals and plants have either wholly failed to reach this water-girt speck of land; or, if they have succeeded, have usually evolved and changed into something new.

But it is not only the living things which are present in a given region which have testimony to offer us. The absences may be as significant as the presences, just as silence may sometimes be as eloquent as speech. On this score the Galapagos and St. Helena and other oceanic islands—islands, that is to say, of volcanic origin, which are separated by many miles of deep water from the continents, and apparently have never had any connection with the mainland—have much to tell us.

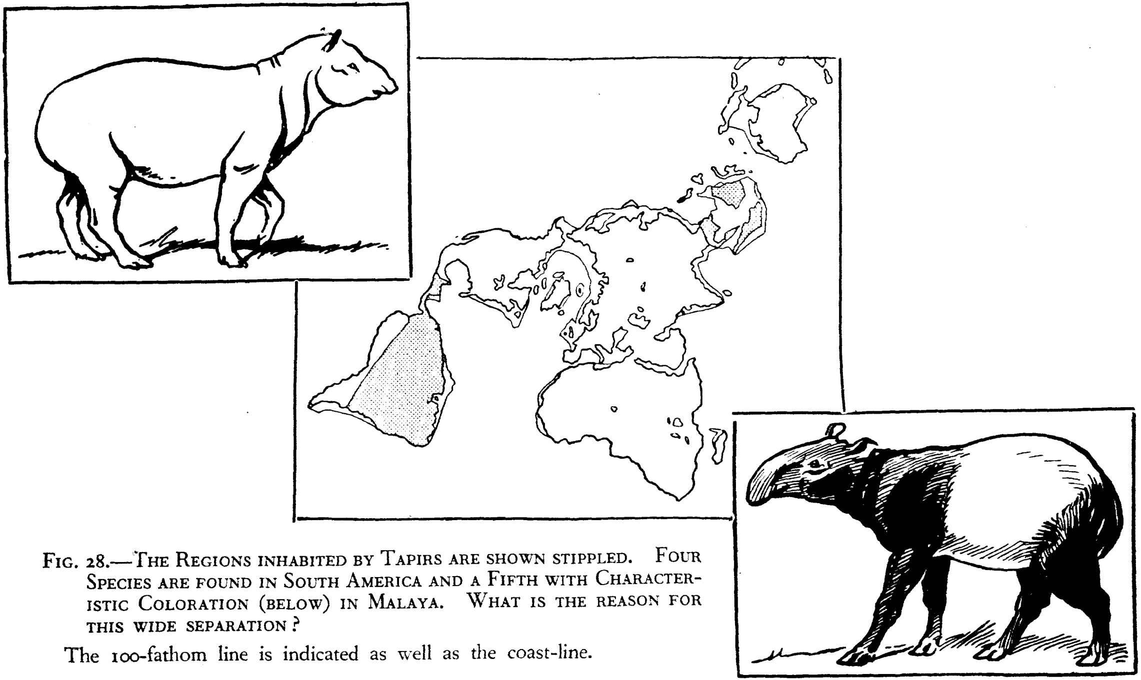


Fig. 28.—The Regions inhabited by Tapirs are shown stippled. Four Species are found in South America and a Fifth with Characteristic Coloration (below) in Malaya. What is the reason for this wide separation?

The 100-fathom line is indicated as well as the coast-line.

If different animals were created and placed in the countries best suited to them, why is it that oceanic islands never possess more than a sprinkling of land-animals and birds and flowering plants, and never any amphibians or land-mammals (except sometimes the too-readily transportable mice)? It is emphatically not because such animals are unsuited to life on islands, for rabbits and goats, cats and frogs thrive well enough when introduced, and often so much too well that they become a pest.

But if the distribution of living things is the result of evolution and migration, the reason is plain. It will never be easy for such isolated patches of earth to be colonized by life at all; only those forms with remarkable powers of dissemination by air or water will reach them. Land-mammals and amphibians have notoriously poor powers of dispersal; they cannot survive long exposure to salt water, nor have they any resistant stage in their life-history which can either be blown on the wind like the spores of lower plants, or resist salt water like the seeds and fruits of some higher plants.

The same reasoning applies to New Zealand. New Zealand is not volcanic like true oceanic islands, but it includes only one amphibian and, apart from bats which can fly, only one land-animal—a rat, which may very likely have been introduced by the Maoris. It is separated from the rest of the continents by such distances, and has been separated for so long a time, that its animal population, at the time of its discovery, was in most ways like that of a real mid-ocean volcano. Yet all the time it was most admirably suited to support those very forms of life which it lacked. The zeal of its acclimatization societies has stocked it with all kinds of European birds and animals and plants, many of which have found the country so much to their liking that they have become most abundant nuisances.

Finally, we have a third set of facts, the facts of discontinuous distribution, when almost identical animals are found only in two or three widely separate regions of the world's surface. Why in the name of all that is reasonable are tapirs found only in South America and Malaya? Why is one branch of the camel family, the camels themselves, found only in Asia and North Africa, while the other, the llamas and their kin, grows only in South America? Why are the lung-fish found only in Australia, tropical South America, and tropical Africa? Here geology solves our riddle. The discontinuity did not always exist: the type was once widespread, but to-day has been exterminated save in a few patches. Lung-fish were among the most abundant of fishes in Devonian (III D) and Carboniferous (III E) times, and were then spread over the whole world; the competition of later-evolved and more efficient fish extinguished almost all of them, and only three representatives have managed to survive, in three patches of tropical freshwater.

The camels can be traced back to the Eocene (V A). Their remains are found at first only in North America. Thence, during the Miocene and Pliocene (V C and D), they spread across two newly-emerged land-bridges both southwards into South America and westwards to Asia. The two emigrant stocks went their own evolutionary ways to what we see to-day, while in their original home the family was abruptly extinguished in Pleistocene times (V E). Finally, the tapirs too, like the lung-fish, were once widely spread. They are known as fossils from various Cenozoic (V) beds in both North America, Europe, and Asia. Doubtless they early penetrated into India and Malaya, and invaded South America by the Miocene (V C) land-bridge from the north. They have been reduced to their present distribution simply by extinction in the regions between.

Discontinuous distribution; the predominance of different groups of animals in different continents; the existence of unique species on remote islands; the total absence of many creatures from countries where they are able to thrive and multiply when introduced—these and many other facts of distribution are concordant.

If the assignment of different kinds and groups of animals

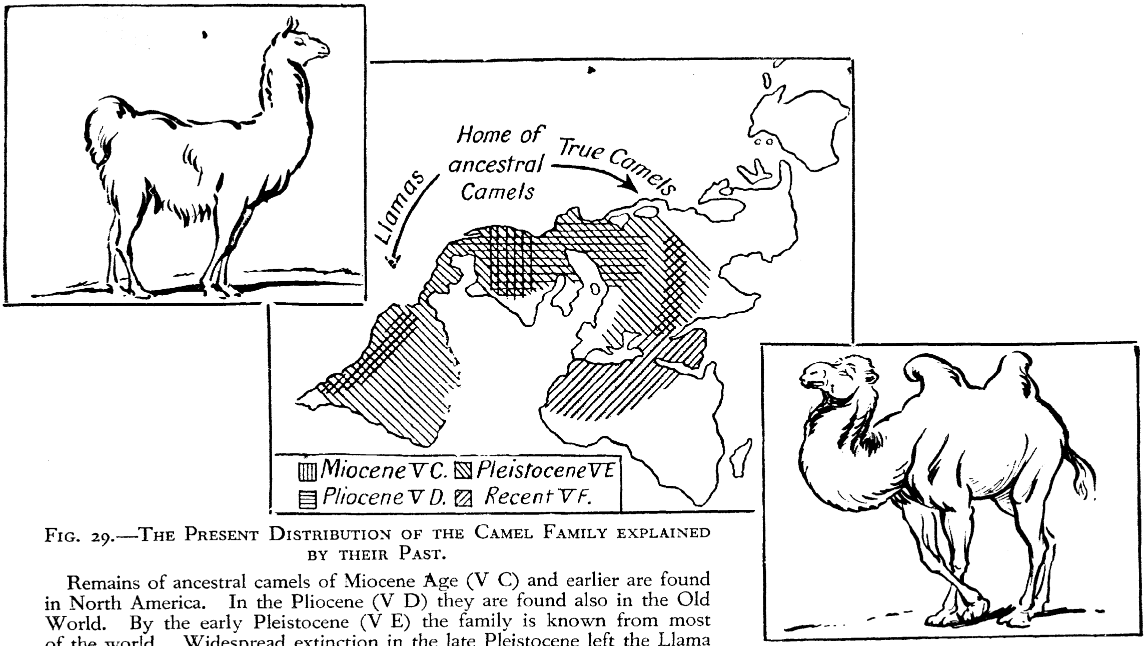


FIG. 29.—THE PRESENT DISTRIBUTION OF THE CAMEL FAMILY EXPLAINED BY THEIR PAST.

Remains of ancestral camels of Miocene Age (V C) and earlier are found in North America. In the Pliocene (V D) they are found also in the Old World. By the early Pleistocene (V E) the family is known from most of the world. Widespread extinction in the late Pleistocene left the Llama branch in South America, the true Camels in Central Asia and North Africa. (Outline of land-masses shown at the 100-fathom line.)

to different regions of the earth's surface was made by a Creator, one is forced to admit not merely that these facts are unintelligible and even meaningless, but that the assignment was often definitely unfortunate. But if we are Evolutionists, the chaos becomes order, the mob of facts becomes a marshalled army, held together in complete consistency by that dominating idea.

The perplexities and apparent paradoxes of geographical distribution attenuate and vanish in the light of two chief principles of interpretation: the principle that connects isolation with divergence of type, and the principle of looking in the past for the explanation of the present. Both principles rest upon the concept of Evolution as their basis. Without that basis we should have to relinquish all hopes of rationalizing animal and plant distribution, just as we should have to give up all hopes of rationalizing recapitulation, or vestigial organs, and to abandon the possibility of a science of comparative anatomy.

## § 4

## *The Evidence Summarized*

We have now passed in brief review a small fraction of each of the main kinds of evidence for Evolution. We have found that the rocks of earth's crust make a book where our planetary history can be read, and that they contain fossil remains which, when deciphered with the same care which an antiquary bestows upon his inscriptions, yield knowledge as definite as any which he obtains, though it refers to epochs a hundred thousand times as remote. The fossils, dated by the rocks, reveal the actual story of life's past changes. The story does not go back to life's first beginnings, nor does it cover all kinds of living things ; but for the latter half of life's existence and for the most elaborate and interesting of life's children, it is reasonably complete. And the story the fossils reveal is one of steady evolution, of progressive change, of multiplication and divergence of forms of life, of extinction of one type and its replacement by another. The fossils are the remains of creatures other than those of to-day, which once were alive, living a different kind of life in different surroundings. They testify to the past of animal and plant life in the same direct way as do the mummies of the Pharaohs, or the baked-clay bills and receipts of prehistoric Babylon, or the slaughtered retinue of the King of Ur, to the past existence of human beings who lived very different lives from ours; they testify to the evolution of life as directly as do the discoveries of archæology to the evolution of human culture.

Then there are the indirect evidences. There are the similarities of general plan which are not to be accounted for save by the descent from a common ancestor of all the animals showing the plan. The similarity of plan implies common descent; the differences in detail imply descent with modification. There are the useless vestiges which yet correspond rigorously with organs that are indispensable in other animals, inexplicable if their possessor be not descended from some ancestor in which the now useless organ had its use. There are the extraordinary phases of the individual's development in which it passes from one strange likeness to another—likenesses to other creatures, often remote and primitive, to which the adult animal no longer betrays any resemblance, whether in plan or in mode of life. These resemblances are meaningless, and, indeed, deceptive, if they are not recapitulations of ancestral phases in which the race once continued for long periods of past time, though our modern creature hurries through them on its way to its own new and different adult life.

All these facts are inexplicable on any theory of special creation. Save Evolution, no rational explanation of them has ever been put forward; and on the evolutionary view not only are they explicable, but full of meaning.

We reviewed the evidence from life's variability. If we laid more emphasis upon it than has often been done in the past, this is because the evidence from variability, like that from fossils, has of recent years increased enormously, both in account and still more in cogency. Now that a number of groups like birds and mammals and butterflies have had their minutest varieties classified and the details of their distribution tabulated, the old idea that species are the most real and definite units of life, or even that they are real and definite units at all, sharply marked off from other kinds of units, has gone by the board. There do exist some sharply circumscribed species-units; but other such units intergrade or interbreed with one another. There is no crucial test by which we can distinguish between a local race or a sub-species and a species, or between a species and a genus. There is often disagreement among systematists themselves as to whether a particular kind of animal or plant shall be classified as a full species or a mere variety. There exist interbreeding groups so variable that we would regard the extremes of variation as different species did we not know of the existence of all the intermediates. All this lack of sharp lines and clear limits is to be expected if life's method is Evolution; but on the Creationist assumption it is chaos and confusion.

FIG. 30.—A MAN AT ABOUT TWO MONTHS OF TRUE AGE.

Front view of a human embryo, four-fifths of an inch long, about seven months before birth.

The considerable degree of variability to be found in all wild forms of life was emphasized, and the conclusions to be drawn from this fact were driven home by an appeal to the astounding changes which man has been able to bring about in his domestic animals and plants. If greyhound, bulldog, toy terrier, and St. Bernard can all be formed out of wild-dog material in a few thousand years, then that living material is of an extraordinary plasticity, and will lend itself willingly enough to change and evolution.

And finally we have recited some of the facts of the distribution of animals and plants, and have shown that they, too, fall into place and become intelligible to the Evolutionist, but remain stubbornly meaningless on any other view.

All these lines of evidence lead to the same conclusion. The way in which each one corroborates all the others is impressive enough, but let it not be forgotten that the actual examples we have chosen are but a fragment of the mass available. If an idea is true, it will apply in every part of its domain. The domain of the idea of organic evolution is the whole domain of life; and the final evidence for Evolution is that throughout the whole domain the idea of evolution helps our comprehension. It explains old discoveries and leads us on to new; it draws order out of confusion; it gives meaning to what is otherwise meaningless, and brings thousands of isolated facts into a single related whole. There is not one single character or quality of human beings, from the construction of their skeleton to the flush on their cheeks, from their embryonic development to their moral aspirations, which does not become more comprehensible, more interesting in itself, and more significant for the future, when viewed in the light that Evolution sheds upon it. Whether we are dealing with the cone of a pine-tree or the skull of a bird, the fertilization of a flower or the instincts of an ant, Evolution illuminates why they are what they are. And there is no other imaginable illumination.

# CHAPTER V

# THE EVOLUTION OF MAN

§ 1. Man: a Vertebrate; a Mammal; a Primate.
§ 2. Fossil Men. § 3. Man's Body: a Museum of Evolution.
§ 4. Man's Place in Time

## § 1

### *Man: a Vertebrate; a Mammal; a Primate*

THERE is no need to stress the physical likeness of the higher apes, chimpanzees, gorillas, or orang-outangs to ourselves. The crowds which gather round their cages in the Zoo are a testimony to this resemblance and the interest which it inspires. Nor is the likeness one of physical structure only: we have but to watch a mother orang with her child, or a young chimpanzee at play, to realize how deep the similarity of behaviour goes. The mother dandles her baby in her arms, kisses it, strokes its head; her gestures and the play of expression on her face have an often pathetic likeness to a human mother's.

But it is perhaps not often realized how extremely close the resemblance is, and how, if a Martian scientist, with no personal prejudice on the subject, had been given the task of classifying the animal inhabitants of our planet, he would at once have put man in the same small group as the tailless apes with the same lack of hesitation with which he would have classified the hive-bee and the solitary bee together; and how quite unintelligible he would have found the long failure of human naturalists to take this step, and the storm of protest which arose when at last a few bold and logical spirits dared to take the objective view of man's place in Nature.

The closeness of our likeness to the apes may best be realized by measuring it against our likeness to other vertebrates. Take a man's body and compare it with a frog's. A man is really very like a frog in the general plan of construction: both have internal skeletons made of bone; a spinal cord running along the back, enclosed in the backbone's tunnel; brain in a brainbox; eyes, ears, nose, mouth, and teeth in the same general relation; two pairs of limbs, with skeleton corresponding almost bone for bone; and a close resemblance in the plan of their internal anatomy. Their chemical arrangements, too, are quite alike. Both have livers which break up amino-acids and store sugars as glycogen; both have a pancreas which secretes trypsin; the adrenalin manufactured by the frog's adrenal glands is not only like but chemically identical with the product of the adrenal glands of man.

In these and scores of other ways a man is not only like a frog, but unlike the vast majority of animal types. The man-frog plan of structure and working is definitely unlike that of a cuttlefish, or an ant, or a crab, or a leech, or a sea-urchin. In zoological terms, men and frogs are vertebrates, and these other animals are not.

On the other hand, if we draw a few other vertebrates into our comparison, we see at once that there are degrees in their likeness. Man is more like a frog than a fish, for frog and man both possess lungs and fingered limbs, and a fish does not. But man is less like a frog than a dog, for man and dog have both hair, and divided hearts, and warm blood, and teeth of several different sorts, and milk, and young that are nourished in the womb; and frogs have none of these things. In terms of classification, men and dogs are mammals, frogs are not.

But, again, a man is less like a dog than a chimpanzee. For man and chimpanzee have nails, not claws, and grasping hands with the thumb opposable to the rest of the fingers, and limbs for walking and climbing; they have no tail; their females have monthly periods and a single pair of breasts; their brains are large and deeply furrowed and convoluted. And in all these ways and many others, notably in their teeth, they differ from dogs. In zoological terms, men and apes are primates, dogs are carnivores.

But the resemblance between man and chimpanzee is much closer than these facts alone would indicate. We have already seen how close is their invisible, chemical resemblance. Then the visible resemblance permeates every detail of their anatomy. Their skeletons are not merely alike in general plan, but correspond actually bone by bone; the grinding teeth are extremely similar in pattern; the ape's hands and face and expression are all but human. In a number of points the chimpanzee or the gorilla differ more from the other great apes than they do from man. It used to be asserted that there existed definite structures in man's anatomy, especially in his brain, which were absent in apes. T. H. Huxley, as far back as 1863, demonstrated in his classical essay, *Man's Place in Nature*, that this was not true. The differences between human structures and ape structures are only differences of degree. Man's brain and brain-case are proportionately larger; but, as Elliot Smith has shown us, this increase is due to the enlargement of parts of the brain already present in the ape—the parts concerned primarily with the faculty of association—and no brain-organs are to be found in man which are not also to be found in apes. The dog-teeth of us men are smaller, and so are our big toes, but our thumbs and chins are larger. We have adopted the upright position, and our anatomy shows minor changes as a result. Our legs are straighter than apes'; our spinal cord is bent in a different way; our pelvis, besides still affording attachment to dozens of muscles, has been turned into a flat basin which supports the internal organs of our abdomen; a new development of the gluteal muscles is needed to hold us upright, with the result that our "lower back" protrudes in a way unknown among animal buttocks; our head is poised on a straight

FIG. 31.—ORANG-OUTANGS, YOUNG AND OLD, DRAWN FROM LIFE.

At home in the family circle; mother transporting her baby; young hopeful resting, and hanging by one leg. Lower right, an old male of the variety which has a fleshy fold round the face in place of whiskers.

pillar of a neck, instead of protruding forward. Our jaws and the bony ridges over our eyes are smaller, our noses and chins larger. Apart from brain-size, the reduced amount and length of hair on the human body and the less hand-like construction of the human foot are perhaps the most obvious differences between man and ape, but even they are only differences in proportions and amounts, no whole structures being gained or lost or transformed into something radically new.

And when we come to behaviour and the mind at the back of behaviour, the chimpanzee is far more like a man than like a frog. To begin with, the actual raw material of an ape's experience, the data provided by its senses, differ from a frog's but resemble our own in many points. The frog lives in a world of black and white; apes, like us, in one enriched with colour. The apes, like us, have a " yellow spot " in their eyes, making them capable of exceptionally accurate vision; the power of discrimination in a frog's eye is much poorer and it pays no attention to any but moving objects. The frog can hear, but its miserable little bag of a hearing organ compares very poorly with an ape's long, coiled cochlea. The range of sound which our ears permit us to hear and the delicacy with which we can discriminate between different tones are almost identical in ourselves and in apes; but the sound-world to which the frog has access is limited and crude in comparison. In one respect, however, the frog has the advantage over us and over the apes. Its whole skin possesses organs of chemical sense, which in us are confined to the moist coverings of nose, eye, mouth, and other mucous membranes. Thus it is able, albeit it would seem in a very crude way, to smell or taste or at least to be stimulated by various chemicals, all over its body. Finally, what emotions a frog possesses appear to be few in number and low in intensity—wholly unlike the extremely human passions of apes.

But if the very bricks out of which it builds its mental life are different from ours, its ability to build with them is no less different. The frog has powers of learning and association, but so feeble that we find it difficult to realize the extent of a frog's inability to profit by experience. Almost the whole of its actions are reflex, predetermined for it from the start by the inherited constitution of its nervous system. The ape, like ourselves, has its due share of reflexes and its complement of inborn instincts with their accompanying emotions; but, like ourselves, it can not only learn, but learn rapidly. Though its actions, like ours, are always built on foundations of reflexes and instincts, yet the great majority of them are what they are because of the animal's individual experience. In a frog's life, learning by experience plays an insignificant part; it plays a preponderant part in a chimpanzee's.

This would be true of a dog as well as an ape, but the ape can go farther than this. One chimpanzee studied by Professor Koehler, though wholly untaught, had the idea of fitting one stick into the hollow end of another in order to get at a banana which was out of reach of either stick by itself; and to do that is to anticipate experience by thought. This observation is only one of many, but it must suffice us for the present. What concerns us here is the fact that chimpanzees and other true apes do have this faculty of anticipating experience, of putting two and two together so as to deal with a new kind of situation in an intelligent way, and that this power, in spite of the most careful tests, has never been detected in any lower animal, even in tailed monkeys. Many animals have that form of intelligence, which we may call intelligent learning, but no others show deliberate invention. It is true that the ape's free ideas are very rudimentary when compared with ours. None the less, our chimpanzee who, instead of doing nothing at all, or of aimlessly fiddling with his two sticks until one chanced to fit into the other, saw beforehand that they would fit and would then serve his purpose—he was, albeit in a humble way, showing the same power which enables an engineer to design a bridge on paper instead of putting something up and trusting to luck that it will stand, or a physicist using his mathematical faculties to calculate how his atoms and electrons should behave if his assumptions are right, so that he can plan the crucial experiment which will tell him if they are right or no. In mental life and mental powers a chimpanzee is less like a frog than he is like a man.

When we compare our human and our simian, not only when full-grown, but during their respective developments as well, the resemblances increase. Compared with a man, an adult chimpanzee has proportionately longer arms and shorter legs; so has an unborn chimpanzee compared with an unborn human being, but the difference is less; the ape fœtus is more human, the human fœtus more simian in its proportions. During most of the later half of its prenatal life, the human embryo, like the ape's, is covered all over with a coat of short, downy hair; so is an ape embryo of

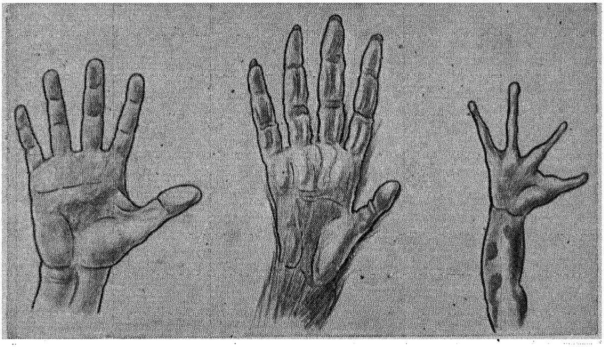


FIG. 32.—A COMPARISON OF HANDS. LEFT, MAN; CENTRE, CHIMPANZEE; RIGHT, FROG.

The hands of Man and Chimpanzee are much alike, the main differences being differences of proportion and of hairiness. The Frog's hand is built on the same general plan, but differs in many important respects. It has only four instead of five fingers, the true thumb having been reduced to a vestige, so that the apparent thumb is really equivalent to our index finger. This false thumb cannot be bent round and opposed to the fingers for grasping purposes; there are no nails; and the skin is hairless and moist.

FIG. 33.—THE SKELETONS OF A MAN AND OF A FULL-GROWN MALE GORILLA. The two correspond bone for bone.

corresponding age. Before birth both ape and man shed this short hair and develop long hair on the head while remaining almost hairless on the body. Man retains this condition throughout life, while the new-born ape soon acquires its thick permanent garment.

The skull-shape of a chimpanzee is much more human before birth; and even the characteristic ape-foot is in the fœtus much less like a hand and much more human than later, while even after birth the human baby's foot, with its inturned sole and eagerly prehensile toes, is charged with hints of a racial past spent in the trees.

In fine, man's structure and development reveal him as zoologically close kin to chimpanzee, gorilla, and orang-outang. Through the invention of language he is made free of a new mental country, to which they have no access; but he does not for that reason cease to be their close cousin, any more than a mentally defective child ceases to be the son of his father, any more than Shakespeare ceased to stand in normal blood-relationship with his cousins, because he entered realms of thought and expression of which they never dreamed.

## § 2

## *Fossil Men*

This testimony from structure and development is confirmed by the authentic voice of the past. Unfortunately, neither apes nor men happen to be preserved as fossils save with extreme rarity, so that we have as yet no such pretty series in our own ancestry as in the ancestry of the horse; but the few remains which have been found tell an unequivocal story.

In the first place, we possess a true missing link between men and apes. He was discovered at Trinil, in Java, in 1892, and christened Pithecanthropus, or the Ape-Man. In the weight of his brain (and brain-development is by far the most important difference between ape and man) he is almost precisely half-way between the largest ape brains known, those of large gorillas, and the smallest normal human brains, to be found among Australian aborigines. He possessed huge brow-ridges over his eyes, like a gorilla, but walked upright, like a man.

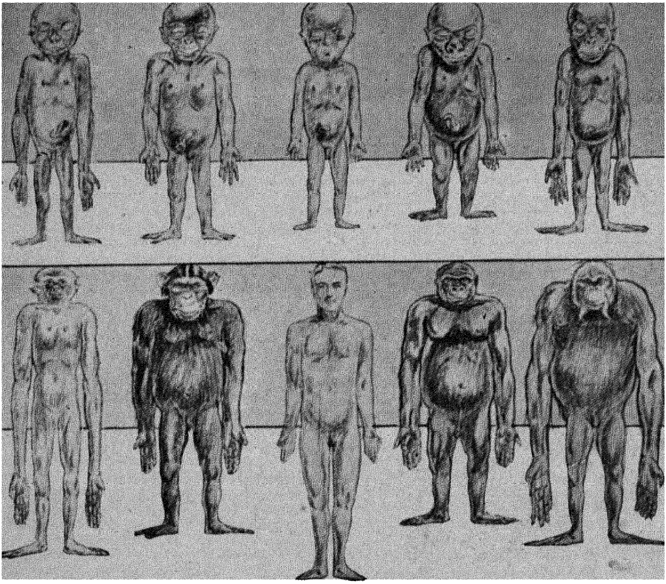


FIG. 34.—THE FIVE KINDS OF MAN-LIKE APES, AS ADULTS (BELOW), AN AS LATE EMBRYOS (ABOVE), TO SHOW THE DIFFERENCES IN PROPORTION OF THE PARTS.

From left to right: Gibbon, Chimpanzee, Man, Gorilla, Orang-outang. The human embryo is in its fourth month, the others at about the corresponding stage of their development. The figures are not drawn to scale, but the sitting height has been made the same for all. They are all drawn in the same position, to illustrate clearly the proportions of trunk and limbs. Man has relatively the longest legs and the shortest arms. Of the others, the gorilla has the most human proportions. The embryos differ in their proportions in the same kind of way as do the adults, but not so much, so that the five creatures are more alike before birth than when grown up. (Modified from Prof. A. H. Schultz.)

Then there is Piltdown man, unearthed in Sussex, obviously a man and not an ape, but so different from ourselves as to demand being put in a new genus, Eoanthropus or Dawn-Man. His eye-teeth were large and savage, his lower jaw almost wholly ape-like, and his brain both small and primitive. Implement-like objects have been found in association with him.

Quite recently, remains of another still more primitive genus of men have been found in China. A few isolated teeth were first discovered, which, though clearly human, were so distinctive that Professor Davidson Black boldly said they must belong to a different genus of man, which he called Sinanthropus. His boldness was justified. In 1928 parts of two lower jaws were found; and in 1929 Mr. W. C. Pei of the Chinese Geological Survey found a brain-case, the only complete cranium known of a subman outside the genus *Homo*. Altogether, remains from at least ten individuals have been discovered up to the date of this printing. Like Piltdown man and the Java Ape Man, Sinanthropus dates back several hundred thousand years, to the early part of the Pleistocene period (V E). His jaws present many resemblances to that of Piltdown man. His skull, however, is closer to that of Pithecanthropus, but definitely more human, with higher vault and better-developed forehead. Crude flint tools and traces of fire have been found in his cave.

Three other extinct types of men which, though admitted to the same genus as ourselves, clearly belong to different species, are Heidelberg man (*Homo heidelbergensis*), without a chin and with a jaw of extraordinary massiveness (Fig. 35), Rhodesian man (*H. rhodesiensis*), with brow-ridges heavier than in any existing human beings, and a brain that to-day would be definitely subnormal, the recently discovered Kanam man (*H. Kanamensis*) of which only part of a lower jaw is known, and Neanderthal man (*H. neanderthalensis*). This last is the only extinct species of man of whom as yet we possess abundant material. The reason for this was that he buried the bodies of his dead. Other species of bygone men, it seems, were left to moulder where they died, like animals; but the Neanderthalers laid out some at least of their dead in their caves and put tools and implements beside them and buried them, presumably because they did not believe life was wholly ended, and so put these things for the use of the departed if and when he or she awoke again. It is rash to guess too precisely what ideas led to these interments. They had ideas and doubts about death, no doubt, that resulted in burial. That is as much as we can say of creatures so remote from ourselves. The majority of Neanderthal skeletons so far discovered owe their preservation to this disposition.

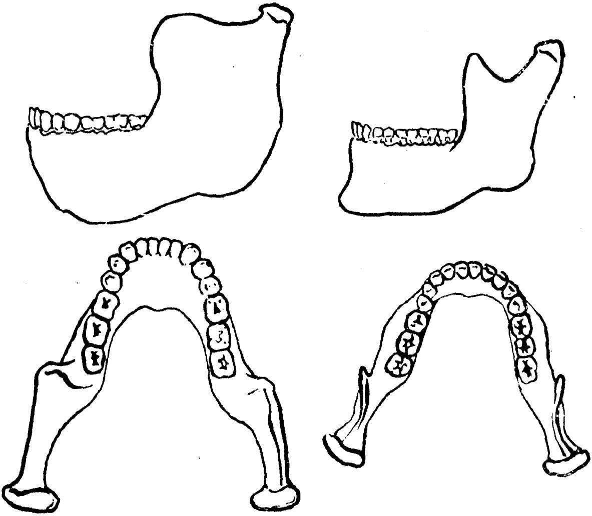


FIG. 35.—THE HUGE, CHINLESS JAW OF HEIDELBERG MAN DRAWN TO SCALE WITH THE JAW OF A MODERN EUROPEAN.

(After Sir Arthur Keith, modified.)

In spite of this human habit of interment the Neanderthalers were distinctly less human than we; they had heavy brow-ridges, no chin, large teeth—though their canines were less ape-like than ours—head thrust forward on a thick neck, and their short, bent thighs compelled them to walk bandy-legged, with their weight on the outer side of their feet. Many of the implements ascribed to extinct human species are so big as to be unwieldy by the hands of any living race of men.

All these extinct human and sub-human forms are of Pleistocene Age (V E), save possibly for the Piltdown and Kanam men, who may perhaps date back to the Pliocene (V D). Their remains, until we come to the Neanderthalers, are mostly found in gravels that may have been disturbed and re-deposited and so are exceptionally hard to date. They are probably only a small fraction of the quasi-human species that still await discovery.

Earlier, as far back as the Miocene Period (V C), there existed in Europe a creature christened Dryopithecus, which obviously is to be put in the same group with the living, man-like apes. But its teeth, though differing from our own in many ways, have a pattern which is more like that of the various extinct species of man than it is like that of modern apes.

Thus the fossil evidence, even though it be fragmentary, is uncompromisingly consistent with the idea that man also is a product of Evolution. Though the stem may still evade us, we have enough of the branches to feel assured it is there. Every extinct species of man is in one way or another more ape-like and less human than any living race of men; in Pithecanthropus and Sinanthropus we have true linking forms between men and apes, only slightly, if at all, on the human side, while in Dryopithecus we have a true ape, some of whose characteristics are more human than those of any modern apes—a pier from the apeward end of the bridge from not-man to man.

The evidence therefore is clear not only that man is closely akin to the apes, but that he is actually descended from an animal which, though without doubt different from any living gorilla, chimpanzee, orang-outang, or gibbon, would obviously have to be classified as an ape, which was covered with hair, provided with formidable teeth, had a brain not above half the size of ours, and spent most of its life on the ground or among the branches in the still prevalent but dwindling forests of the Pliocene.

## § 3

## *Man's Body: a Museum of Evolution*

Man's likeness to the apes shows us clearly enough in what direction to look for his evolutionary origin. But the proof that he has had an evolutionary origin and was not specially created—that rests on a much larger mass of evidence. Our adult human bodies are among the best proofs of Evolution; and the private development of each one of us is an affidavit swearing to the evolutionary history of our race.

Wiedersheim, the celebrated German anatomist, enumerated in the body of man no less than one hundred and eighty organs which are vestigial—wholly or almost useless to us, though useful in other species of animals—each one of them a stumbling-block to the believer in special creation but an ally to the Evolutionist. We may note one or two examples.

The body-hair of men and women is purely vestigial; it no longer serves to prevent us losing heat. And yet each of these tens of thousands of useless hairs possesses a useless muscle by means of which it can be, quite uselessly, raised. For a furry creature to bristle up its hair when the weather grows cold is useful enough—more air is entangled in its coat, and it loses less heat. In the same circumstances we also erect our futile little hairs; but the resultant goose-flesh condition is of no value whatever—we have performed a vestigial action. Even the arrangement of the hairs on our body may recall the past. The hairs on our upper arms point downwards; those on our forearms run upwards and outwards to our elbow; precisely the same arrangement occurs in the orang-outang, and it has plausibly been suggested that in this animal, which often sits with its arms clasped over its head, the arrangement may serve to shed rain off the body, down the spouts of long hair projecting at the elbow. But whatever its significance in the apes, its existence in man is yet another proof of their kinship to him.

A few talented human beings can move their ears. Apart from being a minor social accomplishment this has no value; but for a wild creature, like a rabbit or a zebra, whose safety may depend upon its power of detecting faint sounds and the direction from which they come, the power of moving its ear-trumpets is vitally important. The human ear-mover is indulging in a vestigial action, but the ears of the rest of humanity are one step more vestigial, for the power of moving them has been lost. In spite of this, however, a whole set of muscles to move them is still present, though never called upon for action, since for some reason we are not able to control them. This, by the way, is also true of the great apes, which, like us, have useless vestigial ear-muscles. In tailed monkeys, on the other hand, the muscles are large and can be used, although they are not as strong or supple as those of, say, a dog.

Another interesting vestige in the ear is a little conical projection from the inturned margin of the ear, usually called " Darwin's point," since he showed that it was the remains of the tip of the pointed ear of lower forms, now folded downwards and inwards. It is only found in a certain proportion of human beings (and, curiously enough, is stated to occur more often in men than women); but when present it is, as Darwin wrote, " a surviving symbol of the stirring times and dangerous days of his animal youth."

Again, the little fleshy fold in the inner angle of our eyes (between the openings of the tear-duct in *The Living Body*, Fig. 47) seems to have no function whatsoever; but in most lower vertebrates, including many mammals such as the cats, this same fold is a veritable third eyelid, which can be rapidly swept across the eye from one side to the other. As further proof of man's simian relationship it may be noted that apes and monkeys, too, have their third eyelid reduced to a vestige.

Our wisdom-teeth are on the way to becoming vestigial. In most of us they only appear between the ages of twenty and twenty-five. In quite a number of people, however, they are never cut at all, but remain, useless or even the cause of disagreeable inflammation, within the gums.

Nor is any exception made by man to the animal practice of recapitulating the past of the race during individual development. We have the same family secrets in our embryonic cupboards as the rest of our mammalian relatives. The gill-clefts, the tail, and the furry coat with which our persons were once adorned have already been mentioned (Figs. 62 and 63, *The Living Body*, and Fig. 16 in the present volume). We may add that the human tail is formed complete with all the muscles for wagging it; later, as the tail fades into insignificance, the muscles degenerate or are turned to other uses.

The early human embryo has nostrils connected with the mouth by a deep groove on either side. Sometimes, through a failure of development, this condition remains throughout life, and we call it hare-lip. It is a reminiscence of the way in which the nostrils were formed in our early fish-like ancestors, and you have only to look at a dog-fish or a skate to see that they still show this construction (Fig. 2, *Patterns of Life*). Similar abnormalities of development sometimes allow the prenatal hair to persist, giving us the dog-faced men and hair women of our fairs and shows; or the embryonic tail forgets to shrink and a baby is born with a little pink tail like a sucking-pig's; or the closure of the gill-clefts is arrested and we have adult human beings with actual slits on the side of their neck, or with white patches of skin marking the thin places where they closed just before birth.

Then there is the extraordinary capacity of the new-born human babe to support its own weight for several minutes at a time when hanging by its hands alone; indeed, in most cases the child can hang by either hand singly. This capacity persists for a month or so after birth, but then normally fades away, and only after several years is the child again capable of such a feat. All monkey and ape mothers travel through the branches with their babies. But as they need their own arms for travelling, the baby, even from birth, must have the capacity for holding on tight by its tiny hands to its mother's fur. There can be no doubt that the presence of this power in human infants is a survival, now wholly useless, of what was once a matter of life and death. It is interesting to find, as Mr. Kallen has demonstrated with his daughter, that if the baby be repeatedly stimulated by putting graspable objects into its hands, and tugging upwards when the little hands close round the object, the capacity may be reawakened even after it has died out naturally, and may then be made to persist for many months. The inborn, automatic nature of this power is shown by the fact that it was present in a child born without any forebrain (cerebrum), and persisted in full force until the defective infant died at eighteen days of age.

Another recapitulation, which only fades after birth, is the greater prehensile capacity of the human baby's foot, and the fact that its big toe is much more widely separated from the rest than a grown man's. Why should a baby's foot be half-way to an ape's if there is no real relationship between ape and man?

Those who still doubt or reject the truth of Evolution should ponder their own case. For their own private and particular evolution even though it was all compressed into a nine months' span, was just as spectacular as the slow evolution of life as a whole. Even that valiant apostle of Fundamentalism, Mr. William Jennings Bryan, began his existence as a single cell, passed from this stage of protozoan resemblance through the stage of a cell-colony; hinted at ancestral polyps as he became two-layered; revealed himself akin to Amphioxus in producing a notochord, only to destroy it later in favour of a backbone; indulged in reminiscence of the sea-life led by his fishy forbears by constructing with his amnion a little " private pond " of fluid in which he might embryonically float, and by piercing his neck with gill-clefts, only to do away with them when he subsequently recapitulated his ancestor's greatest feat, the conquest of the land; recalled the furry, four-footed stage of his genealogy by his tail, all ready to be wagged, and his coat of flaxen down; and, even after birth, was unable to help recalling what he later regarded as a blot on his escutcheon—his simian past—by the active, semi-prehensile big toes on his babyish feet and his soon-lost ability (probably never exercised, but undoubtedly present in the first weeks of his free existence) to support his own weight when hanging with his hands.

We are thus no exception to life's rule. The human species has come into being like the rest, not from a sudden act of creation, but slowly, laboriously, by gradual and often devious ways. And having been evolved, man, we are bound to suppose, must still go on along the lines of biological change. So far as our scientific data go, we are bound to believe his present lordship is a precarious one. He may become extinct, like the great beasts of the Age of Reptiles; nothing in his past or in his structure assures us against that; he may linger on in subordination to some new type evolved from another line of life, as the crocodiles and turtles and other reptiles of to-day are subordinated to us mammals; or he may become transformed age by age into something wholly and unrecognizably new, something more powerful or more specialized, as the Eohippus was changed into the horse. In any case let us remember this simple fact—an elementary corollary of Evolution, but never seriously considered before Darwin's time—that there is not the slightest reason for supposing that the powers, intellectual, spiritual, and emotional, which we human beings happen to possess, are the highest of which this planet is capable. Our amphibian ancestor, which certainly had no more brains than a frog, could give rise to descendants with the brains of men. There is no reason whatever for supposing that another such stride, and yet further strides in mental possibility, may not occur. The one sure thing of which the spectacle of Evolution convinces us is that things will not remain as they are. And since there is a vague persuasion very widely diffused at present that in a few million years this planet of ours will " freeze up " and the evolution of life cease, we will conclude this chapter upon the fact of Evolution with a brief note upon Man's place in Time.

## § 4

### *Man's Place in Time*

Evolution, we now perceive, is a present reality, a going concern. There is no sign in man's incomplete being that it has culminated or is in any way arrested. So that a vividly interesting question opens before us: How long can the evolution of life go on? To that question it is now possible to give a tentative answer.

The dating of fossils by rocks, as we have explained it in an earlier chapter, can be at best only a relative dating; it tells us that one kind of animal or plant lived and died before a second kind and after a third; but it tells us nothing as to any absolute date in years. Yet the reader will have remarked that we have been giving the absolute age of different rocks with very considerable assurance: Early Cenozoic fifty million years ago, and so forth. It is time to explain how this is possible.

It is possible because, as the work of recent years has shown, some of the rocks of the earth's crust contain what we may call, without any fantastic exaggeration, geological clocks. They contain timekeepers that were set chemically ticking when the rock was first formed, and have gone on ticking at the same rate, without once needing to be wound or regulated, ever since. These clocks are what are known as the radio-active elements, radium, uranium, thorium, and others, which exist in certain minerals. The work of Becquerel on uranium, which speedily led to the discovery of radium by Madame Curie in 1898, was the starting-point for a series of researches which have altered all our ideas on the constitution of matter, and, incidentally, given earth-history a measurable chronology. These radio-active elements, as everybody knows nowadays, shoot out particles of matter from their atoms, and in so doing transform themselves into different elements. They do this in such a way as to become effectual chronometers.

The particles given off are sometimes electrically charged atoms of the light gas, helium (which is a stable element and shows no further change), sometimes the far tinier electrons, the spinning bricks of which the atoms, save for their cores, are built. Uranium is the parent of radium. After shooting off three atoms of helium and several electrons, it becomes radium. Radium then continues the process of change; it first discharges a gas, radium emanation, and finally, after five helium atoms have been shot away, becomes plain lead. This, having stable atoms, does not change any more; the clock, so far as the lead atom is concerned, has run down, and we know no means by which it can be wound up again. The lead thus produced, though in its chemical behaviour quite normal, differs from ordinary lead in having an atomic weight of 206 instead of 207·2; we can call it uranium-lead. The whole process may be summed up by an equation: 1 atom of uranium = 1 atom of uranium-lead + 8 atoms of helium + energy.

Thorium, another radio-active element, goes through a similar series of transformations, and after shooting out six atoms of helium, also ends up as lead. This thorium-lead, however, differs from uranium-lead in having an atomic weight of 208.

Now, the bearing of all this on the computing of geological dates is very simple. This disintegration does not go on haphazard and wildly. It is timed. Each of these transformations takes place at its own definite rate, as regularly and inevitably as the swing of a pendulum. The physicist assures us that if we took a definite quantity of radium, say a milligram, then after 1,700 years there would be only half of it left—exactly half—the rest would have turned into helium, lead, and traces of the intermediate steps. Uranium, on the other hand, is a slow disintegrator; you would only lose half your uranium after 4,500 million years. Thorium, too, has its own particular speed of metamorphosis. But since the helium and the lead which are thus generated do not undergo any further changes, we can calculate precisely how long it would take for any given proportion of lead to be accumulated in a mineral containing uranium or thorium. And so, if we can find a rock of, say, Lower Carboniferous Age (III E 1) in which, when it was first formed, radio-active minerals containing uranium or thorium were crystallized out, we can tell its age in years by measuring the proportion of helium and of lead which has been produced in these minerals since they were first locked up in their rocky prison.

Lord Rayleigh measured the amount of helium produced by uranium-bearing minerals, and found that a gram of uranium would take nine million years to produce a cubic centimetre of helium, which agrees with calculations based on the rate of step-by-step transformation. As regards lead, it can be calculated that a ton of uranium gives rise to 1/7,400th of a gram of lead every year. Thus, if on analysis we find 1 per cent. of lead in a uranium-containing mineral, this proportion must have taken 1/99th of 7,400 million years to accumulate; while if there had been 10 per cent. of lead, the time needed would have been 1/9th of 7,400 million years. The rate for thorium is slower, but the principle is the same.

The one assumption made is that the radium clocks never change their rate of going; and physicists, after trying in vain to alter that rate by every conceivable means, are agreed that they never do. There are various small mathematical corrections to be made, and various precautions to be taken in the practical procedure; but all such difficulties can be readily overcome. How they are overcome is clearly set forth in Professor Holmes' little book, *The Age of the Earth.*

There, too, will be found an account of other methods of estimating geological time—as by the rate of erosion of the land, by the rate of deposition of new sediments, by the rate at which the sea, which is always receiving salts and always evaporating, grows salter, by timing geological processes against periods of known length, such as the precession of the equinoxes with its 21,000 years cycle, and so forth. These all supply checks upon our radio-active estimates.

In addition there are one or two methods by which, at certain pages of the record of the past, we can get even an estimate in single years. For example, trees form annual rings, and some of the Big Trees of California take us back several thousand years. When ice-sheets cover part of a country, the flood produced by each summer's melting lays down a layer of clayey deposit over the neighbouring regions; and Baron de Geer has shown, by counting these layers in Southern Sweden, that the retreat of the last ice-sheet in Scandinavia took over 10,000 years. But these more detailed methods commonly apply only to the immediate past, and to periods of time that are but one or two ticks of geology's clock.

There is also a further method applicable to any period where marine shells were fossilized. It is based on the fact that many bivalve shells show annual growth-rings like trees, and that the annual growth-rings are divided up into minor rings, each new addition to the shell being made after a feeding period. These minor rings vary much in breadth, according to outer conditions. Thus each annual growth-ring bears its own individual stamp in the number and size of its separate feeding-rings; and the same stamp will be impressed on all the shells in the same neighbourhood. By comparing a whole series of shells in the successive layers from one locality we can identify the separate years by the pattern they have left on the growth-rings, and so count their succession. This method is being worked out by Professor W. M. Winton of Texas; it should give valuable results whenever thick layers of one type have been laid down in one place, and contain the shells of bivalves.

Ultimately, by such means as these, we may carry a surprisingly detailed calendar back for hundreds of thousands and even millions of years into the past from the present time. And even for the remoter periods we are already approaching a sufficiency of knowledge whereby the margin of error can be narrowed down to ten million years or so, which on the geologist's scale of time is not a large figure, for it only means being out by about five or ten per cent.

Such are the data upon which we base the figures we have inserted upon our diagram of geological formations. If the reader will turn back to that he will find one or two points of very great interest in relation to our curiosity about the future course and duration of Evolution (Fig. 2).

In the first place he will remark that there is a huge disproportion between the lengths of the great eras of geological time. The Age of Mammals seems hardly to merit the name of Era at all: it has only endured for about 50 million years. The Age of Reptiles lasted about 125 million years, while the Paleozoic droned on, without even a bird or mammal or flowering plant, for over 300 million. That puts the date of the Early Cambrian back to 500 million. Below these lowest Cambrian rocks there is still a huge thickness of earlier rock-deposits—at least 180,000 feet of them—in which, however, save in the uppermost 10,000 feet, no fossils have been found. The time taken for the formation of these Pre-Cambrian rocks was longer than for all the later eras together; for one of them is radium-dated back to over 1,200 million years.

The earth came into being when the ancestral sun was disrupted by the too-near approach of some other star. Of that stupendous birth you can read in Jeans' *Astronomy and Cosmogony*. The date of that remote event cannot yet be estimated with such accuracy as can the ages of rocks, though the limits are rapidly being narrowed down. As Holmes shows, it cannot be less than 1,600 nor more than 3,000 million years ago; probably the lower estimate is nearer the truth.

Let us provisionally take 2,000 million years as the age of Earth. Life, as revealed by actual fossils, has been in existence for nearly a third of this time. Without any doubt the real age of life is greater, since the first living things would be soft and squashy and very seldom fossilized, and even if they were preserved would, in most cases, have been later baked and crushed out of recognition.

It is only in the last fifth of the earth's history that we know of vertebrates, and in less than a sixth of it that we know of land-vertebrates. Mammals have been on the scene for only a thirteenth of the time, and modern placental mammals for only a thirtieth. And as for man, he is a mere upstart. The earliest creatures that could be called men, or at least not apes, cannot possibly have been on earth's stage for more than a paltry ten million years, or one two-hundredth of the total, and it may well prove necessary to halve even this estimate; while our own species of man boasts perhaps a million years of history—one-twentieth of one per cent. of the earth's full record.

Time is telescoped, and the centuries of history shrivel. Fifteen thousand years ago man was still in the Old Stone Age. Civilization, in the sense of a stable social life based upon agriculture and metal-working, dates back to less than 10,000 years. Ten thousand years—when it took at the very least ten million to generate man from the first tailless ape, and a hundred million for that ape to be brought into being from the first mammal!

With this revelation of the huge spaces of earth's past the doors of the future, too, seem to open. We know a good deal now about the rate of cooling of the earth and of the sun. That sort of knowledge also grows more and more exact. The discoveries that heat may be generated by radioactivity, by shrinkage, and by the actual transformation of matter, have enormously enlarged the possible future of life upon earth. There is every reason to suppose that conditions on our planet will continue to allow life to flourish in the future for as long as they have allowed it to flourish in the past; indeed, this trifle of a thousand million years or so for the future of terrestrial life is almost certainly an underestimate, granted of course that no unforeseen catastrophe breaks in upon it.

Man is part of an unbroken stream of life. That same stream in the dawn of life on earth manifested itself in the form of single microscopic cells; hundreds of millions of years later, after transformation through forms we dimly guess at—forms of polyps, of worm-like creatures, of headless things like lancelets, it flowed through thousands of generations in the form of fish; it emerged on land, it learnt to be a reptile, it covered itself with hair and warmed its blood, and fed its young with milk. Still without break of continuity, it transformed itself to become fully mammalian, its young to grow as parasites upon its life. Four-footed, tailed and hairy, it took to the Eocene forests; it grew into lemur, into monkey, into ape; and finally ape turned man-ape, and man-ape grew to man.

If that self-same stream of life that flows through our human generations and that we call man was once fish, and if those fishy ancestors could be transformed into our present selves in 300 million years, without the aid of conscious purpose in any of the prehuman forbears, who shall prophesy what our race may not achieve and into what it may not transform itself before another such period in the history of life on earth has passed?

To grasp the full implications of this estimate of available time is to realize that we are still only in the dawn of consciousness and thought, and that all human will and wisdom has ever done is no more than an augury of what it may yet achieve. Evolution presents itself as an accelerating process, gathering momentum and hardly yet beyond the beginning of its revelations.

# CHAPTER VI

# THE ESSENCE OF THE CONTROVERSIES ABOUT EVOLUTION

## *The Chief Theories of Evolution*

HITHERTO we have been dealing with facts beyond any reasonable controversy. We have put them plainly and we hope convincingly before the reader. If we have failed to convince, the fault lies in our writing and not in the facts. Life, we have shown, has appeared not multitudinously and again and again in the world, but at one particular stage in our planet's history, and from that one beginning it has developed like a branching tree. It has not been multifariously and repeatedly created in its present or kindred forms; it has unfolded from lowly and simple beginnings, through a vast variety of species, to all the animal, vegetable and other organisms the biologist contemplates to-day. Special creation of each animal and vegetable type is a parable or a myth. Evolution is the shape of life and a fact as well-established now as the roundness of the earth or the relative immensity of the sun. All these three facts have been disputed in the past. To-day controversy about any of them is dead.

Equally dead we shall find is the older and really more plausible belief that life has had numerous origins and, even now, can at times be created afresh. That, it seems, is not so. *Life is one thing.* Every living thing is related through a common descent to all the rest of life. There is no reason a priori why this should be so. But all the evidence is that it is so.

In all the three instances we have given—the round earth, the larger sun, and the evolution of life—men have disputed these great generalizations because they had started in life with contrary assumptions and found the shock of the new idea too great. They had intermingled their moral and religious ideas with the notion of a special creation of each kind of animal at a certain date, or with the notion of a flat earth, or with the notion of a small subservient sun going about our planet, and it seemed to them that if these notions were destroyed their very heavens would fall. But new generations have followed them, have accepted the new ideas and found the heavens of religious feeling and moral impulse none the worse for a broadened and enlightened outlook. To-day there is no denial of the fact of organic evolution except on the part of manifestly ignorant, prejudiced and superstitious minds.

But here we enter upon a less certain and established region of biological study. In the remaining chapters we are going to discuss *how* Evolution has occurred. There we find active and intelligent minds still differing very widely. What are the relations of individual development to the development of the species? There is no question any longer that Evolution has occurred, but our question is now, what has been its method? Or its methods?

This is a field where the débris and glow of recent controversies are still evident and where wide and often flaming differences of opinion are still found. And, just as in the opening pages of this volume we made it quite plain what fact we had to prove, so here it will enable the reader to understand the full significance of what follows if we give first the broad questions our chapters are designed to illuminate, and point out what is still arguable and what is the present state of the discussion. What are the Theories of Evolution between which we are asked to decide?

The fact of vital Evolution has gleamed upon intelligent minds at various phases in the world's history, but the modern revival of biological science had been going on for some time before it rose again to recognition. Linnæus (1707–78) seems to have had no doubts of the fixity of species. It was only towards the close of the eighteenth century and with the increasing study of comparative anatomy and fossils that the fixity of species began to be questioned.

At first the fact of Evolution was seen piecemeal, as a possible change of one species into another within the boundaries of this or that restricted group of allied forms. It was not apprehended as a process comprehending all living things. Perhaps all the carnivores were genetically related, for example, or all the horned cattle. It was then generally called Transformism. The word Evolution came later. And the question whether the process included man was either not raised, or plainly or tacitly answered in the negative.

The first attempt to explain Transformism was to ascribe it to the effort of the living being to adapt itself to the often difficult conditions under which it had to live. The French naturalist Lamarck (1744–1829) pointed out that the individual was responsive to its circumstances, that it used and developed this organ and made little use of and therefore did not greatly develop that, that within limits need and exercise called forth structure; and he supposed that these individual adaptations were in a measure inherited. The three-toed horse—if we may use an example unknown to Lamarck—which under changing conditions was always scampering on firm prairies and scarcely ever going on soft ground, made no use of its once useful side-toes, and so they were not stimulated to develop, while the business toe got all the work and all the benefit. The foals, according to the Lamarckian idea, inherited the enhanced main toe and the reduced side ones. This line of argument was made exceedingly plausible by the known fact that we all develop best the organs we use most: the rower his biceps, the singer his chest. The weakness of the Lamarckian case, or at least the unproven assumption of it, was that the individual development was in any degree inherited.

In ordinary biological discussion the individual development is called an "acquired characteristic"; the size of the rower's biceps, for instance. Lamarck assumed the inheritance of acquired characteristics and found in that a partial explanation of Transformism. To this day the belief in the inheritance of acquired characters is called Lamarckism. With the inclusion of an involuntary response to the environment (such as the response of growing corals to currents or the darkening of some birds' feathers when they are reared in a warm and humid atmosphere) and the inheritance of this response, it is called Neo-Lamarckism—Lamarckism modernized.

Lamarck's realization of at least a limited evolution of species, Transformism, was based on an infinitely smaller knowledge of fact than we have to-day. He relied chiefly on fossil shells, rudimentary structures, and the manifest anatomical resemblances of animals for his belief that Evolution occurred. It was only later (1828) that Geoffroy St. Hilaire called attention to the embryological evidence for Evolution.

Several distinguished living biologists are Neo-Lamarckians. And the view has appealed to many people because of the moral attractiveness of the idea of effort achieving enduring consequences. Master what you can of mathematics and your child will compute with greater ease; be merciful and your children will find it less difficult to practise mercy. One likes to think in that fashion. And with various additions and improvements Lamarckism is to be found vigorously paralleled in much modern thought outside the world of biological specialists. There has been added to the individual effort the idea of an upward driving force of a general sort. Bergson finds an *élan vital*, George Bernard Shaw a *life-force*, both mystical drives towards adaptation, coming from or acting through the organism. Both owe something, no doubt, to Schopenhauer's idea of a driving Will in things. Whether such an hypothesis is necessary or even harmonious with the facts of the case we shall leave the reader to judge at the end of this volume. We give it here as a second theory, which must be treated with respect, the theory of an upward *drive* in life.

Now, while Lamarck was elaborating his transformist ideas, an English clergyman, Dr. Malthus (1766–1834), was developing certain views that did not at first sight seem to have any bearing upon natural history and Transformism at all. His preoccupations seem to have been purely social. He was struck by the rapid increase of the human population about him—and he lived in a prolific age. It was increasing, he thought, much faster than was the food-supply. Consequently there was already a harsh struggle for subsistence going on. Mankind was breeding its way towards starvation; the weakest would go to the wall. Famine and the check of pestilence were the natural counters to this drift towards over-population and an unendurable poverty, and he urged his fellow-creatures to avoid such miseries by restraining their increase through late marriage and through continence. The artificial interference with conception known as birth-control or Neo-Malthusianism, we may note, had no place in his philosophy. That was as far as he got; he betrayed no consciousness of the bearing of his observations upon the ideas of Transformism, of which indeed he may have been quite unaware.

It happened, however, that his writings were read by two scientific travellers and naturalists who were both coming to believe in the fact of Evolution but by no means satisfied with Lamarckism as an explanation of it. ("Creative Evolution" with its *élan vital* was still to come.) These were Charles Darwin (1809–82) and Alfred Russel Wallace (1823–1913).

It is well to note here that Darwin did not "discover" Evolution, as many people suppose. Evolution is not Darwinism and Darwinism is not Evolution. The idea of Evolution is not only at least as old in modern thought as Lamarck, but adumbrations of it are clearly traceable in such ancient writers as Lucretius and Empedocles. But in the minds of Darwin and Wallace, looking for operating causes for the evolutionary process, the phrase of Malthus, "the struggle for subsistence," found a fruitful soil. Both realized a second great fact—for fact it is—in the general conditions of life, namely Natural Selection. Every living species is continually producing a multitude of individuals, many more than can all survive, varying more or less among themselves, and all competing against each other for food and a place in the sun. On the whole, Nature will let the better fitted ones live more abundantly and she will kill off the less happily constituted. The weaker will go to the wall; they will not breed so much; the stronger and their offspring will prevail. Assuming that weakness and strength and, in general, fitness and unfitness are hereditable qualities—and that is the general persuasion—a species must be always on the grindstone, having its unsuitable strains eliminated and its suitable strains left in possession.

Now, let us be quite clear here; speaking with precision, Natural Selection we say is not a theory but a fact. But does it, in connection with the small differences that occur between every individual and its peers and the distinctive resemblance of parent and child, suffice to account for the whole spectacle of Evolution? With or without that element of effort and hereditable acquirement which Lamarckism asserts? There we come to speculative matter, to theories. Darwin thought it did. He did not contradict the Lamarckian hypothesis, but he added a new factor in the process, which factor he drew from Malthus.[a] In 1859 he published a book which made an immense stir in the world, and he called it *The Origin of Species by Means of Natural Selection*. We have insisted that Natural Selection is not a theory. But, on the other hand, this appeal to the fact of Natural Selection and the fact of hereditable variations as giving between them a full and sufficient explanation of the fact of Evolution, is a theory; it is the Darwinian Theory. To the majority of even highly educated people at that period, educated for the most part upon lines of a narrow religious orthodoxy, it brought home for the first time the neglected and repudiated fact of Evolution, and made it seem credible. Explanatory theory and fact to be explained appeared together in their minds, and so to this day, in common talk, Evolution, Darwinism, and Natural Selection are hopelessly mixed and muddled. It became the custom to speak of the Darwinian Theory, the Theory of Natural Selection, and the Theory of Evolution indifferently.

Moreover, Darwin and his associates drew attention to the particular aspect of the question of Evolution that had hitherto been in the background. He followed up his *Origin of Species* by a book upon *The Descent of Man.* He insisted that man was an animal and that if the facts of Evolution were true they applied to man. If other living things had not been specially created but evolved, so, too, man must have been evolved. To do this was to challenge and bring into the discussion the whole world of contemporary theology. What had been a field of interesting speculation for naturalists became an arena of intense interest to the ordinary man.

Darwin's publication was followed by furious controversies, in which Thomas Henry Huxley (1825–95) and Ernst Haeckel (1834–1919) played notable parts in championing the evolutionary cause and defending Darwin and his views from misrepresentation. Huxley liked to call himself "Darwin's bull-dog." But the controversies did much to darken counsel in these matters. The fact of Evolution had to be proved to most people, and many were only too eager to suppose that the defeat or qualification of the theory would abolish the fact. To many of them to the end of their days it remained a theory, and an unsound one at that. All sorts of secondary considerations have played their part in these disputes. There is, for example, a real dislike of the fact of Natural Selection on the part of such a fine and sympathetic nature as Mr. G. B. Shaw's. It seems to him unchivalrous and vile for science to recognize that the weakest do go to the wall. It is hitting the fellow who is down. In the philosophy of a wilful life-force it is natural the wish should be father to the thought. He wishes things were not so, and therefore he declares they are not so, and he does it with great charm, confidence, and conviction. It pleases Mr. Shaw to tell the world at regular intervals that Natural Selection has been "exploded," and it does not hamper the operation of Natural Selection in the very least that he should do this. But Natural Selection has been no more "exploded" by recent research than the rejection of under-weight coins at the Mint has been exploded by the doctrine of relativity. Wherever there are favourable or unfavourable hereditable variations Natural Selection must be at work.

Nearly three-quarters of a century have passed since the controversial cataclysms of the mid-Victorian period, and Darwinism has been criticized in every conceivable way. It cannot be said that it has been destroyed, but it has undergone restatement in certain respects.

The modification of a species by the natural selection of variations is still an undefeated theory. That idea from Darwin's writings lives and flourishes. The remoulding of Darwinism has concerned the part of it which deals with the mechanism of heredity and the intimate nature of variations. For in Darwin's time hardly anything was definitely known about the inheritance of individual differences. The chromosomes to be presently described had not yet been seen; the essential facts of fertilization were unknown; most important of all, experimental breeding had not drawn a clear distinction between variations which are inherited and those which are not.

Since that time accurate knowledge has accumulated on these questions. The microscopic changes in the germ-cells that accompany fertilization were observed; the chromosomes, the bearers of the physical basis of heredity, were discovered, and their complicated but regular movements were traced as they passed from one generation to the next. Moreover, the study of inheritance was attacked experimentally. Even in Darwin's time the Austrian Abbé Mendel

(1822–84) had experimented on the inter-breeding of varieties of plants and had discovered the two most fundamental laws that govern hereditary transmission. But the significance of his work was not recognized at the time. His communication to the little Natural History Society at Brunn (now called Brno) dealt chiefly with peas and arithmetic, not the sort of things that cause excitement and clamour, and in the confused tumult of the nineteenth-century Evolution controversy they passed unnoticed. Only in the opening years of the twentieth century was his work disinterred and brought to bear on the discussion of Evolution.

This rediscovery was the stimulus for an enormous amount of careful experimental breeding of animals and plants. New conceptions arose of how variations originate and are handed on from generation to generation, and of how they may play their part in the struggle for existence.

Here we are merely revising the broad issues before us. Later on we shall discuss the question whether variations occur through a " life-force " driving the whole species in a definite direction, or through some blind disposition to vary evoked by the action of external conditions upon the reproductive process. That is an interesting issue of profound importance. And we shall have to consider the still-vexed question whether the inheritance of individually acquired characteristics, which was the essence of the original theory of Lamarck, occurs or no. This was flatly denied by Weismann (1834–1914) and disproved in many instances. He and his followers are sometimes spoken of as Neo-Darwinians. They believe variation to be a purely random process, resulting neither from a persistent urge nor from the Lamarckian moulding of the individual body; the direction of Evolution being determined entirely by Natural Selection. Their complete denial of the evolutionary value of individual experience gives a flavour of hard predestination to their views. Unless it vary by the grace of unknown forces, a struggling lineage is doomed; no individual luck or effort can save it. And clearly no education, no social protection can cure the innate defects of any inferior human family. Its rôle is extinction.

A very fine and curious issue to which we shall later direct the reader's attention is that of *Orthogenesis.* It is alleged that in a certain number of cases species, even though fairly well adapted to their conditions and without experiencing any change of conditions, have by virtue of a sort of inner drive, an innate destiny of the species, gone through considerable evolutionary change. Professor Henry Fairfield Osborn finds this drive convincingly displayed in various fossil series, such as the horses, camels, and titanotheres. Of course, where the changes produced by the orthogenesis have been disadvantageous, Natural Selection has at last arrested the drive and extinguished the line. But the supposition that the new form, new structure or other characteristic is not advantageous or is insufficiently advantageous to have "survival value" is difficult to establish. It may involve an advantage which the observer has not recognized. And it is still more difficult to show that the drive towards variation in a definite direction was innate. There may be a thousand outer influences working upon the minute elements in reproduction of which as yet we know nothing, from obscure chemical factors in the food to electromagnetic radiations from outer space. There may be a thousand subtle selective influences rejecting this variation and preserving that. Here again our duty will be to sum up the known facts and views and leave the conclusion to the reader.

We have then still active in the biological field (1) the *élan-vitalist*, (2) the Neo-Lamarckian, and (3) the Neo-Darwinian; three distinctive schools as to the origin of variations. They are by no means mutually exclusive. Any follower of either school may attach more or less importance to the variational drive or conversely to the action of Natural Selection, and Orthogenesis may be used to account for more or less or none of the changes that have occurred. In a world of earnest workers these various shades and blending of opinion are hotly debated. Biologists can be as sensitive to heresy as theologians or any other sort of men in deadly earnest, and it is quite easy for dull-minded or dishonest controversialists delving in the literature of the subject to clip out such phrases as that "Darwin has been disposed of," or that "Natural Selection is inadequate," and pretend that a conviction or refutation in some particular is an absolute reversal of view. But, indeed, no such collapse has occurred. Difficulties in "accounting for" variation are minor difficulties in face of the invincible facts of the evolutionary process. Every day the form and details of Evolution, the life process, are seen more clearly, solidly, certainly, and coherently.

We need scarcely point out to the interested reader how temperamental disposition and philosophical and moral preoccupations may dispose men's minds towards one or other of the three types of opinion. This possibility gives this branch of our subject an interest and excitement far beyond the strictly biological field. There is something cold and stern, very attractive to a certain hard, clear type of mind, in the Neo-Darwinian attitude. There is something heroic in the obstinate advance of Orthogenesis. The Neo-Lamarckian view appeals most to those combatant spirits who would figure man in a Promethean and finally hopeful conflict with the universe; again, the mystic and the believer in a continually directive divinity incline very naturally towards the hidden upward urgency of the *élan vital.* For him it becomes the finger of God. It is a return towards the idea of creation, as Bergson's popular and attractive phrase *Creative Evolution* reminds us.

There remains one other temperamental type which has found expression in these discussions, and that is the brilliant sceptic as typified by the late Professor William Bateson. He accepted the fact of Evolution, if only on the palæontological evidence, but, as the outcome of a life spent largely in the study of variation and especially of Mendelism, he developed an increasing inability to satisfy himself how any progressive variation could ever occur. He crowned his scientific career by various lectures and addresses in which he reiterated his imaginative failure. This type of agnosticism was probably the negative aspect of a passionate and unquestioning faith in the implacable unteachableness and integrity of certain Mendelian units of heredity we shall presently describe and discuss. Later work has removed much of the point of his criticisms.

# CHAPTER VII

# VARIATION OF SPECIES

§ 1. The Chromosome and the Gene.
§ 2. Mutation: The Experimenting of the Germ-plasm.
§ 3. Are there Forward Bounds in Mutation?
§ 4. Are Acquired Characters Inherited?
§ 5. Artificially-induced Mutation.
§ 6. Moths and Smoke. § 7. Variation in Plants

## § 1

### *The Chromosome and the Gene*

WHEN the first speculative explanations of the evolutionary process were written, very little was known about the way in which characters were inherited from parent to offspring. In the early years of this century, an enormous mass of accurate knowledge about heredity accumulated. Before we go on to examine the various theories of evolution, we must understand the main results of this period of active research and discovery.

The reader must prepare himself here for a strenuous section. The broad facts and consequences of evolution are of universal interest; the minute study of the mechanism of individual development and variation is, on the other hand, very obscure, outside everyday experience, and can easily be made very complicated. Yet the broad questions we have posed in the previous section are only to be grasped soundly after the nature and bearing of this minute mechanism has been understood.

Unhappily the space at our disposal will only allow in this volume a thumb-nail sketch of the processes of inheritance. In *Reproduction, Heredity and the development of Sex*, a companion book in this series, the reader will find a more detailed exposition of the subject. If he has any difficulty in understanding the remaining pages of this section, he should, if possible, turn to that fuller account, of which what follows is a very brief summary.

There are many creatures which reproduce without any sexual process; but in almost all higher animals and plants sex is universal, so we will confine ourselves here to those with sexual reproduction. Sexless reproduction consists simply in the separation from the parent of a portion of living substance, which then grows into the offspring. Sexual reproduction is more complex, for with it there are two portions of living substance detached, one from the mother and the other from the father; these mix together to form a single unit, which then grows into the new individual. The piece of living substance contributed by the mother is called the egg or ovum, that contributed by the father, the sperm or spermatozoon. After the sperm has entered and mixed itself with the egg, a process known as fertilization, the fertilized egg begins to develop, and gradually transforms itself into an adult organism. The sperms and eggs are known collectively as *gametes* (marrying cells); the fertilized egg, formed by the union of two gametes, is called the *zygote*.

The egg is big and inert, the sperm tiny and active. In spite of this difference in size of ovum and sperm, it is a matter of common observation that the father contributes as much to the characteristics of his offspring as does the mother. Accordingly, there must be something which both parents contribute in equal amount. Careful exploration with the microscope has revealed what this is. Both parents contribute an equal set of *chromosomes*. This is an unfamiliar word, but an important one. Chromosomes are microscopic ribbon-like bodies which exist in the nucleus or central kernel possessed by every animal and plant cell. In each species they exist in a constant and characteristic number: for instance, the body of a man is composed of millions of cells; every cell (with rare exceptions) contains a nucleus, and every one of these nuclei contains 48 chromosomes. Similarly, the sweet-pea has 14 chromosomes in every nucleus, the common fruit-fly has 8, and so on. The number is usually an even one, for reasons we shall discover in a moment.

These chromosomes are the bearers of almost the whole hereditary constitution. Careful and long-continued breeding experiments, based on the ideas first put forward by the Abbé Mendel, have shown that in the chromosomes are contained what we may call the atoms of heredity—definite units of living matter each with its own particular work to do in building up a normal individual out of the fertilized egg.

These units of heredity are usually called *genes*. They are slightly too small to be visible through the microscope, but we know that they are arranged in line, like beads along a string, within the chromosomes. Each gene has its particular place in a particular chromosome.

A complete set of genes is necessary if the fertilized egg is to develop properly. As a matter of fact, normal animals and plants contain two such complete sets of genes. This is the reason why the normal number of chromosomes is an even one. In every cell of the body (except for the reproductive cells) there exists not one but a pair of every different kind of chromosome, and of every kind of gene.

Two further facts must be put on record before we can understand the mechanism of heredity. Though most of the cells of the body contain two complete sets of genes, the egg and the sperm do not. In them, there is only one complete set. During their formation, the two complete sets that the parent cells possessed have been sorted out into single sets, as one might separate two packs of cards that have been mixed together. This sorting process is known as *reduction*. So the reason that the normal individual has two sets of genes and of chromosomes is that he has received one set from his father in the sperm, one from his mother in the ovum.

The other important fact is that each kind of gene can exist in a number of slightly different forms. All the different forms do the same kind of thing in the developing animal or plant, but each does it a little differently in detail. For instance, in rabbits, one form of one gene makes the coat fully coloured, another form makes it pure white, while yet a third has an intermediate effect, and produces a white rabbit with black ears and nose and feet. In the fruit-fly there are over a dozen forms of one kind of gene all affecting the colour of the eye, each producing some particular shade between white and the normal red colour.

Now return for a moment to the fertilized egg. It possesses two complete sets of genes, one inherited from the mother, and one, via the sperm, from the father. The development will be controlled by an interaction of these two sets. In some respects they will agree. If both the parents of a rabbit were albinos, each of them will have contributed an " albino " gene, so their two influences will be in agreement, and the offspring will be albino. But if one parent was brown, and contributed a " brown " gene to the offspring, there will be a conflict in its nuclei ; for it will contain in every nucleus an " albino " gene from one parent and a " brown " gene from another. The result of such a cross varies. In some cases the hybrid is intermediate between the parents ; both the conflicting genes have had an equal say. In others, such as the one we have just considered, one gene overrides the other ; the rabbit will be brown although it carries both types of genes. In such a case, the gene which prevails is called *dominant* and the one which is concealed is called *recessive*. " Brown," in the rabbit cross, is dominant and " albino " is recessive.

When sperms and eggs are being formed, the sorting out of the double gene-set into single sets is apparently a purely random process, and hardly ever takes place in exactly the same way. No two sets of the spermatozoa produced by a man carry identical sets of genes—at least the odds against such a coincidence are great.

After mixing two packs of cards, one with red backs and one with blue backs, you could separate out two single packs in an enormous number of different ways, if you did not mind having cards with differently coloured backs in the same pack. Similarly, an organism has two sets of genes in every cell, like the two packs of cards, and they can be separated out in a vast number of different ways. They do not necessarily sort themselves out into the original combinations.

To take a concrete example, if you cross a tall pea with green seeds and a short pea with yellow seeds, in later generations you will get not only the two original types, but also the two other possible combinations—tall peas with yellow seeds and short peas with green seeds. And, of course, the number of possible combinations goes up very rapidly with the number of genes in which the members of a pair are different.

Thus heredity in sexually-reproducing animals and plants leads to variation, for the offspring of a cross may differ from their parents by combining the parental genes in different ways. But variation of this kind is limited. Even though the number of genes in an organism is great, one cannot go on getting new types for ever by shuffling and recombining them.

There is, however, a second type of variation which is apparently limitless and, therefore, of great importance from the point of view of evolutionary theory: to that we will next turn our attention.

## § 2

## *Mutation: the Experimenting of the Germ-plasm*

Heredity is in its essence a conservative tendency, binding each generation to the organic semblance of the last, and in the preceding exposition of its principles we have treated of the genes as immutable units, shuffled and dealt out in various combinations but unaltered by their treatment, sometimes lying concealed by dominant partners for generations but always emerging unchanged, as atoms emerge unchanged from the molecular combinations in which they take part, or as the cards lie on the table unchanged at the end of an evening's bridge. But now we must tackle an important complication of the story. Sometimes the genes themselves may undergo alteration. Let us consider four concrete instances to show how living things may inherit, and at the same time evolve.

In the year 1791 a Massachusetts sheep-farmer of the name of Seth Wright was greatly surprised when one of his ewes bore a lamb with the build of a pekingese, having a long back and short, bowed legs. Nothing like it had ever appeared in his flock before. Now it happened that he was sorely perplexed because his sheep used to roam into other people's fields; the fences of Massachusetts, it seems, were low in those days. So he noted with pleasure that the new arrival was a male. He killed his old ram and reared and bred altogether from the new; and he found the new shape to Mendelize, for thereafter his sheep were always either completely Ancon (as the new shape was called) or completely ordinary. By picking those of the short-legged type he got in a few years a very considerable flock of animals which were unable to jump over fences—and the variety spread throughout Massachusetts.[1]

In the laboratory of the Carnegie Institute at Cold Spring Harbour, a strain of water-fleas (*Daphnia*) had been bred for 363 generations. The animals of this strain thrive best at 20° C., and die if the temperature goes above 26° or below 11°. After fourteen years, a mutation arose which adapted its possessors to different conditions of temperature. The young of this new type die if kept in the standard temperature conditions. The mutant strain does best at 27° C., dies at

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[1] It was subsequently displaced by the Merino.

20°, and will tolerate 32°. Apart from this altered reaction to heat and cold, no other difference could be found between the two strains. Here we have an excellent example of the germ-plasm throwing up a new type which might be of the greatest service to the species in helping it to spread to warmer climates.

The Florida Velvet Bean could only be grown in Florida and the Gulf States. Suddenly a variety appeared which would flower and set seed in less specialized weather and which could therefore be profitably planted over the whole cotton belt of the United States.

A variety of Tobacco appeared which would not flower in Northern U.S.A. (where its parent plants had successfully existed) but which could be made to flower and seed by keeping it under artificial illumination which corresponded in length of day and night with a sub-tropical summer. Suddenly at a bound the strain had fitted itself for an entirely new climate.

Here we have four examples of mutations. A stock has bred more or less true for generations; suddenly something happens in its chromosomes, some innovating change, and an individual with an entirely new feature, a "sport," appears.

Let us be clear about this process. If we cross an ordinary grey wild-type rabbit with an albino, the offspring will all be grey. But although they do not show it they carry the gene for albinism in their chromosomes; if they are bred with each other, albinos may turn up in the next generation. A gene, like an albino, which can sometimes be carried by an animal without showing its effects, is called recessive. Sometimes a recessive will lurk concealed in a strain for generations and turn up abruptly. Thus, and in other ways, the common shuffling of genes may imitate mutation. But these four novelties recalled no known precedent. True innovation is a quite different thing from the release of a recessive; the change is produced by an actual alteration in one of the genes, not by merely shuffling the old ones about.

It is a genuine innovation, an enduring change in the germ-plasm, and it need not show the slightest disposition towards recessiveness under hybridization.

These little gene-leaps that we call mutations are certainly one very important way in which the race changes. They are the normal ticks of the evolutionary clock. By mutations, now in this part, now in that, races slowly modify themselves.

The classical studies in mutation have been made with various species of that most convenient of insects, the fruit-fly (*Drosophila*). Every now and then, among hundreds of normal fellows, a "sport" appears. The novelty may differ from the rest in eye-colour or in wing-shape, or indeed in the appearance of any part of its body, in length of life, in its reaction to light, and so on. Often the same mutation turns up independently in several different stocks. Altogether in the course of this Drosophila work over five hundred mutations have been carefully recorded. Thus every now and then the germ-plasm experiments and tries something new.

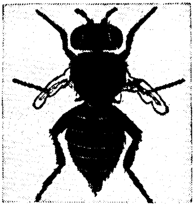


FIG. 36.—A DROSOPHILA WHICH NO LONGER LOOKS LIKE A FLY.
A specimen of a strain combining two mutations, vestigial wings and black body.

(*From " The Physical Basis of Heredity," by Prof. Thomas Hunt Morgan. J. B. Lippincott Co.*)

By skilful crossing it has been possible to pile together a great number of these mutants into a single strain. The resulting insects are amazingly unlike the " normal " parent type. They look more like ants than flies, and it is highly unlikely that if an entomologist were confronted with specimens without explanation he would identify them as *Drosophila melanogaster*. He would think them at least a different species. There are many other well-established cases of mutation in domesticated animals. Among plants, maize and the garden flower called *Primula sinensis*, the Chinese Primrose, are classical examples, but there are plenty more.

It is, of course, impossible to *observe* mutations directly in wild nature, for one has no pedigrees and cannot tell whether a variety appears merely by shuffling of pre-existing genes or whether it is really a mutant. But there is every reason to believe that mutation is frequent in wild forms. There are plenty of clearly demonstrated cases where wild animals and plants differ in characters which are inherited according to Mendelian laws, and which we may presume therefore to have arisen by mutation. Thus the grasshoppers *Paratettix* and *Apotettix* of the Middle Western U.S.A. are found in an astonishing range of colours and patterns, all of which Mendelize. In guinea-pigs and rats, the coat-colours of different wild species have been shown to differ by Mendelian genes. In pheasants and in snapdragons and primulas, where fertile species-crossing is possible, Mendelian species-differences are also known (see Ch. IV).

Note that these mutations that we have been discussing, the Ancon sheep and the Florida Velvet Bean and the Tobacco and the rest, all produce pretty considerable results. They are rather abrupt jerks of progress. But all mutations are not like that. Some are so small as to be barely perceptible, and probably these are the commonest. An abrupt jerk will obviously stand more chance of being noticed by the human observer. Occasionally in the course of very delicate experimentation such inconspicuous mutations have been recorded ; Johanssen observed two in his beans, Castle saw some in rats, and quite a number have been found in the fruit-fly. Such minute changes are probably widespread in animate nature.

Thus, with apparent spontaneity through these greater and lesser mutations, the race makes its experiments. In the remaining sections of this volume we have to see how, out of these mutations, the steady progressive changes of Evolution may be wrought.

## § 3

### *Are there Forward Bounds in Mutation?*

Here perhaps we may find space for an idea that had some currency in the beginning of the century through the work of de Vries (born 1848). It is that there are spurts, jolts, storms of mutation in the case now of this species and now of that. A stock was supposed to evolve in a series of violent efforts, first a rush of variation, then a rest, then another rush, followed by another rest, and so on. These onward pushes he thought supplied the greater part or all of the variational factor in Evolution. They were considerable enterprises, aggressions, novelties. They might yield new species at a bound. It is as if a species or group of species, going along in a humdrum way, were to be suddenly pricked by an unaccountable whipper-in. Recently this idea has been revised in an exaggerated and purposive form by Mr. Hilaire Belloc in one of his all too rare contributions to biological discussion. Unable to imagine how a fore-limb could be transformed from a walking limb into a wing, convinced of the fact of Evolution and equally convinced by the assurances of an eminent Montpellier biologist that the commonly accepted pedigree of the birds is unsound, Mr. Belloc resorted to the suggestion of a rapid series of large mutations, during which the developing birds must have led a retired and embarrassed existence, providentially escaping extinction until the new gift was attained. Contemporary biology has no need and no evidence for this grotesque hypothesis.

The work of de Vries was based almost entirely on the behaviour of one of the Evening Primroses (*Œnothera lamarckiana*) which he found growing ready to hand in

Holland. It seemed to be in the throes of an evolutionary burst, throwing out all sorts of strange varieties among its offspring. His work was already shaped out before the revival of Mendel's ideas or the realization of the full significance of the chromosomes in development, and on the face of it seemed to justify his claim that a species in a stage of violent evolutionary activity might by large and abrupt mutations throw off new forms, some worthy to be classed at once as new species while others constituted marked new varieties.

Unhappily he had hit upon this *Œnothera lamarckiana* for his material, and the species happens to be a very exceptional one. It is loose and inaccurate in its chromosome process to an extraordinary degree. One of de Vries' new types was due to a duplication of all the chromosomes, giving an exceptionally large plant with four instead of two chromosome-sets. The majority, however, owed their origin to the slipping of a cog in the machinery of chromosome-reduction, a fault to which Œnothera, with some other plants, is particularly prone. Sometimes both chromosomes of a pair stick together at reduction instead of separating, so that one gamete-nucleus receives both, the other none. All those with none inevitably die—they have not got a complete chromosome-pack. When those with two members of a pair unite with a normal gamete, the resulting plant has an extra chromosome, being provided with three instead of the normal two of this particular kind. And this, of course, has an effect upon its appearance. For instance, a triplication of one particular chromosome gives rise to plants with very broad leaves.

These types, however, have no evolutionary significance, for they cannot breed true. At reduction, the three chromosomes separate into two and one. If, at fertilization, two meet two the resulting plant, overbalanced by two extra chromosomes of one kind, is unable to live. If one meets one, the normal original type is reconstituted; only when two meets one is the new type repeated, and this in further generations must again always throw a certain number of normals.

Then owing to an extraordinary complication of lethal factors, which kill their bearers, recombinations occasionally can crop up in a previously unsuspected way, and were mistaken by de Vries for new mutations; and finally some new mutations and recombinations appeared as they do ordinarily in other plants and animals.

The net result of twenty-five years of research, summed up in Renner's monograph, is that no special storm of mutation is agitating Œnothera's germ-plasm. So far as we can see, the kind of sports it is throwing now it will continue to throw as abundantly as ever, so long as it exists; and most of them are accidents to the chromosome-machinery, of no significance for Evolution. As regards true evolutionary material, Œnothera is producing no more gene-mutations than do the general run of plants and animals; as regards its other sports, there is no reason to suppose that it is at the moment indulging in a burst of them. De Vries was as unlucky in Œnothera as his material for the study of Evolution as Mendel was lucky in his choice of the pea for his study of heredity.

But even though we dismiss the Evening Primrose as evidence for Evolution by mutational booms, it may still be true that organisms are occasionally subject to fits of change, their germ-plasm to storms of mutation. It is a possibility; there is no reason why this should not be. Few facts, however, are to be found in support of such a view. Every animal and plant which has been carefully and intensively studied—wheat and flies, maize and mice, shrimps and peas—is found to be throwing gene-mutations. Further, the rate at which genes mutate seems roughly the same in all of them. There is some evidence to show that in Switzerland the Bee-orchid has started to produce numbers of varieties in the last fifty years, while the same varieties were scarce or absent earlier. But many more records and experiments on animals and plants, both in a state of nature and under cultivation, will be needed before we can say if such mutational storms are as isolated as they now seem to be or whether they do, indeed, bear upon the evolutionary process to any notable extent.

One tenaciously-held idea at least seems to be without foundation. It used to be implicitly believed by practical breeders and scientists alike, that the bringing of an animal or plant into new and favourable conditions would cause an epidemic of variations. Rich food, protection, and warmth for animals; cultivation, good soil and plenty of manure for plants—these were asserted to bring on mutation-storms. But modern experience is rendering this conclusion very doubtful. We see variations more readily when they are under our eye and when we are on the look-out for them; and in cultivation we preserve many that would go under in nature. That seems to be all.

This idea of evolutionary spurts was much more reasonable when fossil records were incomplete—for instance, when only half a dozen steps in the Horse progress were known—than it is to-day. Now, with the fossil records of the horses and the sea-urchins, of the pigs, camels and elephants, of the pond-snails (*Paludina* and *Planorbis*), ammonites, and many others at our disposal, we can feel reasonably sure that on the whole Evolution progresses slowly and steadily. Whenever we get a reliable fossil series we find that to be the case. The crises of Evolution when they occur are not crises of variation but of selection and elimination; not strange births, but selective massacres. The germ-plasm, it would seem, has gone on throwing up mutations at about the same rate age after age.

## § 4

## *Are Acquired Characters Inherited?*

Now we come to a knotty and controversial question, and the best way to get clear about it will be to attack it historically.

Lamarck, in his discussion of Transformism in the later eighteenth century, believed that a species modified itself as a result of the cumulative inheritance of the efforts of its constituent individuals. The ancestral giraffe stretched out its neck to reach the leaves of high trees; this elongation was transmitted to some extent to the offspring and thus, by generations of stretching, the species produced an innate elongation. The blacksmith wields his hammer and his muscles swell and harden; as a result of his exertions his children (on a Lamarckian view) are the more muscular. White men venture southward into the tropics; as a protection from the blazing ultra-violet light their skins become tanned, and thus by generations of cumulative tanning the coloured races of to-day are supposed to have arisen.

Lamarck held that, in the race as well as in the individual, exercising a faculty led to its further development. He did not invent this idea. Its truth was generally assumed at his time, as applied to human pedigrees or the breeding of domesticated races of animals, and had been so assumed for centuries. He simply adopted and extended the idea and showed how it might be imagined to play a part in Evolution. Moreover, he believed that neglected or unused parts shrank away and finally disappeared; the classic example of this was the hind legs of the whale, which were reduced to mere vestiges when these aquatic mammals gave up walking about on land and took to swimming in the sea (Fig. 14).

In addition, the modern followers of Lamarck stress the inheritance of the direct efforts of the outer environment. Everyone is familiar with such direct modifications of the individual. Animals on a low diet grow up stunted; trees exposed to a steady coast wind grow all in one direction; plants grown in darkness never form green chlorophyll. More subtle reactions are the individual immunity acquired after an attack of measles or small-pox, or the succulent fleshy leaves produced on geraniums and many garden plants by watering with salt water. The Neo-Lamarckians suppose that such effects, as well as those of use and disuse, are also inherited in their degree, and contribute to evolutionary change.

There are two ideas to disentangle here. One is the strictly biological problem: Do modifications imprinted on an organism during the rough-and-tumble of its lifetime affect the characters of its offspring at all? This is the problem with which as biologists we shall concern ourselves here. The other is the philosophical idea of the race perfecting itself by striving. We need not concern ourselves with this side of the question; plants and bacteria evolve as well as we do, and they cannot be said to strive without distorting the word beyond recognition. And in any case, unless the biological question is answered in the affirmative, the philosophical does not arise.

It is clear enough that the problem is of vital interest, for if acquired characters can be inherited we would reasonably expect education and the effects of occupation to be inherited; we could hope that by nursing our children carefully we were imprinting a permanent improvement on the race and there would be no limit to the improvement which education and social betterment could make on the human species, however carelessly it bred.

Let us remember that there is a strong "common-sense" bias in favour of the inheritance of acquired characters. The tales of the giraffe, the blacksmith and the sunburnt white sound entirely plausible. In the often-quoted example of the pointer dog it is natural to assume that the dog stands rigid at the scent of game because he has been taught for generations to do so by his masters, and the habit has become an instinctive character of the race. Yet at the present day the majority of trained biologists show a definite bias against Lamarckian interpretations. Let us note their reasons for this opposition.

When Lamarck put forward his views, the chromosome machinery of inheritance was still unknown. The profoundly illuminating nature of its discovery is not often realized. Darwin, who believed in the inheritance of acquired characters as a subsidiary cause of evolution, suggested a purely theoretical mechanism to explain it. A number of tiny particles, which he called gemmules, were supposed to be formed all over the body, and to swarm into the testes or ovaries by way of the blood-stream. From every organ, every tissue, they were supposed to come—from the head and the stomach, the ears and the feet—and they crowded into the germ-cells like the animals into the Ark. Then, in the embryos of the next generation, they were supposed to supervise growth and development, each going to the appropriate part according to its origin, back to the head or stomach or ears or feet, and thus the children were formed after the pattern of their parents. Now it is easy to see how on such a basis the inheritance of an acquired character could be explained. An injury to an arm, for example, by affecting the arm-particles, might at the same time damage the arms of unborn and unbegotten children. This view, with minor variations, was held widely before the chromosomes were discovered.

Contrast with this the modern gene theory. In the view we have just examined the determining particles were dispersed in the embryo, some going to the head, some to the feet, and so on. Like letters in the post, each had its appropriate destination. But on the modern view the determining particles (the genes) are not thus separated; as a result of the delicately adjusted processes of cell-division the whole complex is distributed together, much as a number of copies of a newspaper are printed, all alike, and distributed. Some sets go to the head, some to the feet, and they work according to their situations. It is like copies of one and the same popular newspaper going here into the hands of the sporting man, who reads merely the racing news, here to the speculator, who concentrates on the City column; Mr. Everyman runs his eye ineffectively over most of it and concentrates on the crime and cricket, while Mrs. Everyman (when he has done) consumes the Court and social intelligence and the fashion and household pages.

Some genes go to the testes and ovaries, and it is from these sets that the future germ-cells are derived. On this modern view there is evidently no direct continuity of protoplasm between the body of a child and that of his parents—except

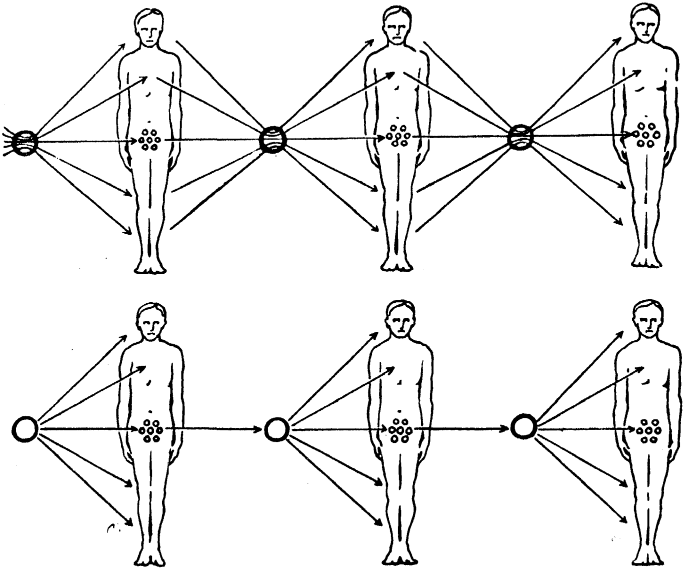


Fig. 37.—Two Theories of Heredity. The Upper Diagram illustrates Darwin's Theory of Pangenesis. Particles from all Parts of the Body were supposed to Migrate into the Germ Cells ; in the next Generation they go out again to the Corresponding Organs and Control their Growth. Below, the Relations between Germ-plasm and Soma as they are now understood. The Germ-plasm in each Generation produces Bodies (Soma), but these Bodies contribute nothing to the Bodies of their Descendants. Only the Germ-plasm continues.

for the reproductive organs of the latter. It has been neatly said that most of the body of a father is not really paternal to his children, but is their uncle ; one has to go back nearly to the previous generation to trace direct living continuity between a father's nose and his son's nose.

This point of view was stressed by Weismann (1834–1914). His distinction between germ-plasm and soma is illustrated by Fig. 37. When the chromosome mechanism was discovered he pointed out that it made the inheritance of acquired characters difficult to believe. And he tested the point by direct experiment. If the view which Darwin propounded, of a contribution from every part of body to reproduction, is true, then local mutilation of the body, by injuring some of the hereditary particles, will produce corresponding injury in the next generation; if the later view is correct, and the germ-plasm is separate from the beginning, mutilations of the soma will have no effect upon it. So he tried the effect of cutting off the tails of mice, with entirely negative results. Generation after generation of mutilation did not curb the tendency of the young mice to grow tails. The biologist might say with the poet: " There's a divinity that shapes our ends, Rough-hew them how we will."

There is ample corroborative evidence on this point. The Jews, for example, have practised circumcision for at least four thousand years, and yet they are still born of the same structure as Gentiles. And there are plenty of examples of similar failures to influence the shape of the race. The flat-head Indians and various African tribes compress the heads of their children into the most abnormal shapes. Chinese women of the upper classes were for many centuries compelled to compress their feet to mere trotters. Many races distend their ear-lobes with pieces of wood until they reach to their shoulders; and the women of some African peoples enlarge their lips in the same way until they protrude like fantastic beaks. But in not one of these cases is there any trace of an inheritance of the effect, whether it lead to a stunting as with the Chinese women's feet, or to over-growth, as with distended lips and ear-lobes.

Most familiar of all such failures is the absence of any hereditary effect on language. Not only do English children have to learn their own language, but they learn it no quicker than they would learn French if brought up from the first in a

French-speaking household. Here is a habit practised daily and hourly through all but the first year of life; and nothing of it, neither words nor ideas, neither grammar nor accent, has become engrained in the hereditary constitution.

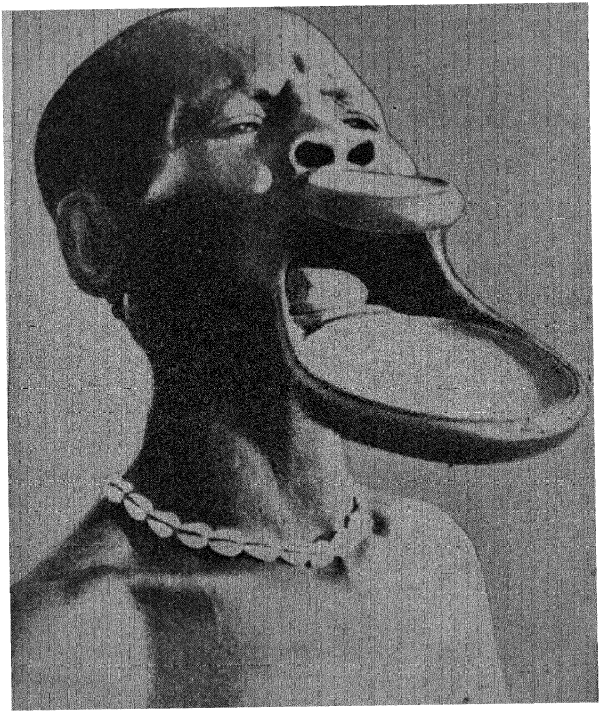


FIG. 38.—DISTORTION PRACTISED BY AFRICAN TRIBES: THE WOMEN OF THE SARAJINGI TRIBE IN THE LAKE CHAD PROVINCE DISTEND THEIR LIPS WITH WOODEN PLUGS.

(*From "La Croisière Noire," by G. M. Haardt and L. Audouin-Dubreuil. André Citroën, Paris.*)

❧ By these facts the older view of the hereditary mechanism was undermined, and the probability of a complete independence of the germ-plasm was strengthened. It became extraordinarily hard to see *how* an acquired character could be inherited. Weismann proceeded to look into the evidence for the phenomenon. Is there any need for us to admit this theoretically incongruous hypothesis into the harmony of our ideas? In a word, is there any clear case of such inheritance on record?

Many supposed examples, he found, could be dismissed as the result of mere chance, or of the natural but unfortunate tendency of human nature to remember and exaggerate striking coincidences, while allowing the much more numerous cases where nothing striking occurred to fade out of mind. A man has a finger amputated; his son is born with defective fingers. A woman bears a scar on her face as the result of a wound; her child has a birthmark in "exactly" the same place. Such facts may be perfectly true (although we often find we have to discount some of the exactitude of the resemblance on account of this tendency to make the best of a good story), but they do not prove anything. Isolated cases never prove anything, because they may be due to chance and we do not know the odds. Children with defective fingers or marks on their faces are also born from perfectly normal parents. Only a systematic collection of observations, selecting nothing and omitting nothing, or a systematic set of experiments, in which the results of treatment can be compared with those of a control experiment in which no treatment is given—only these will prove anything, whether positively or negatively. They will show us what is due to chance alone, and what to the treatment. To trust to these anecdotes of isolated cases is like backing a horse odds on when his real starting-price is completely unknown.

Many other cases Weismann found to be based on misapprehension. The facts were correct, but the interpretation was wrong or at least not necessarily right. Stockbreeders, for example, tell us that when barbed-wire fencing was first introduced in the Western United States there were many cases of cattle injuring themselves on the new-fangled fences, but that after a comparatively few years such accidents became extremely rare. This is often cited as a case of inherited experience; but it could equally well depend not on the young animals inheriting anything, but on their learning directly from the old, and this is on general grounds more likely.

Again, it is perfectly true that many seashore plants produce unusually fleshy leaves. So do many garden plants, such as geraniums, when they are watered with salt water. But in the shore plants the character is inherited; it appears even if they are grown miles away from the coast. May it not be that they owe their fleshiness to the cumulative effect of generations of exposure to the salty spray? Perhaps, but not necessarily. Succulence appears to be a useful quality in such situations, for the presence of salt makes it more difficult for the plant to withdraw water from the soil—the soil is, physiologically speaking, dry; and the fleshy leaves provide a reserve store of water in case the roots fail to keep up the supply. It is just as possible to suppose that mutations making for fleshiness occurred among the salt-plant's genes, were preserved because of their utility, and thus fixed in the hereditary constitution.

And so with the dark-skinned tropical races of man. Pigment is very necessary where the sun's rays are intense to protect the tissues from over-dosage with ultra-violet rays. There are some very fair people who never tan; they burn and peel, and suffer a great deal in low latitudes. In the tropics this protection is so essential that those who happened to have a hereditary constitution making for dark skin survived better than those of lighter colour. It is so essential that any further mutations towards dark skin were seized upon by natural selection. This is in itself just as good an explanation as that the actual tanning effect is cumulatively handed on by heredity. Only further evidence can decide between them: and as a matter of fact the constancy of negroes' skin-colour in such high latitudes as that of New York or Chicago is sufficient proof that full sunburning is

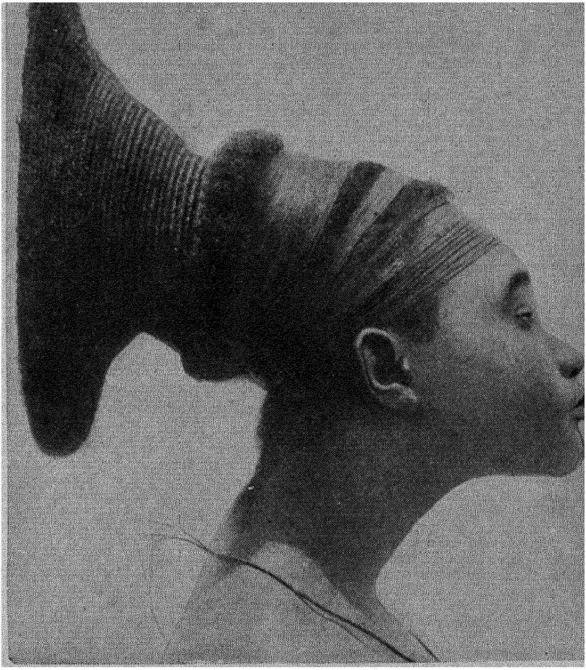


Fig. 39.—Distortion practised by African Tribes: the Women of the Mangbetu (North-eastern Belgian Congo) compress their heads into an Elegant Pointed Shape. Though these practices (Figs. 38 and 39) have gone on for generations, the children are born normal.

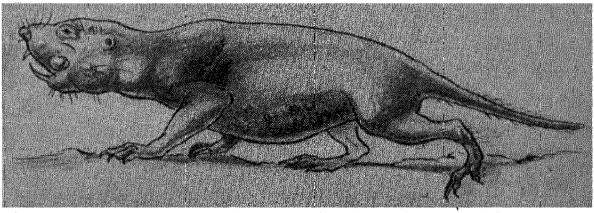
(*From " La Croisière Noire," by G. M. Haardt and L. Audouin-Dubreuil. André Citroën, Paris.*)

Similarly with the pointer dogs. The instinct of pausing a moment at the scent of game is found in the wolf and is not uncommonly seen in many breeds of dogs, some indivi-

FIG. 40.

duals showing it more markedly than others. By breeding in each generation from those animals in which the trait was best developed, man could as easily have built up the breed of pointers by selection of suitable variations as he did the breed of bulldogs or pouter pigeons.

An idea first developed in detail by Professor Mark Baldwin must not be overlooked. He pointed out that individual modifications, though not inherited, might co-operate with inherited mutations in helping the course of evolution. Suppose that the conditions of an organism's life are changed, whether through a change in outer conditions such as climate, or, in animals, to a mutation in instinct, forcing the creature to new modes of living. The new conditions modify the structure of the organism in each generation, so that it manages to survive—a sheep, for example, taken to a colder climate grows longer wool. But if a mutation crops up which alters structure in the same direction, this will be selected—the sheep might mutate so as to produce still longer hair under the same degree of cold, and this would adapt it still better to the new conditions. Modifications will often enable the species to hang on, so to speak, until the right mutation turns up.



FIGS. 40–1.—ONE OF THE HAIRIEST AND THE LEAST HAIRY OF LAND MAMMALS—THE SHAGGY MUSK-OX OF THE ARCTIC, AND THE SAND-RAT HETEROCEPHALUS (ABOUT FIVE INCHES LONG), WHICH BURROWS IN THE HOT SAND OF AFRICAN DESERTS.

The one (on p. 180) has abundant hair even when brought into warm climates, the other (above) is always almost hairless.

Let us consider in more detail what happens in the case of heavily furred animals. There is a direct individual relationship between temperature and thickness of coat. It is no good establishing fox-farms in too mild a climate; the fur is short and sparse, the pelts of little value. Now exposure of most mammals to warm conditions, while it brings about an increase in thickness of the outer skin or epidermis, diminishes the length of the hairs and also the thickness of the lower layer of the skin, or dermis. Cold has the opposite effect—thick dermis and luxuriant hair, but thin epidermis. This admirably adaptive modification depends on the existence of the machinery of temperature-regulation, combined with the fact that the hairs' growing roots project far down into the dermis. In the heat, the blood-vessels nearer the surface are opened up to cool the animal, and so the growing zone of the epidermis, just above these capillaries, is more richly nourished. In the cold, the surface vessels are narrowed; more blood flows in the lower layers, and the epidermis is on short rations while the dermis and the hair-roots are richly supplied.

But besides such differences due to modifications, there are differences due to heredity. The musk-ox is always and everywhere a shaggy beast, while the tropical buffaloes are always sparse of hair, and the Somaliland sand-rat *Heterocephalus*, like some breeds of fancy terriers, is all but hairless. The power of modification enables a mammal to penetrate into colder regions than it could otherwise tolerate, and there the species has to await the necessary mutations before extending its range farther into the cold.

There are many cases where the apparent inheritance of an acquired character is due to a confusion of cause with effect. For example, it is probably true (though statistics do not appear to have been collected) that the sons of blacksmiths are on the average physically stronger than the sons of, say, tailors. But is it not likely that men who inherit strong constitutions will be more inclined to become smiths than sit cross-legged and ply a needle, while tailors will be largely recruited from those whose poor physique rules out heavy labour?

A somewhat similar example is the supposed inheritance of the effects of alcoholism. In spite of numerous experiments, the matter is not yet fully settled. One thing is certain, that some species of animals can be made dead-drunk day after day and generation after generation without showing any deleterious effects whatever on health, length of life, fertility, capacity for learning, or any other measurable characteristic. This is true for mice, rats, and fowls. Indeed, in fowls, the average vigour and weight of the strain were increased by such treatment. Pearl, who made these experiments, suggests that the effect was really selective, the weaker eggs being prevented from developing. In guinea-pigs, on the other hand, Stockard found that the result of alcoholic treatment was, in some strains, distinctly bad, fertility being diminished and the percentage of monstrosities increased. Possibly, alcohol-damaged germs are killed in fowls, but just pull through in guinea-pigs.

For practical purposes what we want to know is whether man in his reactions to alcohol is more like a fowl or a guinea-pig. So far as the statistical evidence of Karl Pearson goes, he is more fowl-like—at least there is no evidence of inherited alcoholic degeneration in drunken stocks. The frequent occurrence of epilepsy, criminal tendencies, feeble-mindedness, and other undesirable traits in the same families where alcoholism is prevalent seems certainly to be not so much an effect of alcoholism as a cause. The unbalanced and the weak-minded take to drink more readily and under less provocation of outer circumstances than do men and women of better stock. The drunkards begin from a bad strain There are two ends to this stick, and the end which it seemed simpler and more natural to grasp may well be the wrong one.

One more example of the sort of trap that awaits the incautious adventurer in this field. Man is unique among living things in possessing language and a method of transmitting the results of experience from one generation to the

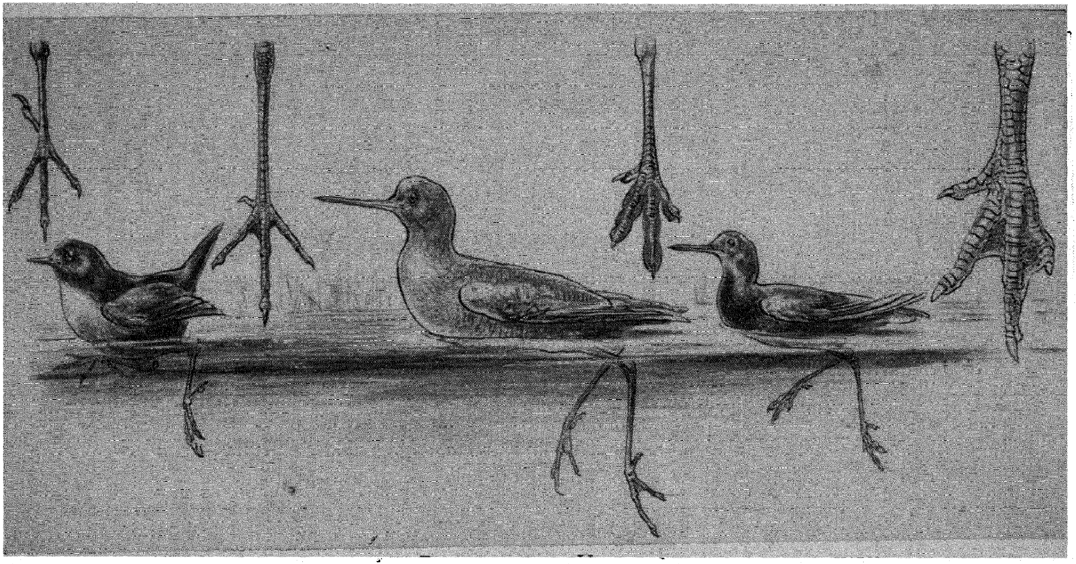


FIG. 42.—VARIATIONS, PROFITABLE AND USELESS, AND A FAILURE TO VARY.

Left to right, a Dipper, a Redshank, and a Phalarope, with larger drawings of their feet. The third of these water birds has evolved webs on its toes, but the Dipper has none and the Redshank hardly any. On the extreme right is a farmyard mutation of no biological utility—a webbed hen's foot.

next. The handing on of tradition, in the widest sense of the word, from father to son may be looked on as a special method of inheritance, which in many ways stimulates the inheritance of acquired characters, for by its means a son may inherit his father's opinions, or his refinements, or his special techniques. Moreover, the human child is very plastic and subtly absorptive, so that it is often difficult to discriminate between this sort of transmission and true inheritance through the germ-plasm. The sons of a blacksmith make better blacksmiths than the sons of a tailor. Is this because of inherited muscularity or because they were brought up in a smithy?—because of their germ-inheritance or because of their tradition-inheritance? Here then is another source of confusion, one of the many muddy sources from which the idea of inheritance of acquired characters draws refreshment.

We see that indubitable proof of the inheritance of acquired characters is unobtainable from mere observation of the animals and plants and human beings that live their lives and propagate themselves around us. Always there is the possibility of error. The world is so complicated a place that other influences may always have been at work.

It is, of course, possible that experimental evidence of such a mode of inheritance could be obtained. In animals or plants under domestication the circumstances can be controlled and simplified, and the possibility of such rival influence as selection, for example, can be removed. A number of experimental researches have indeed been made, which seem at first sight to give evidence in favour of Lamarckism, but not one of them is in any sense final. Many of them, when repeated by other investigators, have failed to give the original results. Many others have given negative results from the outset. We will not trouble the reader with a catalogue of these experiments. Not one but has some possible alternative explanation, some little slip that invalidates its testimony.

So that the reader, in this disputed matter of the inheritance of acquired characters, is free to choose which side he pleases. He can believe in it if it suits his philosophy. But he has to admit that it is at present quite impossible to see how such a mode of inheritance could work. There is certainly no inescapable argument in its favour. A large majority of contemporary biologists rejects the inheritance of acquired characteristics because it is a totally unnecessary hypothesis. They do not find it explains anything that variations due to mutation, whose occurrence is known and proven, cannot explain equally well.

This is perhaps best for humanity. It would doubtless be very desirable if the benefits of healthy upbringing, good education, and mellow experience could be entailed upon our descendants. But if they could be entailed, so could the effects of disease and unhealthy homes, the cramping effects of bad education and the fruits of vice and laziness and degenerate living. And it must be confessed that over the greater part of history, the bad has outweighed the good in the conditions under which most human beings have had to live. Disease, drink, excessive toil, slums, semi-starvation alternating with gross excess—the machinery of our germ-plasm is mercifully such that no taint rests upon us through the inheritance of these degradations.

## § 5

## *Artificially-induced Mutation*

It should not be inferred from our refusal to accept the inheritance of acquired characteristics that we think it impossible to modify the germ-plasm from without. It is entirely possible to do that. Mutations can be produced at will. But the thing is done by going straight for the germ-plasm and tackling that, and not by worrying with the individual body which bears it.

This work on the production of mutations is a product of the last few years. Until very recently no way of deliberately altering the germ-plasm was known. It seemed that the mutations were like the transformations of radio-active elements—something truly spontaneous, in the sense of being determined from within, not to be influenced in their rate of occurrence by any treatment which could be devised. But during the last few years we have at last received proof that this is not the case, and with this proof a new and vitally important field of research is opened up—the investigation of how to control the variation of animals and plants, not by the tedious and indirect methods of selection, but directly and immediately.

The most spectacular success is that of H. J. Muller, of the University of Texas, who chose the fruit-fly for his experiments, because its genetic constitution is already so well worked out. Briefly, his method was to bombard the fly with X-rays. He employed pretty heavy doses, enough to induce a slight degree of sterility in the flies, and he found that some wave-lengths were better than others. By this means he succeeded in altering the germ-plasm directly. There was no effect on the flies actually exposed to the X-rays, but among their offspring mutations turned up, literally by the hundred. He got flies with white eyes instead of the usual red, flies with unusually small wings, flies with their tiny bristles forked instead of straight, and all sorts of other strange forms, and the alteration in the genes was permanent, for the new varieties bred true after Mendel's laws. Some of them were dominant and some recessive. Some were altogether new; some were identical with mutations that had already turned up spontaneously in untreated fruit-fly cultures. To put it crudely, the germ-plasm had been thoroughly shaken up.

This line of work is being extended to other kinds of living things, and positive results have already been obtained with maize.

An exciting speculation, based on Muller's results, is that some at least of the natural mutation which is always in progress may also be due to X-rays. For X-rays do occur in the radiance that falls on our earth. True, they are very scarce; but then the mutations of wild things are much rarer than the artificially produced mutations of Muller's flies. And the two variables roughly cancel out, so that the suggestion is entirely plausible. A disturbing idea, that life has evolved and is still evolving under the spur of those strange rays, shot casually into our world from unknown corners of the universe!

## § 6

### *Moths and Smoke*

Besides X-rays, it seems that chemical influences can produce mutations. An interesting example of this was found a few years ago by Heslop Harrison, an English biologist. It concerns the black or "melanic" varieties of moths that are occasionally found wild.

About a century ago the first recorded examples of a dark or "melanic" variety of the peppered moth *Amphidasys betularia* were caught in England, and for years afterwards the variety remained rare. Collectors were keen, so that it is unlikely that the variation first appeared much before the date of its discovery or that its rarity was only apparent. It gradually became commoner, until by the beginning of this century it was in some districts more abundant than the normal type. Where it was common was in industrial regions and near big cities; in the countryside it remained rare. Other species of moth in similar localities gradually followed suit, until to-day in regions like the manufacturing areas of Northumberland or Durham scores of species are usually found of dark type instead of with their original white or brown or grey ground-colour. Sometimes the transformation has been amazingly rapid. In North Durham, for instance, Professor Harrison records that the moth *Ypsipetes trifasciata* was transformed from the normal light type to a dark one within twelve years; in 1898 no black mutants had been seen, while by 1910 the original light type was hardly to be found. Rather later than in Britain, melanic moths began to appear in other countries, but always in areas where industrialism had reached a certain pitch. They are now known from Germany, France, Belgium, and the United States. Moreover, wherever the breeding behaviour has been tested, the two forms have been found to differ in one Mendelian gene only, dark being almost always dominant to light. No help in escaping the notice of enemies seems to be conferred upon these moths by their dark colour; it is not a protective variation.

Now all green things in industrial districts are coated with a grime that is rich in poisonous metallic salts. It occurred to Harrison, struck by the coincidence between the distribution of black moths and of industrial smoke, that this might be the cause of the change. Accordingly he made the caterpillars of various moths eat tiny quantities of heavy metals, especially lead and manganese, with their food. His suspicion was justified; in the metal-fed cultures a few mutants with black wings appeared. Moreover, the colour, once it had been produced, bred true even without further metal-feeding. The chemical agencies had induced permanent changes in the germ-plasm.

Here, then, we have proof that environmental factors, X-rays or chemical substances, can actually induce mutation in animals. This must be distinguished very clearly from the Lamarckian method of inheritance that we discussed in the last section. The Lamarckian method was directly *adaptive*; the individual responds in a favourable way to some factor in its surroundings and the response is supposed to be inherited. But in these actually proven methods of modification there is no direct adaptive response. The experimental agents simply knock the germ-plasm about, so to speak. They produce random mutations, not adaptive responses.

And, indeed, mutation seems in general to be a perfectly random process. There is no evidence of adaptive striving or set purpose in the way new varieties turn up. The race varies in all directions at random, in a manner as casual and apparently purposeless as the desultory X-ray bombardment that may be the variation's cause. Out of these random, purposeless gropings of the race Evolution builds. But how? To that question we shall very shortly turn.

## § 7

### *Variation in Plants*

So far we have dealt only with so-called gene-mutations, i.e. changes involving a single gene. But there are other ways in which the germ-plasm can be modified. Mutation is apparently something of an accident, the result of diet or the impact of an X-ray, and the accident can affect more than a single gene.

Often if the chromosomes of a number of closely related plants are counted they turn out to be simple multiples of each other. Thus, different kinds of wheat may have fourteen, twenty-eight, or forty-two chromosomes in their body-cells—all multiples of seven. Then roses and brambles may have fourteen, twenty-one, twenty-eight, thirty-five, forty-two, or fifty-six. Bananas may have sixteen, twenty-four, thirty-two, or forty-eight. And similarly with a great number of cultivated and wild plants. This phenomenon is called "polyploidy," the presence of multiple chromosome-sets, and is apparently of widespread importance in the vegetable world.

We can presume that these races (which generally show evident differences from each other) arose by sudden doubling, trebling, and so on, of the chromosomes of the member of the series which has least. This can be imagined as happening in various ways. For example, a dividing cell might go wrong and fail to pull itself into halves after the chromosomes had been split. But we have no space to go into the details of polyploidy here.

The fascinating thing about these phenomena is that sometimes they seem to show us species evolving before our eyes. In the garden flower *Primula sinensis* a race suddenly sprang into being (during the last hundred years) with double the normal number of chromosomes. It differs in flower-colour, stem-colour, leaf-shape and growth-form from the parent variety, and because its chromosome-outfit is so unlike that of its parent form they are almost completely sterile together. About one in a thousand attempts to cross the two succeed. Such hybrids as are obtained are intermediate in type between the two parent plants, and are even more sterile. Surely, by all the accepted definitions of species, a new species has sprung into being?

Moreover, in this sense one can actually make species. If a tomato plant is repeatedly cut down always at about the same place, its cells begin to go wrong, and often doubling of the chromosomes appears. If this occurs, then a new kind of stem may grow out and produce leaves and flowers, the whole being quite different in appearance from the original plant from which it is growing. And the new variety is sterile with the old.

We must note that this sort of thing does not happen in animals, except in very rare exceptional cases. Plants have more varied methods of evolutionary progress than animals, corresponding with their more various methods of reproduction. But these strange polyploids share with gene-mutations their strikingly accidental nature. Both turn up, apparently by chance. Both are sporadic happenings, and yet they provide the raw material for evolutionary progress. To the way in which steady, orderly improvement of the race results from these random variations we must now give our attention.

# CHAPTER VIII

# SELECTION IN EVOLUTION

§ 1. The Meaning of Darwinism.
§ 2. Natural Selection as a Conesrvative Force.
§ 3. Natural Selection under Changing Conditions.
§ 4. Selection of Characters useless to the Species.
§ 5. Isolation as a Species-maker.
§ 6. Crossing may Produce New Species.
§ 7. Failures to Vary and Extinction

## § 1

### *The Meaning of Darwinism*

IN an earlier chapter we noted how Charles Darwin propounded the view—which he applied at first only to animals and plants and extended later to man—that in general the evolution of species was due to the Natural Selection of Variations. Let us be perfectly clear, even at the risk of repeating one or two things already said, what his phrase " the struggle for existence " means. The essential fact on which it lays stress is that the power of living things to multiply is so great that every living species is constantly tending to press upon its means of subsistence. The daily life of any wild creature is primarily a struggle, against enemies and rivals, for a share in those limited means. In that struggle the less capable, the less well-equipped are pushed to the wall. They are pushed out of the game, they fail and die, and their sort dies with them.

Every animal and every plant produces offspring in such numbers that many must die if the numbers of the species are not to increase in every generation. The elephant is the slowest breeder among animals; Darwin estimated that an average pair produces only six young in ninety years of reproductive life. But even so, if all the young survived, a single original pair would in five hundred years become fifteen million. Most animals and plants produce their eggs and seeds by the hundreds or thousands, and yet their average numbers remain steady throughout the generations. This can only happen if, out of all the offspring produced by each couple, on the average only two survive to reproduce their kind again. All the rest must die—it is a question of the simplest arithmetic.

The numbers which must normally die are vividly brought home to us when we see a species temporarily released from pressing on its means of subsistence by being imported into a new country where it happens to thrive. In a few years it fills the whole area. The Canadian water-weed was accidentally introduced into England in the middle of the last century. Within ten years it was clogging the waterways and holding up canal traffic all over the country. The English sparrow is to-day as common and as much of a pest in America as it is in England, but it filled the United States to saturation point in the geologically negligible time of less than a century.

The struggle may act at any period of life; it affects every department of existence. There may be a struggle within the womb; in most mammals more eggs are fertilized than there can be young born. Under every forest tree there is a struggle among the seedlings—a struggle for air, for light, for nourishment from the soil. There is a struggle between closely related species: the brown rat when it invaded Europe almost exterminated the black rat. There is a never-ending struggle between eater and eaten: among the eaten to escape, among the eaters to secure enough prey. There is a struggle among plants to escape being browsed out of existence, a struggle among seeds for wide dissemination. There is a struggle against the forces of nature: of the migrating bird to survive the gale, of the flower not to go under in the rain-squall, of the reindeer not to be frozen in the arctic winter. There is a constant struggle against disease and against parasites. There is a struggle for mates and breeding-places in animals, a struggle for cross-fertilization in flowering plants.

The struggle for existence, as Darwin was careful to point out, is in a sense a metaphorical struggle. It is rarely a conscious effort; there is automatic competition, and some competitors are automatically crowded out. The fast-growing embryo in the womb does not know that it is causing the death of its less-favoured brother-embryo. The black rat was not engaged in conscious warfare with the brown rat, but it simply throve less well and multiplied less rapidly. The bird knows that it is being beaten down by the wind or caught by the hawk; but the true struggle in Darwin's sense lies between it and its stronger or swifter congeners that weather the storm and escape the enemy, and of this the bird knows nothing. But if the struggle is metaphorical in this sense, its results are real enough. The better-equipped survive, the worse-equipped die; that is no metaphor.

Without variation, however, the struggle would bear no fruit for life. If all individuals in a species were exactly alike, then it must be a mere question of luck which failed, and the struggle for existence could not alter the characteristics of the species. Or if they differed but their differences were not inherited, it would not matter from the evolutionary point of view which went under. But since many differences of an advantageous or disadvantageous sort exist and are inherited, the struggle for existence acts on a species like a filter or a sieve. It selects types of success and failure, sets a premium on advantageous variations and continually removes a large majority of the disadvantageous ones, so that the average of the species moves in the advantageous direction.

To picture this selection, this combined effect of struggle and variation, at its work, let us go back in thought to the fir-trees in a forest, each letting fall its thousands of winged seeds. Many fall under their parent; many others just outside its shelter; others are carried farther. Everywhere in the forest and for some distance beyond its boundaries the ground is strewn with seeds every season. The struggle begins at once. There is much purely accidental destruction; as in the parable, some fall on stony ground and cannot germinate, some where they are choked by other plants. But there is a selective struggle, too. An old tree has fallen; there is a vacant spot in the forest. This, too, is covered with seeds. But some germinate faster or better and so gain a start. Among the horde of seedlings some send leaves up or push roots down more slowly; they will invariably lag and be overshadowed and killed out by their brothers. Some will have less green chlorophyll; some will have leaves less well arranged to catch the light. Some will be particularly efficient at drawing water and salts out of the soil, others at turning the raw materials into new substances for growth. The net result is that some grow faster than others. " From him that hath not shall be taken away," and those that are backward become still more handicapped as their competitors overtop them; the disproportion in growth increases and the innate vigour of the few finally involves the death of the less well-equipped many. There is struggle, there is variation—and so there is selection.

We may perhaps quote Darwin himself to show how he envisaged the struggle and its results in one of the higher animals.

> Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey—a deer, for instance—had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf was hardest pressed for food. Under such circumstances the swiftest and slimmest wolves would have the best chance of surviving and so be preserved or selected—provided always that they retained strength to master their prey at this or some other period of the year, when they were compelled to prey on other animals. I can see no more reason to doubt that this would be the result than

that man should be able to improve the fleetness of his greyhounds by careful and methodical selection, or by that kind of unconscious selection which follows from each man trying to keep the best dogs without any thought of modifying the breed.

It was this sifting of variations—the automatic preservation of the favourable and elimination of the unfavourable—which Darwin meant by Natural Selection. It would be quite inoperative without inherited variations. But given that, it explains the process of Evolution with a completeness approached by no other explanation.

Here we propose to study the process of selection itself in its chief modes and varieties of action. Natural Selection, as we have said, is a fact in the process of evolution and not a theory. It is not in itself the *cause* of anything whatever. Professor Fairfield Osborn, in a recent enumeration of the factors in the evolutionary process, set it aside from the others as "non-energetic," an excellent distinction. The others, the various causes of variation, were "energetic," but Natural Selection was simply a passive stop or release of what the others had produced. And that is the essential conception of its action. It is a filter; it is a sieve; it is a balance to reject or accept. Either a variation in the germ-plasm qualifies for success or survival or it disqualifies. The disqualification of a variation may be absolute—as when two recessive lethal genes get together to kill a yellow mouse in the uterus—or relative, when there is merely a disadvantage that enfeebles the new type, puts it at a disadvantage, or prevents it breeding as freely as the species in general. The advantage of a variation, on the other hand, is always relative. It gives the individual an ampler life and fuller opportunities of distributing the new advantageous gene.

We lay this much stress on this fact that selection *is* selection and no production, not because we lack any respect for our readers' intelligence, but because there exists a voluminous foolish literature of controversy in which Darwin is alleged to have taught that Natural Selection, in Heaven knows what inconceivable way, *produced* variations. Thereupon he is trounced, disposed of, burnt in controversial effigy and generally made an end to. Some victim of such mephitic controversy may chance to breathe the purer air of this work, and for him it is that we underline the obvious and explain to him that A means A, and not X, Y, Z. All about us and at every moment Natural Selection is going on. Mr. Everyman slaps at a fly, and it moves or does not move quickly enough to avoid him. He catches a glimpse of Mr. Everymouse, who was not smart enough to keep out of his way, and he decides to put down a trap. He strokes his cat, which is neither clever not patient enough to get Mr. Everymouse, and goes out into the street, so preoccupied with the painful question whether he will keep his cat or send it to the chemist, that he is nearly knocked down by an automobile he has failed to observe. He stumbles back clumsily, bruises his hand against a wall, and is invaded by some myriads of bacteria of a devitalizing and dangerous type. Will his white corpuscles do their duty?

All living individuals are being thus tested in every moment of their lives by little trials that may or may not put them aside among the " rejects " of life. With man, mouse, cat, or bacterium goes so much distinctive germ-plasm, to pull through or to be wiped off for ever from the possibility of further development, according to their individual reactions.

## § 2

## *Natural Selection as a Conservative Force*

We are apt to speak and write of the factors of the evolutionary process as though they were driving us on to incessant fresh developments, new things and strange things, but that is by no means always the case. The action of Natural Selection is probably on the whole conservative, except during periods of marked change in the meteorological or biological environment. It has no bias for wild-eyed novelty. It is just as effective in keeping things in their places.

We have compared it to a filter. But it is, we may say, a directive filter. And the direction in which variation is guided by selection is determined by the environment. While that remains stable, selection will be a stabilizing force, a conservative influence. If a species is well adapted to its rôle in life, Natural Selection will be busy pruning the variants that depart too far in any direction from the temporary ideal. But the environment may change; and it may offer inducements to responsive change. This revolutionizes the selective policy: and Natural Selection in such a changing environment becomes a radical influence in the politics of life. It is now all for new ideas.

A good instance of Natural Selection as a conservative force is supplied by the common sparrow. The English sparrow, as proved by its rapid spread over the world, is a species excellently adapted for ordinary all-round activities. After a severe storm in the United States a number of sparrows were found in distress, beaten down to the ground. They were taken indoors and tended; some revived, some died. Measurements showed that those which died comprised fewer specimens with wings of average length and more with wings unusually long or unusually short. Selection by storms was evidently preserving the central type.

We have further the remarkable fact that no measurable differences, whether in size, proportion, or plumage, can be found between the sparrows of Britain and those of various localities of the United States, where the bird is an alien intruder, and this although many of the environments which it has colonized (such as parts of the American desert) are different from anything to be found in its original home. This is indirect evidence of selection keeping a well-balanced type stable.

To jump from birds to molluscs, snails preserve a record of their growth in the inner whorls of their shell. When measurements of proportions were made on the inner whorls of a number of adult land-snails, and compared with the proportions of young snails of size corresponding to their inner whorls, it was found that the young snails had a greater range of variation. The old snails represented the shots on the central part of the target; the fringe of scattering shots had been eliminated. Natural Selection was refusing the novelties.

And just as Selection the Radical seems capable of guiding variation along paths of far-reaching change, as in the stock of horse or elephant, so it appears that Selection the Tory may keep organisms in a state of evolutionary immobility over awe-inspiring periods of time. The classic example is Lingula, a mud-burrowing lamp-shell. Examples of this identical genus, differing only in trivial details from living species, flourished in the Cambrian (III A) seas, 500 million years ago. We do not know the length of a generation in Lingula: ten years is certainly well over the mark, but even this would give us fifty million generations of stability—fifty million generations during which all essential changes in the constitutions and habits of the creature have been prevented. It is, of course, possible that the absence of change is here due to the failure of variations to occur rather than to the success of Natural Selection in keeping them pruned down. We can only say that mutations have been found in every organism in which they have been carefully looked for, and that their total absence in this or any other case is unlikely.

The pruning effect of selection is also exerted in another way. Whether change or stability is being encouraged, the organism must be kept up to the mark. Wherever mutations have been studied, many of them are found to be deleterious. Mutations are random changes, and random changes in such complex machinery as that of life will often inevitably be changes for the worse. Natural Selection will always be occupied in ousting these from the germ-plasm of the species. Drosophila keeps on throwing mutations with striking effects; often the same one is repeated again and again, yet they are scarcely ever found in Nature—the reduced vigour which they entail leads to their automatic elimination. They fail at the Natural Selection entrance tests.

*Per contra*, the absence of selection will allow types to persist and spread which normally are kept down to a minimum. Black rabbits (whose black colour is due to a single recessive mutation) are not uncommon as a natural " sport." In most places but few are found. They arrest the gunner's interest, and are easier marks; as a result their numbers are kept down to a low level. But in some parks in England where no shooting is allowed, black rabbits are unusually numerous. Since the larger birds and beasts of prey have been exterminated in England, the gun is the main agent of selection; and this is here absent. Again, the imported rabbits which were turned out or escaped in New Zealand were of all possible coat-colours; and these survive in the large wild warrens which they have established, giving them a strange appearance. New Zealand possesses no land mammals to prey upon rabbits, and very few enemies of any other type. Rabbits are killed off as vermin by poison and other wholesale methods. It is safe to prophesy that if such a parti-coloured population were turned out in Europe, the percentage of greys in it would rapidly increase; it is the absence of any selective need for a coat of invisibility which allows the other types to persist in New Zealand.

On the Galapagos islands the traveller, so Beebe assures us, can tell without any trouble which birds are resident and which are migrants; the migrants are all as shy as are the run of birds in inhabited countries, while the residents have no fear of man. If the migrants had no fear of man, they would (alas for human nature!) have been exterminated in the inhabited countries where they pass the rest of their life; but on the uninhabited Galapagos there has been no such selection. Thus favourable and unfavourable are often relative terms. What is favourable enough on a desert island would not pass muster elsewhere.

The preservation of "unfavourable" varieties is seen most obviously in domestic animals and plants. It tickles our fancy to conserve hairless lapdogs and pouter pigeons, albino rabbits, and double-tailed goldfish; it pays us to breed impossibly large bulls and pigs that can scarcely waddle; it delights us to have double flowers even though they be sterile. We alter the incidence of selection, we pet what the natural process destroys, and these types, which could not for a generation hold their own in nature, are made to abound and multiply.

As an illuminating example of the way in which mutation and selection co-operate, we may consider water-birds' feet (Fig. 42). The Dipper is a water-bird, but with no special adaptations of structure to aquatic life. It is kept a water-bird by its instincts. However, if a mutation for webbing or lobing of the toes were to appear in the Dipper stock, it is difficult to believe that it would not be fixed there by selection. This indeed seems to have happened among the wading birds (*Limicolæ*). Most of these can swim, though without a trace of webbed feet; and this faculty must often serve them well in getting across deep channels or securing a tit-bit otherwise out of reach. The Phalaropes are birds of this sub-order, but in them broad lobes are developed on the toes, making it possible for them to swim much more efficiently, and indeed to pass whole months on the open ocean. In them, the needed mutations have cropped up. Incipient webbing has also repeatedly appeared as a mutation in domestic fowls and pigeons. But as they do not normally swim, it is of no use to them; whereas as waders were already in the habit of swimming, webbing or lobing could be at once seized upon by selection.

The germ-plasm is like a garden, and Natural Selection in many respects like its gardener. Weeds are always cropping up in it, and threatening to swamp the cultivated plants. Selection, as well as sometimes helping in the creation of new types of flowers or fruit, is for ever busy with the humbler task of weeding. But there are gardeners *and* gardeners;

some have not the time or energy for weeding of a professional standard ; others may even prefer an untidy garden. Thus, dropping our metaphor, sheltered conditions often allow variations to persist which more rigorous selection would eliminate. It is commonly believed that this applies particularly to human heredity. Modern civilization is said to be lightening the severity of the selective process upon our race. It is also commonly believed by the same people —but usually at different hours of the day—that modern civilization is more exacting upon nerves and health than any previous state of society.

## § 3

## *Natural Selection Under Changing Conditions*

But now passing from the consideration of Natural Selection as a species-conserving and species-regulating influence, let us look at it in operation as a fosterer of variations and so as adapting species to new conditions. Here is a case we quote from J. B. S. Haldane's admirable *Possible Worlds :*

> The assertion is still sometimes made that no one has ever seen Natural Selection at work. It is therefore perhaps worth giving in some detail a case recently described by Harrison. About 1800 a large wood in the Cleveland district of Yorkshire containing pine and birch was divided into two by a stretch of heath. In 1885 the pines in one division were replaced by birches, while in the other the birches were almost entirely ousted by pines. In consequence the moth *Oporabia autumnata*, which inhabits both woods, has been placed in two different environments. In both woods a light and a dark variety occur, but in the pine wood over ninety-six per cent. are dark, in the birch wood only fifteen per cent. This is not due to the direct effect of the environment, for the dark pine-wood race became no lighter after feeding the caterpillars on birch-trees in captivity for three generations, nor can the light form be darkened by placing this variety on pines. The reason for the difference was discovered on collecting the wings of moths found lying about in the pine wood, whose owners had been eaten by owls, bats, and

night-jars. Although there were more than twenty-five dark living moths to each light one, a majority of the wings found were light-coloured. The whiter moths, which show up against the dark pines, are being exterminated, and in a few more years Natural Selection will have done its work and the pine wood will be inhabited entirely by dark-coloured insects.

There is a simple and pretty instance of the rôle of Natural Selection in bringing about adaptation. Another, equally simple, is known from agricultural practice. Various strains of cereals imported into Scandinavia, in the course of a few years changed their flowering and seeding period in adaptation to the shorter summers of their new home. This was for long supposed to be due to an inheritance of acquired characters. But careful experiment at the famous research station of Svalot showed that it was a simple effect of selection. As wheat is normally self-fertilizing, a wheat-field consists of a mixture of pure lines. The important seeds belonged to a number of pure lines differing in the rapidity of their maturing. The rigorous selection of their new northern environment weeded out all save the most rapidly maturing, and so the average of the stock was changed. There is here no actual record of new mutation in the same direction; but any that occurred would have been seized upon by selection and fixed.

Of course, these are small changes, but then, if we are to produce larger ones we must either alter the time-dimension of our experiments and observations or do something to accelerate the process. We cannot, unless we go back to Methuselah and a long way beyond, produce any current instance to set beside the long-continued, steadfast evolution of the horse. But evidently that evolution went on by steps, each individually as slight as these two. Nature is leisurely and works with a vast profusion of material. We can, however, work faster than she can, by cutting out all the futile trials and vain repetitions in which she indulges. Let us, for instance, put the biological experimentalist, Professor Castle of Harvard, in the place of Nature, and Castle's selection in the place of the loose, wide, hit-and-miss of Natural Selection, and let us see what can happen to certain rats.

Castle worked with piebald "hooded" rats. The standard type of this breed has black head and fore-quarters, with a black stripe along the back; the rest of the coat is white. This pattern is fairly variable, and Castle used it as material to study what effect could be produced by stringent selection for more or for less black. In one lot he bred only from those with most black; in another, only from those with most white. The results were striking: selection achieved types far beyond the range of variation normally found in the piebald strain. Selection for more black drew the "hood" along the back and spread the black line along the spine right down on either side. Meanwhile selection for more white in other rats from the same original stock had reduced the hood to a mere smudge on the nose and ears, and removed every trace of black from the body (Fig. 43).

At first sight these modifications imply (as Weismann and the Neo-Darwinians postulated) that selection could stimulate new variations to come into being; and so, indeed, they were at first interpreted. But the results were, as a matter of fact, mainly due to new recombinations of already existing factors. The hooded pattern, whether exaggerated or reduced, always behaves as a simple recessive to normal; but the degree of hoodedness, or, in other words, the amount of black, was affected by quite a number of what we may call modifying genes. These by themselves cannot produce a piebald pattern; but once the hooded gene is at work, they can modify the extent of its influence. Each of them singly has only a very small effect; in the medium-hooded rat there are many present, some making for the extension of black and others for its restriction; in the very black hooded rat a large number of extenders of the black patches are present, and so on. In the ordinary mixed stock it is thus very unlikely that all the plus or all the minus modifiers will ever become assembled in one individual as the result of chance mating. Selective breeding, however, will sift the

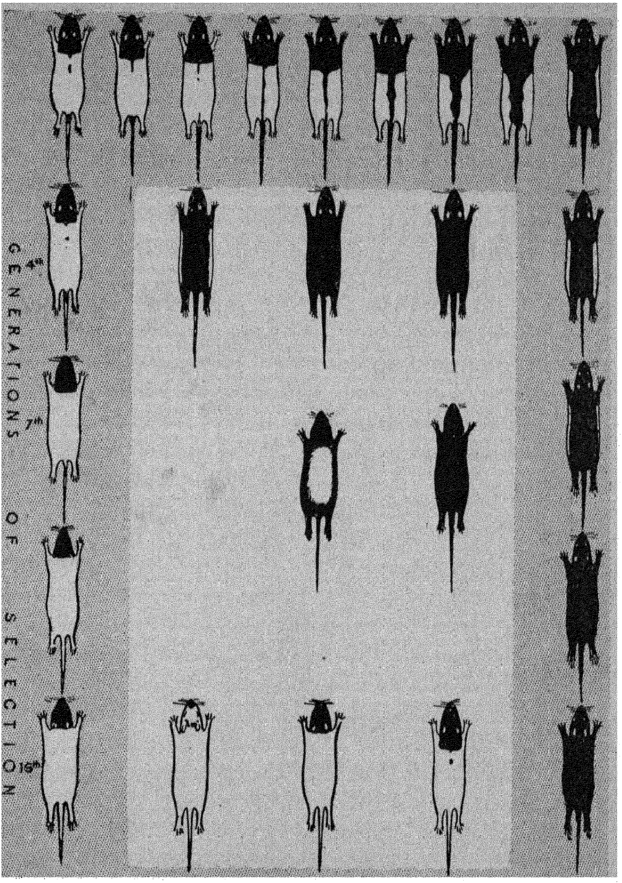


FIG. 43.—HOW SELECTION MAY GRADUALLY CHANGE A RACE.

Above, the range of variation in the ordinary hooded variety of rats. The effect of selective breeding for sixteen generations, choosing always the whitest rats as parents, is shown on the left. The effect of selecting for black is shown on the right. After sixteen generations the averages of the two strains are outside the range of the original strain. Inset, above, the average and extremes of the black strain; the lower surfaces of two are also drawn. The darkest has only a tiny patch of white on the throat. Below, the average and extremes of the white strain. The lightest has only small spots of black on the head. (Diagram constructed from Prof. Castle's tables.)

random heap; selection for more black will accumulate more and more of the plus modifiers, the black-extenders, in the germ-plasm; and vice versa. Once the combination of all the plus modifiers has been thus brought into being, a pure line has been produced and selection will have no further effect, unless the germ-plasm itself changes by mutation.

But changes in the germ-plasm can and do occur. In the early stages of such an experiment, while the stock is still very mixed, it will be impossible to distinguish the effects of a mutation from those of a better combination of previously existing modifiers, so that many mutations may pass unnoticed. But once approximately pure lines have been established, the appearance of new gene-changes can be spotted; and in this way at least two mutations which modify the hooded pattern have been identified by Castle. One of these was in the same direction as the selection that was going on; selection in this line was being made for more black, and the new mutation was a black-extender. It was incorporated by selection in the germ-plasm of this line; and thus the range of variation was still further enlarged in the black direction.

Exactly the same sort of thing happens in Nature, only on a grander, looser scale and over vastly longer periods. Castle's work teaches us two vital facts. First, selection in a cross-bred stock can bring about the recombination of existing genes, and so cause the stock to overstep its old limits of variation. Secondly, even though mutations be rare, yet selection in a given direction acts as an automatic trap for all mutations whose effects are in the same direction; thus, if it continue for a long stretch, it may accumulate plenty of these rare visitors, and so in time wholly alter the racial constitution. If mutations go on appearing, the amount of change that can be wrought is unlimited. In a word, it gives an explanation for the steady change of a race in a given direction—and that is precisely the sort of thing that the fossil record shows.

There are many who cannot bring themselves to believe that such trifling alterations, even if accumulated over the generations, can ever give rise to the broad and striking changes of large-scale evolution. They forget the extreme slowness of the change revealed whenever we trace Evolution in action. Only because palæontologists are thinking on a different scale of time from ordinary mortals can they speak of bursts of rapid evolution and the like. During such periods change may be faster than at other times ; but judged by our ordinary standards it is still of an appalling slowness. The Cenozoic Period (V) from its beginning to the Pliocene (V D) was a period of remarkably " rapid " evolution among the mammals. But, all the same, it took about forty million years to make a horse out of an Eohippus ; and yet the changes involved, important though they are, are changes of detail, not of essential plan, such as were needed to transform reptile to mammal, or fish to amphibian.

Suppose that we take the average age at reproduction of the horse and its ancestors to be five years (which is a generous estimate), we have, in this forty million years of change a procession of some eight million generations. During the whole period the horse-stock passed through eleven stages deemed worthy of generic rank. It changed its genus ten times ; so that we can broadly say that it takes 800,000 generations for a new genus to evolve.

It is more difficult to calculate, even in this crude fashion, the time needed for specific change ; but if we give the central line of each genus-stage eight minor stages worthy of ranking as species, we have again probably been generous : yet even this would leave 100,000 generations for the evolution of each new species. If we reflect that in the most extensive experiments on selection the limit as yet attained is about a hundred generations, and that even with Drosophila it would need three thousand years to run an experiment covering 100,000 generations, we may begin to feel that to demand " new species in our time " is an impertinence in face of Nature's lengthy patience. If Homer had been a biologist instead of a poet, and had begun a selection experiment with the aim of artificially creating a new species of Drosophila, and if the experiment had been carefully continued ever since, we should now be just nearing the moment when we could expect a result. Let us hope that three thousand years hence our descendants will not be lamenting our lack of foresight in setting experiments of this kind going; for only by means of such long-range work can the larger problems of Evolution be brought to the final test of experiment and control.

## § 4

### *Selection of Characters Useless to the Species*

It is often to be noted that some adaptation is extremely well developed in one animal and totally absent in related animals living under the same conditions. One butterfly exhibits an amazingly close resemblance to its background, while another that would seem to stand in equal need of such protection is without it altogether. One flower (like the common spotted orchid) possesses elaborate devices for securing cross-fertilization; another (like the bee-orchid) modifies the same mechanism to ensure self-fertilization. Often, too, the adaptation seems more delicate than we should imagine necessary.

From such facts it has not infrequently been argued either that apparent adaptations are really not adaptations at all, since their absence in other species shows them easily dispensed with, and, therefore, presumably not at all a matter of life or death; or, on the other hand, that though they may be useful, selection plays no part in their origin, but that some inherent tendency to particular adaptations exists in some species, but is lacking in others.

But such arguments are not cogent. Take a butterfly as example. The struggle for existence is at its hardest during its caterpillar and chrysalis stages; and in any case a limit is soon set to the numbers of the species by its food-plant; however many eggs may be laid, there is subsistence only for a limited number of caterpillars. Thus variations which merely help or hinder the survival of the butterfly stage itself can have no effect on the future of the race, unless they actually prevent all, or almost all, the butterflies from reproducing. Even if two adults survive where only one survived before, and twice as many eggs are successfully laid, no more than the fixed maximum of caterpillars can find food. In the same way, a diminution in adult numbers, if not too extreme, will be compensated for by the survival of a greater proportion of the caterpillars that hatch; again, if the caterpillars are over-abundant, they fall a readier prey to ichneumons and other parasites, and vice versa. The caterpillar stage acts as a buffer, taking up all minor fluctuations in the numbers of the adults. And yet it is perfectly possible for variations affecting the adult to be selected. If a variation crops up which gives its possessors greater immunity from attack by making them look more like a dangerous wasp or a nauseous butterfly, a larger proportion of these mimics than of the remainder will survive to reproduce their kind. The caterpillars will be kept down to their maximum numbers, but there will be a greater proportion of those which inherit the genes for the mimicking resemblance. Thus, when the butterfly stage of the next generation is reached, there will be a greater proportion of mimics than in the last. And so the process will go on, generation after generation, until the better mimics have wholly replaced the worse; and it will be repeated every time that there arises a new mutation making for greater resemblance to the "model." Yet, as Dr. Nicholson of Sydney has pointed out, the species as a whole will be neither worse nor better off than before. There has never been any danger of the race going under in the struggle against parasites or elements, or in the competition for food with other species; the struggle has been wholly within the species; it has concerned the survival of one variety in place of another, not that of the species as a whole.

Something very similar is to be seen in our human affairs. Shopkeepers can perfectly well make the same profits by opening for eight hours as for twelve hours—provided that all do the same. But if, when eight hours' opening is the rule, some take it into their heads to stay open for nine, the others must follow suit or lose money to their rivals. There is, of course, an alternative, which is that there should be a mutual agreement to open for a fixed time. The existence of this alternative is a reminder that comparisons of animal and human affairs, while often illuminating, must never be pressed too far. For man, with his affairs based on easily-changing tradition instead of the more slowly plastic germ-plasm, is able to cut the Gordian knot by just such conscious methods as mutual agreement, which are outside the range of animal possibility.

Another human example is seen in the results of unlimited competition in armaments. When one competitor adds a battleship, the others must do so too ; the same happens with cruisers and destroyers and submarines ; the armaments go piling up, and yet no nation is relatively better protected than at the beginning. Indeed, all are worse off, since all are spending more than they need. Something of this sort too may occur in animals. For example, the brilliant but cumbersome plumes of polygamous male birds like the peacock or argus pheasant must have been developed, like the mimicry we have been discussing, without any benefit accruing to the species as a whole. In some ways they must actually be disadvantageous, since they utilize a disproportionate share of the energy and material resources of their possessors, and make them so much more conspicuous and less agile that they must incur greater mortality. They confer advantage simply on one male as against another male.

If we like to coin a special term for the selection which can thus transform all the individuals of a species (or of one sex within a species) without conferring any advantage on the species as a whole, we can call it *intra-specific selection.* Darwin showed himself acutely aware of one aspect of this process produced by competition, namely, that between rival males or between rival females, and called it Sexual Selection. It has given us the vast size and strength of the bull bison and the elephant seal, the mane of the lion (apparently a defensive protection in conflict), the vast antlers of a stag, and the brilliant plumage of birds to which we have just alluded. Darwin's theory of Sexual Selection has undergone more adverse criticism than any other part of his work, but resent research has largely rehabilitated it.

There is no validity in the argument that adaptations of this sort are not really adaptations at all if other species get on quite happily without them. It is of no biological concern to the species whether they are present or no; and yet whenever the necessary variations turn up, they will be automatically preserved by selection. And so long as such variations arise, they will go on being selected; until the adaptation may become astonishingly perfect. It is characteristic of this intra-specific selection that it will neither extinguish an unadapted type in which no variations making for the adaptation have occurred, nor check the adaptation, once started, from going on to exaggerated perfection; while ordinary natural selection, in which the character selected is of value to the species as a whole, will achieve both.

It seems certain that a great deal of selection is working to produce adaptations of this curious sort. It is equally certain that in the human species similar results, equally obligatory for individuals or nations who wish to keep their heads above water, but equally useless to the community or the world as a whole, will be produced by the struggle of a purely competitive society, or of purely competitive international relations—unless man does what the animals cannot do, and, by deliberate agreement and convention, destroys the need for that vast amount of merely useless but otherwise inevitable competition.

## § 5

### *Isolation as a Species-maker*

Natural Selection gives a satisfactory explanation of all evolution that is advantageous. But many of the differences between closely related creatures do not appear to confer any biological advantage at all. How have they come into existence? It may be that further discovery will show that this is due to our ignorance, and that all these characters are really useful in themselves, or necessary accompaniments of some useful property. And if so, our second problem is only part of the first, and the origin of divergence is one and the same question as the origin of adaptation. But meanwhile we must treat the question on its merits.

In the first place, mere geographical separation certainly helps in the development of difference. Many wide-ranging species can be divided into geographical races or sub-species, inhabiting different areas. When there is no geographical break, one sub-species generally fades gradually into another across an intermediate zone. This is beautifully illustrated by the wrens of South America. There is an almost continuous wren-population over the continent; the wrens of different regions differ markedly in size, in colour, in pattern, in proportions, but the various types grade into each other.

Here and there, however, an isolated patch of wrens is separated from their congeners by some barrier, such as a high mountain-range, a stretch of sea, or a desert, and then we find no transitional forms linking them with other races. We can if we like call these groups species and the grading divergences sub-species; but apart from such verbal quibbling, it is clear that isolation has produced sharply marked types.

This effect of isolation in helping to bring new types into being is one of the everyday facts of systematic biology. It is most obvious where the isolation is most complete, for example in the plant and animal inhabitants of islands. Both St. Kilda and the Shetlands, for instance, have a distinct sub-species of wren. The puffins of Spitzbergen are all a little larger and have beaks a good deal bigger than those of the rest of Europe; and we know no adaptive meaning in the divergence.

In other cases, the divergence that is helped and hastened by isolation may be a useful one. We have, for instance, the case of the Florida Deer-mouse, recently investigated by Sumner. This animal is normally dark grey-brown, blending nicely with the colour of the soil. On a little island off the coast, all made of snow-white sand, exists a sub-species whose colour is nearly white—again blending beautifully with the background. On the coast opposite the island a third type is found which is intermediate in colour between the other two, and this, although it inhabits the same white sands as the island race. Selection of light variations must have been at work both on the island and on the shore; but while the island race is isolated, there will be some intercrossing between individuals from the interior and from the shore, and this will hinder selection at its work.

In our chapter on geographical distribution we spoke of the many animals and plants peculiar to the Galapagos islands, and how they were related to those of South America, the nearest mainland. But that was only part of the story. There is the further remarkable fact that of the archipelago's land animals and resident birds most types are represented by separate species on each of the main islands. This is notably true of the extraordinary giant tortoises; of the mocking-birds; and of the various genera of peculiar Galapagos finches, found nowhere else. It is equally true of the plants. As Darwin wrote: "We have the truly wonderful fact, that in James Island, of the thirty-eight Galapageian plants found in no other part of the world, thirty are exclusively confined to this one island"; and many genera are represented by a single different species on each island.

Chance immigration from the continent, followed by new evolution on the archipelago, would clearly account for the animals and plants of the archipelago as a whole. But what about the differences between the inhabitants of the separate islands—differences which become still more remarkable when we realize that on the American continent single species of similar creatures—mocking-birds, for instance—have ranges extending over hundreds of miles? The environments provided by the various islands are very similar, so that it seems most improbable that the conspicuous differences between the island-species are adaptations to conditions of life. It would rather seem that the prevention of intercrossing between the populations of the various islands has left each stock free to develop along its own line, and that each has happened upon a slightly different one. Mutation is a matter of chance, and here one mutation to which Natural Selection had no objection arose, and there another. Life was easy and adverse forces not very stringent. This extraordinary blossoming of distinct species, each on its little island patch, so impressed Darwin that he wrote, thirty years later: " When I visited the Galapagos archipelago . . . I fancied myself brought near to the very act of creation."

Equally striking are the snails of the Philippine Islands. The Philippines contain about 115,000 square miles of land, divided up among 30 large- and medium-sized islands and over 3,000 small ones. In spite of the difficulty which land snails find in getting carried overseas, the Philippines possess over a thousand species of these molluscs. The nearest land area in the same latitude is that of French Indo-China and Siam. This includes close on half a million square miles, but only 600 kinds of land-snail. The Philippines with their isolated islands must have been a veritable factory for snail-evolution. And we could multiply examples from every archipelago.

In fact, the degree of isolation of an island runs closely parallel with the number of types which are peculiar to it. Great Britain's isolation from the continent is too slight and too recent for many of its birds to have developed into new species—the Red Grouse is its only undoubted case. On the other hand, it does enjoy some measure of isolation, and as a result, many of its birds show slight but constant differences from their continental relatives; they have evolved into new sub-species. The long-tailed tit is a familiar instance, the bullfinch another.

The Canary Islands, on the other hand, though some of them lie only about fifty miles from the African coast, are separated from it by a channel over 5,000 feet deep, and have never formed part of the continent. And on them half a dozen birds have evolved into distinct species.

And for the extreme of isolation, let us take St. Helena, perhaps the most isolated spot on the globe, the most insular of all islands. Animals and plants have either wholly failed to reach this water-girt speck of land, or, if they have succeeded, have usually evolved and changed into something new.

Patches of water can be isolated by land as well as patches of land by water; and in the lakes of Ireland and Northern Britain there has been a remarkable divergence of fish belonging to the trout tribe, quite like that of birds on the Galapagos islands. Char of various kinds, vendace, gwyniad, and pollan—there are a dozen species of the two genera, *Salmo* and *Coregonus*, each restricted to one or a few lakes, while those species of the family which go down to the wide sea instead of living all their life in an isolated lake range over very large areas.

Thus isolation promotes divergence. It seems indeed to promote divergence irrespective of any advantage which the divergence might bring with it. This seems to be due partly to isolation preventing new types being swamped by intercrossing with the old, partly to the release of mutational forces from urgent competitive and destructive conditions. Oddities flourish in out-of-the-way places. The primarily conservative disposition of Natural Selection spares the corners. But the advance of knowledge will probably reveal other agencies at work. It is worth noting that however great the variety which isolation brings into being, it never seems to promote steady advance or long-continued specialization. To achieve that, stringent selection seems to be necessary.

But sharply distinct types may also come into existence by another method of isolation. If a species with many local varieties inhabited a large area, and then some change of conditions killed off the inhabitants of the central belt, the two end-groups would be separate with their differences ready-made. The shallow-water octopus, *O. apollyon*, was first described from the western coast of America. On the opposite side of the Pacific, off China, another form was found, differing markedly from the first in the size and shape of the peculiar arm by means of which the male transfers sperm to the female, and also in proportions and colour. It was naturally assumed to be a distinct species, and called *Octopus hongkongensis*. Later, however, it turned out that these two types formed only the two ends of a continuous chain of forms which extended from China round the northern Pacific, across by the Aleutian islands, and down to California. The two ends of the chain are very distinct, but all kinds of intermediates occur in the northern Pacific zone. If the chain were broken, as it might be for instance by the deepening of the sea between America and Asia, there would exist two distinct types with an unbridged gap between them. And we could equally well have cited such chain-types from among other groups, such as butterflies and birds.

## § 6

## *Crossing May Produce New Species*

New types can come into being through crossing. In the most striking examples, the cross at once gives what must be called a definite new species. For instance, when the two kinds of poppies, *Papaver nudicaule* and *P. striatocarpum*, were crossed, the offspring were quite distinct from either parent, were fully fertile and bred true. It is as if the cross between horse and ass were to give us, not a sterile hybrid, but mules that were fertile and could perpetuate their kind indefinitely.

This was possible owing to their chromosome behaviour. Poppy chromosomes go in sets of seven. One of the parents had two such sets, the other ten; their gametes therefore had one and five sets respectively. Fertilization gave six sets, or forty-two chromosomes. At reduction the six sets paired up, three against three, and all the pollen-grains and eggs had three sets; thus a true-breeding new type was made with six sets or forty-two as its ordinary chromosome-number.

In other cases the cross gives a type in which chromosome-sets do not find themselves able to pair up in this tidy way. It is therefore usually sterile; but in some specimens a doubling of the whole chromosome-number occurs (usually by the division of the chromosomes without division of the cell); chromosome-pairing can then occur, and so the new type become fertile. This is known among Primulas, for instance, and in Evening Primroses; and sometimes the new type is relatively infertile with the old. Here again something like a species is generated all at one bound.

There are still other ways in which new types can be created by crossing. Two distinct species may have the same chromosome-number, and also be fertile when crossed. Mendel's two Laws will then see to it that a great number of new types appear by recombination. Professor Baur of Berlin, for instance, crossed the garden snapdragon (*Antirrhinum majus*) with a wild species, *A. molle*. The first hybrid generation was, as we should expect on Mendelian grounds, uniform. It was also fertile, and in later generations produced a host of new types by segregation. Of some ten thousand plants raised there were not two exactly alike. This is precisely what was to be expected if the differences between the two species depended on a fair number of

Mendelian gene-differences, probably between fifteen and twenty. If the two differed in only ten gene-pairs, segregation could produce over 1,000 recombinations; if in fifteen genes, over 30,000; if in twenty, over 1,000,000.

Some of the types of flowers thus produced by recombination were quite different from anything seen in either parent, or indeed within the snapdragon genus, but resembled other genera of the family *Scrophulariaceæ*. We should like to know, of course, whether these types could hold their own in Nature, or might even be better adapted than their parents to special conditions; and investigations on this point are being carried out. Very similar results, as we mentioned in an earlier section, were got by Luther Burbank among his plant hybridizations.

But there are cases where crossing certainly does produce new types capable of holding their own in Nature. The most striking are found among those plant-groups which seem made to puzzle the classifiers. Roses, brambles, willows, hawkweeds—those, as any botanical amateur knows, are a terrible tangle of overlapping types. In every case free crossing between distinct species is the root-cause of the diversity and the tangle.[1]

Where animal species-crosses are fertile, as in various pheasants and in the natural crosses between two species of the American woodpeckers known as flickers, curious irregularities of pattern often crop up in the recombinations. Each species has worked out its own delicate balance between the different genes responsible for plumage-pattern; when the two are crossed, unbalanced combinations appear which are very easily upset by modifying factors or by environment. We may presume that the same sort of thing holds good with the genes responsible for other and more deep-seated characters. Thus in higher animals, which are far more complexly regulated bits of mechanism than any plant, after a

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[1] Not only segregation, but complications due to parthenogenesis and to difference in number of chromosome-sets may be involved; but they all result from the fact of crossing.

wide cross, the majority of recombinations are likely to be a little shaky in their adjustments, and therefore of no evolutionary account.

Nevertheless, there is one animal species in which this sort of thing has happened on a minor scale—our own. The inhabitants of Northern India are almost all brown-skinned and dark-eyed, although many of them have features closely resembling those of fair-haired European people. There is every reason to believe, however, that the invaders who burst into these plains from the north in the middle of the second millennium B.C. were fair-haired and blue-eyed, and that the dark-skinned population they conquered had features not at all of European type. The fair complexion has gone, the features have been preserved. We know that intense sunlight is harmful unless prevented from penetrating by an absorbent layer of pigment. During the hundred generations or so that have elapsed since the Conquest and the resultant intermarriage of the two stocks, the fair-skinned must always have been at a disadvantage compared with the dark-skinned. But the European types of features were at a premium, as being the hall-mark of the conquering race. The genes for fair skin have disappeared, but the new combination of aristocratic features with dark skin has survived.

Almost exactly the same thing appears to have happened in Greece. The Dorian irruption, somewhere about the twelfth century B.C., was of fair northern men; and yet there are scarcely any blue-eyed people in modern Greece. Some of their genes, but not others, have been selected out of existence, and so new types have been created.

To sum up, then, new types, often worthy, in plants at least, to be called species, may spring fully-formed from a cross, like Minerva from the head of Jove, without a long process of selection behind them. But though crossing, like isolation, may sometimes increase the variety of evolving life, like isolation again, it seems incapable of producing evolutionary advance. These agents of Evolution are only subsidiary. Mutation remains the great driving force.

Even if crossing between distinct types never took place, even if we could eliminate all the effects of isolation, Evolution, with Natural Selection at the wheel, would still go on so long as animals and plants continued to vary and the conditions of the world about them to change.

## § 7

### *Failures to Vary and Extinction*

Some of the more ardent followers of Darwin went a good deal further than the master. Natural Selection made it unnecessary to do as Paley did, and ascribe every adaptation to the direct agency of the Deity; but they proceeded to make a deity of Natural Selection. Weismann, for example, went so far as to maintain what he called " The Omnipotence of Natural Selection." Such exaggerations gave excellent occasion to the antagonists of Darwinism. But, as a matter of fact, few naturalists failed to realize at any time that the action of Natural Selection is a limited one. It is limited both by the quantity and the quality of the variations supplied to it.

Every case of extinction of a species is a failure to provide any variations which could have been used to meet and overcome the circumstances which were leading the species downhill. Sometimes we can see precisely what was lacking. The Great Bustard, for instance, that magnificent bird which once nested commonly enough in East Anglia, has now disappeared from almost all of North-Western Europe. The cause seems to lie in its excessive instinct of wariness. It leaves its eggs readily at the sight of man, and refuses to return to them so long as he is still in view. The result is that as soon as cultivation invades its haunts, the hen bustard is so often and so long off her eggs that they grow addled. If some mutation had but arisen to reduce this inherited cautiousness, the bird could have survived longer—perhaps long enough to reap the advantages of the modern sentiment in favour of bird-protection. As it was, the species cut its own throat by its shyness, for the right mutation never appeared.

The Great Auk, on the other hand, was doomed by its inveterate tameness. This bird had next to no fear of man and was massacred by sailors for food and oil in such numbers that it became wholly extinct during the nineteenth century. Could but a fraction of the Bustard's shyness of temperament have been granted to a few Great Auks, selection would have preserved them, and in them the species.

In many other cases we cannot put our finger so accurately on the cause of extinction. We know that when the Brown Rat, disseminated by trade, spread over Western Europe, the indigenous Black Rat quickly fell on evil days and was in many places brought to extinction on land (though it survived by taking to a life aboard ship). But we do not know what failed the Black Rat in the struggle, what variation would have saved it. Nor do we know why, of the different kinds of Zebra, Burchell's and Grevy's should have survived the opening-up of Africa, while the Quagga became extinct. Our absence of detailed knowledge does not, however, make the principle less cogent. One species or one group becomes extinct, another in the same conditions survives. The former could have escaped its doom if its germ-plasm could have produced the right variations and produced them with sufficient speed—but it did not.

This leads us at once to ask whether some species or whole groups may not be much less prone to vary than others; unfortunately, we cannot as yet answer this with any certainty. It is often asserted that highly specialized creatures, such as elephant or ant, fully evolved trilobite or dinosaur, lack the power of variation. This, however, seems to rest upon a misapprehension. Dog, horse, and pigeon are all highly specialized animals; and yet sufficient mutations have appeared in them in a short five or six thousand years to allow man to produce such extreme types as bulldog and dachshund, percheron and racehorse, fantail and pouter.

Variation thus may be abundant enough in specialized creatures. In Nature, however, the very fact of high specialization handicaps many variations which might have been useful enough to a more all-round and generalized creature. Just because a horse is so well adapted to running, it is further removed from any possibility of becoming adapted to climbing, or flying, or burrowing; and a variation, say, towards more carnivorous teeth, which might have been profitable to an animal not yet wholly committed to one particular line, would, in the horse, merely find itself in opposition to the majority of its other characters. Natural Selection the conservative frowns on such innovation. But alter the tendency of selection, as man the radical does when he breeds his stocks, and the versatility of the creatures is at once revealed.

A highly specialized animal is precisely one which has already been forced by selection about as far as it can profitably go along one particular adaptive line. A horse cannot reduce its toes to less than one; nor improve the mechanical construction of its limbs much beyond their present pitch; nor grow larger without sacrificing speed. Specialized adaptation to one particular mode of life is thus in its very nature a cul-de-sac; variations may occur, but they can only rarely be of service to the specialized animal or plant. The specialized animal is *in its own way* almost as perfectly adapted to its mode of life as is possible; if some other creature should find a better way, it is helpless. Thus Natural Selection has relatively little power to modify highly specialized creatures; but this lies more in the nature of specialization itself than in any failure of the specialized organism to produce mutations as fast as more generalized types.

But some kinds of animals and plants do seem to have a smaller capacity for variation than others. Almost every species of duck, for instance, is relatively very constant; even when its geographical range is a wide one, few or no variations are to be found. Wrens and titmice, on the other hand, are considerably more variable; each widespread species is divisible into a number of distinct sub-species, which usually grade into each other on the borders of their ranges. The same is to be seen in plants. If examples are needed, the wild pansy will serve, with its dozens of varieties in flower-shape and flower-pattern. On the other hand, however, that beautiful Alpine plant, the eight-petalled Dryas, is always very much the same, whether on the Alps or the tops of Scottish mountains, on the Great Divide in Colorado or at sea-level in Spitzbergen, nor does the ubiquitous bracken-fern show any noticeable variation from England to its antipodes.

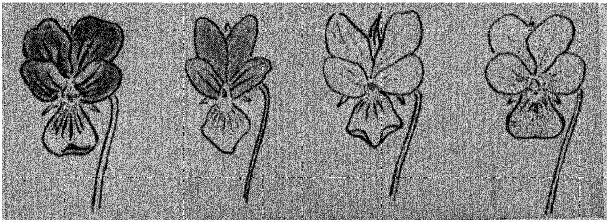

FIG. 44.—A VERY VARIABLE SPECIES. THE WILD PANSY OF EUROPE, VIOLA TRICOLOR, IN FOUR OF ITS NUMEROUS VARIATIONS.

The first is deep blue, the second light violet, the third white with a dash of yellow, the fourth yellow with a little white; the shapes, too, are markedly different.

It is certainly true that in the brief space during which Drosophila has been investigated, quite a number of mutations, such as that from red to white eye, have appeared in more than one species, and often repeatedly, a fact which argues the limitation of possibilities; and a similar recurrence of mutations has been found in most other organisms that have been carefully studied. It looks as if their germ-plasm had only a limited repertory of tricks. Limitation is also argued from such facts as the restriction of colour or pattern in various groups of animals and plants. Woodpeckers run to reds, blacks and whites, with occasional outbursts into green, yellow or brown; but blue and its combinations seem to be unknown among them. Gulls, on the other hand, show almost exclusively a combination of white with grey-blue or black; reds, yellows or greens are never found in their plumage. Among plants, the tendency of composites (like dandelion and daisy) to have either yellow or white flowers is familiar.

But such facts may be misleading. The prevalent colours may provide some advantage we do not yet understand; or their prevalence may mean only that they constitute the path of least resistance, not that variation cannot produce other colours. The Pierine butterflies or "Whites" give us a useful warning in this respect. As their popular name implies, the prevailing colour is white, usually combined with black; yellow, orange and greenish are also not uncommon; we might well suppose that their variation was restricted to these colour-themes. But in South America a number of Pierines have become mimetic; they mimic butterflies of the Heliconiid family. And among these mimics we find colours and patterns wholly unlike anything found elsewhere among the Whites. Thus an undoubted tendency to keep to certain colours need not prevent others being produced if need arise.

More to the point are some of the failures of breeders to obtain from Nature something which they particularly desire. Blue roses are the most famous example. For centuries a blue rose has been one of the goals of every ambitious rose-grower; and yet, though bluish-purple has sometimes been obtained, true blue is as far from achievement as ever. It is quite easy for roses to be all shades of red, yellow or white; but while it is perhaps not impossible, it is clearly very difficult for them to become blue. Black tulips are another case in point. During the tulip mania of the seventeenth century, every effort was made to breed a black-flowered tulip, and huge prices could have been obtained for such bulbs. The flowers were darkened to a deep bronze, but real black eluded the grower.

There are other limitations upon variation to consider. Natural Selection has never been given the chance of refusing or accepting a wheel. Not only has the principle of the wheel never been utilized in the bodies of living things, but it is impossible for it to be utilized. It is impossible, because a living organ rotating like a wheel could not be supplied with blood-vessels and nerves. The " Wheel Animalcules " or Rotifers, we may note in passing, simply have circlets of cilia in their structure and not wheels.

Important, too, are some of the broad restrictions to be found in larger groups. No arthropod and no threadworm possesses cilia. No insect has developed any form of skeleton save of pure chitin ; no mollusc and no vertebrate has any chitin at all. No vertebrate has any metal but iron in its respiratory pigment ; while sea-squirts can use nothing but the rare element vanadium. Chlorophyll, wherever found in plants, varies but little in its chemical composition and mode of working ; but it is never found in animals, even though many animals, such as reef-building corals, reveal their need of it by taking green plants into partnership with them. The reason for such restrictions we can only surmise. The insect constitution may be incapable of giving rise to cartilage or bone ; or else, insects having happened to make a start with an external skeleton of chitin, the production of substances suitable for an internal skeleton would be valueless without an impossible remodelling of their whole organization. But whatever the precise cause, the fact of restriction remains.

In other cases we can better understand the limitations. No insect weighs more than a few ounces, although if they could have attained the size of horses or even rabbits they would almost certainly have prevented the rise of vertebrates to pre-eminence on land and have become the world's dominant animals. No flying creature, bird, bat, or pterodactyl, has ever reached a hundredth of the bulk of a large elephant, for they all are well below a hundred pounds in weight.

This latter restriction depends on aerodynamic laws; with wings as propulsive machinery and muscles for power, larger creatures could not attain sufficient speed to avoid stalling. And the fortunate restriction of insect size is due to their having embarked on the method of breathing by air-tubes; this method, the most efficient of all ways of breathing for quite small land animals, becomes rapidly more and more inefficient with increase of bulk, since oxygen must diffuse along their tubes to reach the tissues; and if these are too long, diffusion takes so much time that the supply of oxygen is inadequate. Advantageous as size would have been to insects in other ways, Natural Selection could not give it to them, because their plan was fixed in a mould which automatically made size above a certain small limit a handicap to efficiency.

Thus, to sum up, the power of living things to change is definitely restricted. Sometimes it is restricted through the limitation of variation: one germ-plasm may be much more stable than another, or one type of constitution may readily produce variations in some directions, but be debarred by its own nature from producing them easily or even at all in others. Sometimes it is restricted by the mere fact of previous evolution; for specialization, without necessarily restricting the supply of variations, automatically makes the great majority of them less advantageous. The specialized animal is committed to a certain line of advance: variations that would take it along other lines can only be useful if it can manage to destroy or modify the plan it has already built up; and even to its advance along its own chosen line a term is eventually set—it reaches the limit of efficiency prescribed by mechanical or chemical laws.

But when all is said, the liberty of change open to evolving life is much more impressive than its restrictions. Here a door is shut, there a limit imposed, but the range of variety and height of attainment is prodigious. When one kind of creature goes under and becomes extinct, it is often, perhaps usually, because another has varied in new and more successful ways. The single type pursuing a particular direction of specialized advance is restricted, but the group of which it forms part is evolving in many and diverse directions. This or that line of advance, this or that change has been barred; but life as a whole has never ceased to experiment and discover.

# CHAPTER IX

# IS THERE A MYSTICAL EVOLUTIONARY URGE?

§ 1. Straight-line Evolution. § 2. Do Races become Senile?
§ 3. The "Élan Vital" and the Life Force.
§ 4. Is there Purpose in Evolution?

## § 1

### *Straight-line Evolution*

WE have treated of mutation as a random, sporadic event happening without design or any appearance of persistent aim. This is how it presents itself to the working biologist. In the living creatures, fruit-flies or maize or whatever they may be, in which he studies variation, new mutant forms of many and varied kinds appear; now one feature of the organism is changed and now another; there is no observable tendency for the germ-plasm to improve itself progressively in a particular direction. Now at first sight this fact of random variation disagrees with the testimony of the fossils. The palæontologist, deciphering his vast histories, finds Evolution pursuing definite and steady trends. The horse-stock, for example, proceeded onwards through millions of years, always steadily horsewards. At the same time such creatures as camels, rhinoceroses, and pigs for certain, and in all probability the rest of the modern mammals, were slowly and minutely perfecting themselves in their own directions. And as we have already assured ourselves, there are plenty of examples of such steady, progressive evolution among other groups of organisms. Out of these facts has grown the idea of an inward directive force somewhere inside the germ-plasm, that makes it vary always in one direction. This is the theory of *Orthogenesis.* On this view the evolution of the horses was due, not to their having taken to the open plains and to any individuals with long legs and complicated grinder teeth having therefore an advantage over the others, but to some innate, independent, orthogenetic tendency of horse-protoplasm to lengthen its legs and complicate its molars.

Now it is obvious that we ought not to assume these mysterious inward directive forces unless we are compelled to do so, unless the facts do not admit of a more intelligible explanation. And in these cases of horse and pig, camel and rhinoceros, they certainly do. In each example the animal is adapting itself very admirably for some particular way of life; and since the changes are manifestly advantageous, Natural Selection acting on random variation will account for them perfectly well. Each successive stage in the horse evolution was an improvement on the last because it adapted the stock still further to a running and grazing existence. Moreover, as we have already seen, once an advance has been made in a particular direction there will naturally be a bias that way, for variations which happen to be on that line will be especially useful, while those that are off it thereby lose their value as weapons in the struggle for existence. A mutation making for millstone ridges on the teeth would have been perfectly useless to the whale-stock, which was evolving a method of straining the nutritious sea through whale-bone, and the millstone would have weighed as heavily round the neck of an evolving tiger. But such mutations were extremely useful to the developing herbivores of the Cenozoic; they had already begun to adapt themselves for grinding grass, and any such improvement of their molars was of great assistance. So that on the whole, other things being equal, animals and plants will naturally tend to evolve in straight lines.

But there are exceptions. There are plenty of cases of animals which have successfully turned aside during their evolutionary histories. Some change in themselves or in the outer world has made a new line more profitable. The evolution of elephants is an excellent example of an evolution which did not keep to one direction. Then many land types have reversed their evolution by going back to water; whales, seals, penguins, ichthyosaurs and plesiosaurs, water-tortoises and turtles, water-insects and some kinds of water-snails are all proof that there is no rigid orthogenetic tendency in living things. The race is always on the lookout, so to speak, for avenues to explore; when a new way of life presents itself it is seized upon. We ourselves are examples of the possible tortuousness of Evolution. One of the most distinctive features of mammal evolution has been the development of hair, and yet we ourselves are hairless. But it can safely be said that we should never have evolved if our ancestors had not warmed themselves with hair. Again, our later ancestors until quite recently were specializing themselves more and more perfectly for an adventurous clambering monkey-life in the trees, but we have broken away and deserted the arboreal habit. Nevertheless, it is to this habit in our ancestors that we owe the delicate plasticity of our hands, perhaps even the keenness of our sight and our upright posture.

There are, however, examples which afford stronger evidence of an obstinate orthogenetic tendency than do the horse and other ungulates. There are cases in which a race slowly and obstinately develops a character which, as far as we can see, is of no very vital use.

To illustrate this we may consider the Titanotheres, a group of clumsy, browsing mammals having the build and general appearance of a rhinoceros, that rose very early in the history of mammals and rapidly attained formidable dimensions and widespread abundance before their extinction in the Oligocene period. At first small, they approached and nearly attained the size of elephants; and all the larger, later types have a pair of horns, diverging like the limbs of a V and placed near the tip of the nose. Within this curious group there are several distinct lines of evolution. Osborn, the well-known American authority, distinguishes at least four. One line retained its front teeth and remained stocky. Another lost its incisors, became more of a grazer, and grew longer-limbed and speedier. In both these two trends the horns remained fairly small. In the other two the horns were better developed; the third, like the second, lost its incisor teeth; while the fourth, of which the gigantic Brontotherium was the final representative, kept its incisors and went in for great bulk and slow, browsing habits.

Now in all these four lines the horns show an independent but parallel development. The earliest representatives, the founders of the four lines, were all hornless. Then, as the lines evolved, each developed horns quite independently of the others, but all four in a parallel way. First a horn-rudiment appeared, a mere thickening of the nasal bones. Then little bosses grew. Then the bosses sprouted into V-shaped horns. Finally, in the culminating animals of all four lines the horns had the same general type, a type found in no other mammal, and were seated on the same part of the skull. Believers in orthogenesis say that this independent development of the same type of horn in four parallel lines is impossible to explain on the Selection theory. It demands, they say, the idea that the germ-plasm of the original Titanotheres was predetermined to vary in a definite way, wound up, so to speak, like clockwork, and that in the different stocks it simply unfolded itself in its predestined fashion. The horns *had* to appear and grow at a certain stage in the development of each of the four lines, quite apart from any question of advantage or disadvantage. This is one of the classical examples of orthogenesis.

There is, however, a more intelligible explanation than that. It is well known that in horned or antlered animals (such as sheep, goats, cows, antelopes, deer) the proportionate size of the horns depends on the size of the individual. The bigger an individual of any such species, the greater are his horns in proportion to the rest of him. And it so happened that during their horny unfolding all the four lines of Titanotheres increased steadily in size. Suppose that all the Titanotheres, the earliest as well as the last, had a general tendency to produce horns of their characteristic type. Suppose that the manifestation of this tendency depends on the size of the animal—as it does in deer and sheep and the like. The earliest Titanotheres were too small for their horns to appear at all (just as a young male red deer is too small for his antlers to appear), and as they increased in weight their horns were thereby allowed to develop more and more magnificently.

Thus the steady evolutionary growth of horns in Titanotheres turns out to be an incidental consequence of increase in size. And increase in size in such animals seems definitely to be of advantage. The majority of lines of mammals (and indeed of most vertebrates) show this tendency to grow as they evolve; it gives them greater strength and sometimes greater speed, to help them in their struggle for existence. So the supposedly orthogenetic horn-growth is bound up with biological advantage after all. It is what Darwin called a " correlated variation " ; not itself of direct advantage, it is the automatic consequence of a change which has other advantages. Even here there is no need to invoke the inner guiding principles; Natural Selection and random variation will do all that is necessary.

## § 2

## *Do Races become Senile?*

Natural Selection will account for the great bulk of straight-line evolution. But when all the cases are eliminated in which an obvious biological advantage plays the rudder that keeps the evolutionary course straight, there are still some examples to explain. The most striking come from among the Ammonites. These animals, so abundant in the seas of the Mesozoic or Secondary Era (IV), grow progressively more richly sculptured, with successive chambers more intricately dovetailed into each other, as the millennia pass. Finally, not long (geologically speaking) before their final and complete disappearance, a number of quite new types appeared. The beautiful spiral became wholly or partially unrolled, and the regular gave place to the fantastic.

It has been found difficult even to guess at any biological advantage which might explain the existence of many of these later and stranger forms; and Alpheus Hyatt, the American palæontologist, followed by many later authors, has sought to explain them as an expression of what he called "racial senility," due to some kind of inevitable degeneration of the germ-plasm of the group, comparable to the slow individual ageing that Mr. Everyman cannot avoid, and similarly heralding an inevitable and internally determined extinction. The previous trend towards elaboration of sculpture and dovetailing he and his followers would interpret as due to the age-changes of the germ-plasm during its maturity.

There are really two ideas here combined—that of racial ageing and that of orthogenesis. If it could be definitely shown that these latest types of Ammonites derived no biological advantage from their bizarre shapes, we should be forced to accept an orthogenetic explanation of internally determined evolution. It must be admitted, however, that we know next to nothing about the mode of life of Ammonites, or about the changes which may have been taking place in the late Mesozoic (IV) seas. The example reminds us of our ignorance and warns us to keep the idea of orthogenesis in reserve in case it proves necessary after all. But our experience of the Titanotheres and their horns also gives us a warning—that we may discover some advantage lurking in the background of apparently quite useless happenings. It is perhaps wise to suspend judgment. It would be rash to demand a wholly new principle of evolution to account for what is almost an isolated case, before we are certain that other methods of proved efficacy are entirely ruled out.

Racial senescence is another matter. The idea of racial senescence is only a metaphor, taken over from the individual life-cycle; and to this the self-reproducing stream of germ-plasm presents no similarities; the phrase is not really anything more than an analogy, and a loose one at that. But the idea has often been toyed with, usually by palæontologists. According to the upholders of this view, the signs of racial old age include the development of bizarre shape and of great bulk, and especially the production of horns and spines and other excrescences. Indeed, there is example after example where such exuberance in a race heralds its extinction.

But when we look into the matter, what do we find? We find that these characteristics are often displayed by stocks which soon afterwards go down the evolutionary hill and become wholly extinct. That is all. It is an interesting fact; but that the specialization or the spininess are expressions of anything comparable to senility—of this no proof is forthcoming.

The explanation of the actual facts seems to be quite different. Specialization, as we have seen, tends to be pushed on by Natural Selection towards a limit. When that limit is reached or neared, various things may happen. Quite often specialized types continue to thrive without essential change. The fully specialized horses appeared in the Pliocene (V D), and have remained with little change ever since. The same is true for many other of the most specialized mammals, such as the whales. Crocodiles, the still more specialized tortoises, and many families of flowering plants, have scarcely changed since the Cretaceous (IV C); lobsters and many fish, including such very specialized types as skates and eagle-rays, date back still earlier; and among the lamp-shells, with their elaborate current-producing mechanism, some forms, as we have seen, have persisted from the earliest Paleozoic (III A).

In other cases, a change of outer conditions sets in, and the specialized type, which was well adapted before, can no longer maintain itself, and becomes extinct. Slow and gigantic herbivores that could thrive well enough when plant-life was luxuriant are liable to die out if the climate grows drier and vegetation more sparse. So, too, die creatures who are tied to water for their reproduction. And drought seems thus to have extinguished the giant Amphibians of the Trias (IV A). Forest dwellers must go if their home is all replaced by prairies. This appears to have happened to Hypohippus, the side-branch of the horse-stock which specialized its teeth for browsing on succulent forest-vegetation. As the Miocene (V C) climate grew drier, the forests shrank, and it perished. Cold is an equally potent cause of extinction; the Glacial Period gives as abundant evidence of that. But while some whole groups were then frozen out altogether, like the " tank-armadillos " or glyptodonts, the giant sloths, and the mastodon type of elephants, in other groups which appear to be equally specialized, like the rhinoceroses, camels, or the true elephants, only some species became extinct while other persisted—further proof that specialization in itself need not be the cause of extinction.

In perhaps the majority of cases, however, extinction is not due to so simple a cause. The specialized type is confronted with the competition or the attacks of new types which start from a higher level of organization or possess some special advantage. And it is this competition which, often in conjunction with changed and less favourable conditions, brings about the old types' downfall. Some of the Dinosaurs might well have survived the drought and the cold of the Cretaceous (IV C) if they had not had to compete with the evolving mammals. Within the mammal stock itself the extinction of so many specialized groups in the first half of the Tertiary (V A and V B), including such formidable creatures as the four-horned Dinoceras and all its kin, was undoubtedly due to the rise of new mammalian types with better physical construction and, in particular, more elaborate brains. And if we need another example, we have only to think of the extinction of modern mammals which has been caused by the coming of man.

An example often invoked to support the idea both of orthogenesis and of racial old age, is that of the wonderful sabre-toothed cats which, first found early in the Oligocene (V B), became extinct only during the Glacial Epoch. Their most striking character—to which they owe their popular name—is the elongation of their upper dog-teeth into a pair of exquisitely constructed and formidable daggers, almost as long as the whole jaw, thin blades of living ivory with fine saw-teeth on their cutting edges. This construction is fully developed only in the latest-evolved species types, such as Smilodon; in earlier forms the "sabres" are smaller, and the whole skull more like an ordinary cat's.

It is often asserted that the gigantic daggers of the latest sabre-tooths not only could not have been useful, but must have interfered with the capture of prey, and so have directly brought about the animals' extinction. Their long-continued enlargement would then be due to orthogenesis; while their final exaggeration would be a symptom of racial senility. Both the advance and the extinction of the stock would be due to inner causes.

But the truth seems to be quite different. The huge teeth of the sabre-tooths are not biting organs in the ordinary sense—almost uniquely among teeth, they are stabbing daggers. While the true cats were becoming adapted for chasing and devouring the fleet grazing ungulates, the sabre-tooths were evolving along other lines. They were the enemies of the huger and slower browsers (the lumbering, tough-skinned giant sloth seems to have been a favourite prey of Smilodon) and their dagger-teeth were evolved to pierce the tough hide of pachyderms. Their whole structure is beautifully adapted for clinging with the feet and then delivering downward stabbing blows, not for gripping with the jaws.

Now one of the most noteworthy events of the Pleistocene (V E) was the change of climate, with the consequent elimination of so many kinds of big, heavy mammals and the restriction in range and numbers of the few survivors.

The sabre-tooth of the Pleistocene, far from being a senile type or one that had been forced to overshoot the evolutionary mark, was a beautiful piece of living mechanism evolved to cope with the increasing size and thickening skin of its special prey. And it became extinct not because it ceased to be adapted, but because its prey died out.

Thus, specialization *need* not be the preface to extinction. And when it is, the extinction is not brought about by some inner ageing of the germ-plasm, but by changes in outer conditions or in living rivals and enemies. Very specialized types are more easily extinguished than others; but this is because they have moulded them-

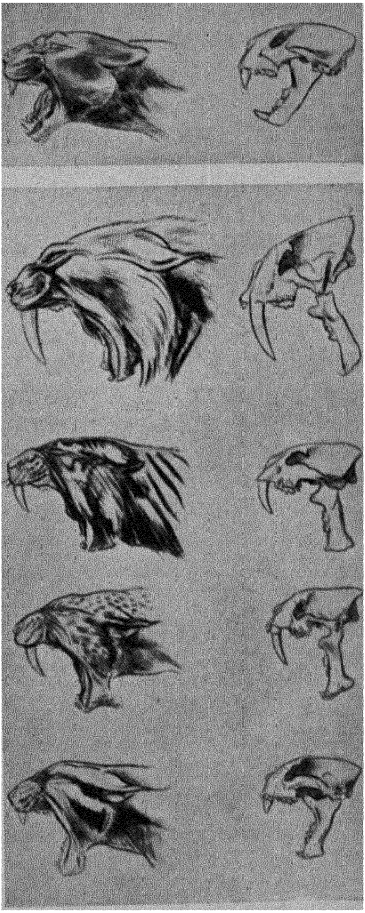

FIG. 45.—STRAIGHT-LINE EVOLUTION IN THE SABRE-TOOTHED CATS.

Right, skulls; left, reconstructions of heads. The Sabre-tooths gradually increased in size, enlarged their upper canines, made their jaws able to open more widely, and reduced the size of their lower-jaw teeth. From below up: Dinictis and Hoplophoneus (Oligocene, V B); Machærodus (Miocene, V C); and Smilodon (Pleistocene, V E). Top, above the line, a true cat (Jaguar), to show the very different construction, with upper and lower canines about equal, and large flesh-cutting molars.

selves too perfectly to the passing world, not because they are "racially old." In their speciality they have gone too far to turn back before extinction comes.

Racial senility is thus on the same footing with orthogenesis as an explanation of evolutionary happenings. In the great majority of cases there is no need to invoke it, because a simpler and more intelligible explanation will work as well or better. A few examples remain in which we can as yet assign no reasonable outer cause for extinction. The disappearance of the Ammonites is one; the extinction of the great fish-lizards, the Ichthyosaurs and Plesiosaurs and Mosasaurs in the seas, of the late Mesozoic Period (IV), long before the appearance of whales as competitors, is another. As with the few possible cases of orthogenesis, these remain to remind us of our ignorance. With the growth of knowledge, we may find out that there was an outer cause for their extinction after all; or we may discover that occasionally the germ-plasm does fail the race. But even if the latter alternative prove right, it too can have had but a minor importance in Evolution. Extinction is for the most part brought about not by any internal wearing-out or ageing of the germ-plasm, but as a natural consequence of the universal struggle.

## § 3

### *The "Élan Vital" and the Life Force*

The theories so far discussed are none of them what philosophy calls "vitalistic." To account for Evolution they demand no special and mysterious qualities in living matter. Granted that it can reproduce and vary, a few simple forces come automatically into play, and Evolution by means of selection is the result. There is a machinery underlying Evolution as there is a machinery behind chemical combination or the laws of gaseous pressure. But as we have noted in an earlier chapter, there are other theories in existence whose proffered explanations are not mechanistic at all, but vitalistic. They ascribe Evolution to some directing force which is supposed to be purposive, or at least of the same nature as purpose, and to reside in life, but not in matter which is not alive.

Of such theories there are many. The most celebrated creative force is Bergson's *élan vital* or vital urge, which reappears, expounded in exaggerated form, a pantomime giant, as the Life Force of Mr. Bernard Shaw. The Shavian Life Force need not detain us long. It is Lamarckism in caricature. Life evolves, says Mr. Shaw, by trying, by more or less conscious effort. Evolution takes place because all life is purposeful in its degree. In ourselves the Life Force may be at cross-purposes with our conscious but more superficial selves; racial purpose may conflict with individual purpose. But however disguised, however deep below the level of ordinary consciousness, the essence of the Life Force is purpose. Quite apart from the difficulty of ascribing even rudimentary purpose and foreknowledge to a tapeworm or a potato or collective aspiration to the tapeworm race or the potatoes of the world, there remains the impossibility of transmitting the results of this purposeful striving to posterity. If, as we have given ample reason for believing, acquired characters cannot be inherited, Mr. Shaw's Life Force does not exist.

Bergson's *élan vital* is in a rather different case. For him the vital urge is something inherent in the very nature of life, but absent from dead matter. It is in some not very comprehensible way intermediate in its properties between the blind activities of lifeless matter and the conscious and purposeful activities of mind. In operation, it reveals itself as a constant tendency towards adaptation. For M. Bergson it is this tendency towards adaptation which accounts for the existence of adaptations, and not such material considerations as the struggle for existence and the elimination of the less fit by Natural Selection; and equally without aid from struggle or selection, it makes tactfully but firmly for movement onward and on the whole upward in Evolution. The *élan vital* itself causes evolution. It is orthogenesis translated into vitalistic terms.

But when we begin to look into the argument closely we see that the *élan vital* is a mere metaphor. It is in reality not a new and mysterious creative principle, but the elementary chemical properties of living matter, idealized and personified. Living matter has, as its basic property, the power of metabolism and self-reproduction; and it varies. From these two properties there follow over-multiplication, the struggle for existence, the survival of the fitter, and the constant stress of Natural Selection. If we like to call the combined effect of the struggle and the variation *biological pressure*, we can do so. Then why, it may be asked, should we not be poetical and call it *élan vital?* But biological pressure is a resultant of simpler forces, all unconscious, none vitalistic; while the *élan vital* is defined as a property in its own right, not further analysable, and partaking in some obscure way of such mental properties as purpose. Bergson's *Creative Evolution* gives one of the most vivid pictures ever painted of Evolution at work, but as an exposition of evolutionary method it is valueless. It is a brilliant and poetical description, and it has very properly won its creator the very highest literary distinction. But it is not a scientific explanation.

## § 4

## *Is There Purpose in Evolution?*

Bergson and Shaw, in common with many others, have been so much impressed with the apparent purpose revealed in the slow, stupendous drama of life, that they have not hesitated to make purpose the key of Evolution. They see purpose not only in its results, but would make it the very heart of its method. This question of purpose in Evolution is a crucial one for biology and for the contribution which biology is to make to general thought. Let us briefly summarize the conclusions of this chapter; they will help us to decide if evolutionary purpose is real or only apparent.

Our main conclusion is that the chief agency of evolutionary change seems to be the sifting action of Natural Selection upon random variation of the germ-plasm. Lamarckism will not work, because neither the direct effects of the environment nor those of conscious or unconscious effort are normally inherited; and orthogenesis is, in most cases at least, a quite unnecessary hypothesis. But the theory of Natural Selection provides an adequate explanation for the great majority of the facts of Evolution; it can explain the detailed adaptations of animals and plants and their long-continued trends of specialization, the rise of new types and the extinction of old, the progress of life, its retrogressions and degenerations, and much at least of its variety. The implications of this are far-reaching. Without constant struggle and competition, Evolution could not have occurred; without the failure and death of innumerable individuals, there could have been no gradual perfection of the type; without the extinction of great groups, there could have been no advance of life as a whole.

And then we see Evolution as a response of life to its environment. It is as much a response as a child's drawing away of a burnt finger from the flame, or the growing of thicker fur by a fox exposed to cold; but the response is effected by a peculiar and roundabout method. It is effected by a method of trial and error. The environment of a species changes. The species is constantly throwing up new variations. Most of them are no good and are eliminated; a few are improvements and are preserved and incorporated in the evolving flow of life. The type is thus changed, and changed so as to better fit the new conditions of its environment.

Let us not forget that the environment of any living thing includes not only the lifeless environment, but also the living environment of enemies and prey, competitors and parasites. A great deal of evolution is a response to change in that living environment. The horse's speed is a response to the increasing speed of its devourers: its tooth-structure a response to the spread of tough grasses over its feeding-grounds. Environment, in this extended sense, determines evolution—indirectly, by the sifting, trial-and-error method of selection, but none the less surely. An organism apart from its environment is meaningless; if the environment had been different, so would be organism. If this earth were bigger, all the mechanical construction of land animals would be different, for the force of gravity would be greater. If the surface of the earth were perpetually shielded by clouds from the sun's rays, as on some other planets, the human inhabitants of the tropics would not be black. Before the power of colour-vision was evolved there can have been no animals which practised concealment by adopting the colour-pattern of their surroundings, as chameleons or leaf-butterflies do to-day.

The result of Evolution and Natural Selection is a constant increase in fitness. But there are limitations to the perfection of fit attained. Trial-and-error is a rough-and-ready method. What it produces is something that will work, by no means necessarily something that will work perfectly. The creatures that exist are those that happen to have survived: taken together they represent an equilibrium which manages to be more or less stable, rather than life's best possible way of utilizing and sharing out the resources of earth.

But—and now we begin to touch on the question of purpose—as far as we can see, the variations which alone make evolution possible are random variations. That is not to say that they may not be limited in quantity and quality; but that from the point of view of Evolution they are at random. In every organism they take place in many directions; the environment, acting through struggle and selection, picks out those that are headed in one particular direction. The identical variation that is selected and kept in one environment may be rejected in another. To take but one example. So long as great swamps abounded and the amphibians that lived in them had not evolved to their limit of size and power, variations making for the capacity of living and reproducing on dry-land would be of less value than those promoting success in the ample watery environment. But once this environment began to shrink and dry, those same variations would go up in biological value and would be selected, and so impetus be given to the evolution of reptiles.

Variation is at random; selection sifts and guides it, as nearly as possible into the direction prescribed by the particular conditions of environment. Once we realize this, we must give up any idea that evolution is purposeful. It is full of apparent purpose; but this is apparent only, it is not real purpose. It is the result of purposeless and random variation sifted by purposeless and automatic selection.

The term purpose has a very definite meaning. It is a psychological term, describing a certain familiar state of our own consciousness: it implies the prevision of an end, and a determination to reach that end. For evolution to be purposeful, one of two things must be true. Either living things themselves must be purposive in their evolutionary changes—the flower must somehow want to attract bees, the horse intend to lose all its toes but one; or else, although the living animals and plants themselves betray no purpose, purpose must exist in the mind of a divine Being, who is manipulating life and its environment to bring about His purpose, as we manipulate matter and events to bring about our purposes.

The first alternative is that of Bergson and Shaw; and, as we have seen, we must dismiss it. Variation and selection in themselves are blind. Life is by them passively moulded towards adaptation and perfection, and is not the arbiter of its own destiny. The forms of life are as much the automatic product of outer forces as the forms of mountains, lakes, and valleys, although the machinery of their production is different.

The second view is the view of a number of more or less modernist theologians. It is Creationism up-to-date. Instead of creation of the whole scheme of things ready-made, it implies the gradual working-out of a preconceived plan, the gradual realization of a divine purpose. This may, of course, be true. Science cannot say yes or no to such ultimate questions. She can, however, point to facts and ideas which bear on their reasonableness.

She can, for instance, justifiably turn to the theologian and reason as follows. If the natural selection of random variations is the main agency of Evolution, then Evolution receives a scientific explanation in terms of known natural forces. It receives as natural an explanation as does the pressure of air through the impact of its myriad separate molecules, as envisaged by the kinetic theory of gases; or the formation of sulphuric acid from heated iron pyrites, steam and the fumes of nitric acid through the atomic theory and the laws of chemical combination. Not only is the fact that Evolution looks purposeful no proof that there is true purpose behind it; but if there is real purpose behind it, there must be real purpose behind the transformations of dead matter, too.

The biologist can also point out that Evolution, whether looked at as a whole or in detail, is very far from coming up to what we might expect if it were in truth the realization of some exterior cosmic purpose. Firstly, it is extremely slow. Then the method of selection is not only slow but wasteful and, in higher animals at least, involves great suffering. Worst of all, it has achieved much that seems definitely bad. Evolution has deprived barnacles and oysters of movement and brain; it has produced the female mantis, who begins eating her mate during the act of pairing; it has generated the blood-thirsty land-leeches and mosquitoes, and fitted the ichneumon-fly grub to devour its living caterpillar prey slowly, from the inside; it has brought into being not only strong, intelligent and beautiful creatures, but also degenerate parasite and loathsome diseases. In brief, we are confronted with the gravest theological difficulties if we too light-heartedly set out to see purpose in Evolution. The wiser and saner course is to acknowledge our ignorance of ultimate causes and designs. If we do so, then, while frankly confessing that we do not understand what may be behind Evolution, we can yet appreciate at fullest value what it has achieved and seek to turn its further progress into channels that seem good to us.

For when we reach man, Evolution does in part become purposeful. It has at least the possibility of becoming purposeful because man is the first product of Evolution who has the capacity for long-range purpose, the first to be capable of controlling evolutionary destiny. Human purpose is one of the achievements of Evolution.

Human purpose has arisen as a product of the mechanical workings of variation and selection. But now that consciousness has awakened in life, it has at last become possible to hope for a speedier and less wasteful method of evolution, a method based on foresight and deliberate planning instead of the old, slow method of blind struggle and blind selection. At present that is no more than a hope. But human knowledge and power have grown very marvellously during the last few hundred years. The multitude of our race living to-day still does not know of more than a minute fraction of what is known to man, nor dream yet of the things he may presently do..

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