EVOLUTION
THE WAY OF MAN

VERNON KELLOGG

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BY

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TO

MY WIFE

CHARLOTTE KELLOGG

WHO HAS DONE MUCH TO

MAKE THIS BOOK READABLE

PREFATORY NOTE

I have made this book untechnical, and tried to make it truthful. I have written much of it out-of-doors, and have drawn my examples as much as possible from familiar instead of foreign plants and animals. Also I have tried not to forget that we are all more interested in the evolution of man than we are in that of any or all other creatures.

I have tried to make this book human and personal. Too much of the evolution written about has been too far away from most of us. There is plenty of evolution all around and in all of us.

V. K.

CONTENTS

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CHAPTER I

EVOLUTION; WHAT IS IT?

EVOLUTION is again an exciting word. It has been at other times; most notably in the years just after the publication of Darwin's *Origin of Species*. One hundred years before that, too, when Lamarck and St. Hilaire were being attacked by Cuvier and the clergy for their transformation ideas, it, or its French equivalent, was a word to stir men to wrath.

And now again it creates excitement. Its utterance is the stimulus to much discussion: keenly scientific discussion, absurdly uninformed discussion, bitter discussion, trivial discussion; discussion of a single problem, as the origin of man; discussion of all things of earth and heaven, from the color pattern of a butterfly to the whence and whither of man's soul.

Evolution is defined in a score of ways, but not clearly in any way. Each one defines it for himself, and no two define it alike. It is used in the titles of hundreds of books, and each book covers what it will. We need a general treaty of understanding. How can there be evolutionists and antievolutionists when there is no agreement between them as to what is meant by evolution? When each one means what he pleases to mean, with little or no regard to what his colleague or antagonist means. At least, every one who talks or writes about evolution should try to explain, at the very beginning, what he proposes to talk or write about. Let me try to do that for this book in these very first pages of it.

I am seated, as I write, in a pine wood near the ocean side. There are insects and birds and a few squirrels in the trees, and in the tide pools of the shore a rich variety of beautiful and strange salt-water creatures. Each beetle and woodpecker, each starfish and sea anemone, has a body form and characteristic appearance of its own, a way of breathing and feeding, of protecting itself, of producing and caring for its young, all different in detail from the forms and ways of the others, but all fundamentally similar in purpose and achievement. The same is to be said of the trees and the bushes and the grasses and the tender little flowers of this hillside, and of the giant kelp and the red-and-green seaweeds of the near-by ocean shore. All these plants and animals are alive and trying, even if unconsciously, to keep alive, at least until the young or the seeds or the spores shall be produced which are to assure the continuity of the life chain.

And among the birds and butterflies and the pine trees and the lupines, watching the gulls and the sea-lions and catching the glint of the washing seaweeds as the tide runs out, am I; I, also alive and of a given form and habit of body and body parts, and unconsciously breathing and circulating my life-preserving blood, and consciously careful to feed myself, and to protect myself from beasts of prey or murdering bandits, and also taking care, the very best care I can take, of a little girl who shall, if all goes well, be a link between us and our grandchildren; that is, "assure," as with the sea anemones and the blue lupines, "the continuity of the life chain."

Now evolution means to me, first, something of an explanation of why and how there are so many kinds of living creatures with all their varied forms and manners, yet all striving for similar ends and with much commonness of method. It means something of an explanation of the likenesses and the differences and the relationships among these animals and plants. And, finally—and I say this without misgivings and without shame—it means to me something of an explanation of the likenesses and differences and the relationships between myself and all these other living things.

But evolution means to me only *part* and not *all* of an explanation of these things. It is no ultimate explanation of any of these things; that is, of life itself and the final cause of the variety and yet identity of all life, including my own life. Evolution can be only a more or less immediate or detailed explanation of how, granted life, granted matter, granted energy, granted any existence of anything at all, and granted an ultimate cause or causes, the form and behavior of living things can be and are as they are. It is an explanation of process, not primitive cause. It explains much that I seek explanation for as I study the amazing variety and the astonishing fitness to their surroundings of the host of living creatures, including myself and my kind of creature, on this earth. But it does not explain to me, in any ultimate way, the fact that there are living creatures or an earth. Or that I have a consciousness of myself and of my relations to the other living things and the earth. Or that I have visions and aspirations of a kind not referred to in the books of biology, and recognize that other human beings have them, and feel that the most important things we live for are things of which I get no glimpse in studying the sea anemones or the pine trees.

But evolution, even thus limited, means so much, and so much more than I can ever make apparent by words; it means so much about nature and so much about man and so much in connection with our eager, ceaseless attempt to know the how and why of all life, that when I deliberately set myself to try to explain what it is to me and how much it means to me, I am like Christopher Morley's impotent Gissing, who "felt like a clumsy strummer seated at a dark, shining grand piano, which he knows is capable of every glory of rolling music, yet from which he can only elicit a few haphazard chords."

Evolution means outrolling, unfolding. It means a reasonable, satisfying, ennobling conception of life, a conception that gives life infinite promise. Organic evolution is the outrolling of the plan of life, the unfolding of the possibilities of life. It runs naturally and logically from simple to complex, from the general to the special, from the lowly to the high, from amœba—and simpler—to man. Will it, some time, be to something higher? That would be hard for us to admit. And we need not admit it, for we simply know nothing about it. All that we know is what has been and what is. The future suggests itself, but rarely really reveals itself in advance of its time. For the present we need only consider man, and our type of man, as the highest round in evolution's ladder, the apex of evolutionary achievement. But, for myself, I see nothing impossible in a higher man. Nature seems so infinitely fecund, evolution so unlimitedly possible, and time so interminable and hence so generous to evolution.

Evolution means continuity, means transmutation, the origin of the new from the old; means change, continuous movement, gradatory development. It means genetic relationship, blood cousinhood, an all-embracing genealogy of life. It means the fundamental unity of all life, however varied the appearance and manner of it in different living kinds and individuals. It means a continuous living stream varying in appearance in its different parts, but never really broken or with its parts really separated. Every living creature, be it monstrous whale or microscopic phosphorescent animalcule in the ocean, free-roaming tiger in the jungle or minute parasite that crawls about over the tiger's skin, wheeling eagle surveying its broad domain of air and land over a life span of many years, or swarm of fluttering May flies dancing an evening's life away about an electric light by the lake shore, giant Sequoia holding its proud place in a Sierran forest through thirty centuries, or tenderest bit of transitory moss that nestles at its base—every living creature, large or small, long-lived or ephemeral, active or quiescent, myriad-celled or single-celled, is, in certain fundamental structure and behavior, like every other living creature. It has need, to remain alive, of certain physical and chemical surroundings which every other living creature has to have, and it does certain things which every other creature does. As varied as life seems to be it has its rigorous limitations. But these limitations not transgressed, their requirements met, it can play its variations, it can embroider and adorn itself almost endlessly. It can change itself from one form into another. It can throw off one branch after another. But it is all of one piece.

The study of evolution is especially the study of the significance of this variety of life, arising out of identity, and of how it comes about. This variety has its major expression in the different great branches of plants and animals, then in the differing classes within each of these branches, then, gradually lessening in degree, in the orders and families and genera and differing species or kinds, and, finally, has its least expression in the differences among the individuals belonging to a single species. There are no two animal or plant individuals exactly alike in the world; not even offspring of the same parents, not twins, not even "identical twins." The extent and the limitation of this variety are determined by degrees of blood relationship and by relation to environment. These two influences are what determine the form and manner of each individual, its size and shape and color and habit and life span.

Evolution is the reasonable explanation of this abundance of kinds of animals and plants and of the amazing adaptations of these many kinds to their environment. We have found and described and classified and named about 500,000 living kinds of animals and 250,000 living kinds of plants. There are certainly many more kinds of both animals and plants still to discover and catalogue. Not one of these but presents its own problem of adaptation—adaptation in form of body, of legs, of wings, of sense organs, of roots and stems and leaves and flowers and seeds, in habits of food-getting, of escaping or conquering enemies, of home-building, of production and care of young, of manner of growth, of fertilization of flowers, of distribution of seeds.

Much of the beauty and glory of nature is its variety. And much of the interest of nature springs from the significance of this variety and from the significance of the fundamental likenesses underlying this variety. How? Why? Those are the questions of the naturalist. Evolution is the most reasonable answer. And as we ourselves are in and of nature, evolution is the answer to many of our questions about ourselves. Why do we have so many things in our bodies that are much like corresponding things in the bodies of other animals? Why do we pass through—in the development of each of us from fertilized egg cell to mature individual—so many stages that are like stages passed through in the development of other vertebrates? Why do the human fossils of early glacial time show that man of that time had a smaller brain, heavier jaws, and a skeleton that indicates a less erect posture than has man of to-day? Why are there living races of men of much more primitive make-up than others also living to-day? Evolution is the reasonable answer to these questions.

But, again, I do not claim that evolution is the answer to all the questions we can ask about ourselves. Even were there none about consciousness and charity and imagination and soul, there are always those about the primal origin of life, of which we are a part, and about the ultimate whence of it. But in our attempt to understand ourselves we can look too much at ourselves alone; we can too easily forget that we are but part and parcel of nature. About any part of nature every other part teaches something. Hence, if we would understand as much as we can about our own evolution, we must understand as much as we can about the evolution of all of nature.

And hark! how blithe the throstle sings!
  He, too, is no mean preacher:
Come forth into the light of things,
  Let Nature be your teacher.

. . . . . .

One impulse from a vernal wood
  May teach you more of man,
Of moral evil and of good,
  Than all the sages can.

CHAPTER II

GROWTH AND TRIUMPH OF THE EVOLUTION IDEA

THE conception and formulation of the evolution idea, as we know it to-day, were not the achievement of any one man; not even of Darwin. And if not of Darwin, then certainly of no other. The idea of evolution and its expression have been the result of many men's thinking through many years. It is the old story of the slow progress of human understanding.

As usual in tracing the history of a great philosophic conception, we go back at least to the Greeks. Empedocles has been called the "Father of Evolution." So has Aristotle. Others might be. If one searches the writings of the Greek philosophers and naturalists, as Henry Fairfield Osborn has done to write his *From the Greeks to Darwin,* sentences here and there reveal ideas, hypotheses, guesses, about the origin and relations of the kinds of creatures that can easily be construed to mean, and, perhaps, really mean, that this one and that one had glimpses of the Great Answer. Empedocles thought organisms were created in separate parts of a great variety which were subject to the attracting and repelling forces of love and hate—the two great forces in nature—and if the right parts managed to get together a viable creature was produced. If the wrong parts got joined, the creature could not persist. One can call this, if he wishes to, and as some have called it, an early expression of natural selection. Empedocles believed in spontaneous generation, and assumed that nature did not produce lower and higher forms simultaneously, but that plants came first and animal life only after a long series of trials.

Aristotle, a hundred years later, opposed Empedocles' ideas of fortuitous origin of characters, favoring the idea of intelligent design in the origin of organisms. He thought the variety of life originated from a primordial soft mass of living matter. He had an idea of an ascending series, presumably a genetic series, beginning with plants, then "plant animals," such as sponges and sea anemones, then animals with locomotion and sensibility, and thence, by graded stages, up to man. He recognized the influence of heredity and at the same time believed in the modifying influence of environment, and in the inheritance of acquired characters.

After Aristotle, who was assuredly the outstanding naturalist and natural philosopher of his day and, indeed, of the whole stretch of time from the beginnings of recorded human history up to the revival of science in the sixteenth century, the evolution idea languished. This stretch of time included that long period dominated completely by theology and appropriately, at least from the point of view of science, called the Dark Ages. But the evolution idea was not, however, entirely obliterated from men's minds. It simply could not be. There are always, even in the darkest of dark ages, inquiring minds, minds that do not accept, without questioning, the asseverations and dogmas of the pundits whether in science, philosophy, politics or religion. And there must have been men through those centuries between the coming of Christ and the so-called revival of learning in the Middle Ages who asked questions about nature and about the teeming life all about them. They must have asked questions of themselves and of others.

But it was not an auspicious time to ask these questions too loudly, much less to utter too boldly as answers any guesses or ideas that might irritate the dominating theologians. A few records exist, however, which indicate that some of the more open-minded theologians of sufficiently high place to afford to speak up were not able to forego utterance of their feeling that something besides the dogma of specific creation according to biblical legend was necessary to explain the abundant and various forms of matter and living creatures. Gregory and Augustine, in the fourth century after Christ, both attempted certain forms of explanation of the variety of life, which have, in their essentials, ever since figured largely in attempts at reconciling the declarations of Genesis with the perceived facts of science.

Gregory taught that creation was potential. God imparted to matter its fundamental properties and laws. The objects and completed forms of the universe developed gradually out of chaotic material. And Augustine ventured the idea that the biblical account of creation is allegorical. He expounded the declaration, "In the beginning God created heaven and earth," to mean that "in the beginning God made the heaven and earth, as if this were the seed of the heaven and the earth, although as yet all the matter of heaven and earth was in confusion, but, because it was certain that from this material the heaven and earth would be, therefore, the material itself is called by that name." And in the thirteenth century Thomas Aquinas expounded Augustine's ideas without attempting any refutation of them, which was equivalent to admitting a kindly interest in them.

This was not getting very far in a thousand years. It shows what authority in the hands of men dominated by one idea, even in the realm of the intellect, can do. But such a state of things cannot last for-ever. The revolt is sure to come. And it is likely to come more violently the longer and more nearly completely it has been withstood. It did not come, in this case of the struggle of science against theology, until the sixteenth century when, with Francis Bacon as chief protagonist, science made itself loudly heard and demanded recognition. Bacon picked up the evolution conception where Aristotle had left it, and expanded it and made it more specific. He proclaimed the mutability of species and explained this mutability as the result of the accumulation of variations. He declared that variations of sufficiently pronounced character to produce new species could and did sometimes occur, and that old species might change retrogressively or degeneratively to such an extent as to be transformed into new species.

He stirred men to a new examination of animal and plant kinds and to their behavior and relationships as species. By the eighteenth century enough had been learned about nature to warrant naturalists and natural philosophers like Buffon and Bonnet and Erasmus Darwin and Oken, and finally Lamarck and Geoffrey St. Hilaire, to formulate and clearly announce the concept of organic evolution as an explanation of species forming and adaptation. This explanation declares that new species come from old by transmutation; and denounces, at least by implication, the theological dogma of special creation. Adaptation comes by plastic response to environmental conditions; hence, is not specially planned.

This challenge to theology was promptly accepted. And the response and attack came not alone from the theologians but from naturalists as well. All of the great influence of Cuvier, dean of French anatomists and scientific favorite of the French court, was thrown against his colleagues Lamarck and St. Hilaire and their special theory of evolution, as well as against evolution in general. The great Swedish botanist and father of biological taxonomy, Linnæus, clung to the dogma of the special creation of species, and was a formidable obstacle to the acceptance of the evolution idea.

But greater than the influence of the reactionary biologists in preventing any popular acceptance of the evolution idea was that of the theologians. They denounced it as impious and heretic. They did not debate it; they simply banned it. And, for the time, they held it thoroughly in leash. However clearly formulated and clearly stated, however specifically applied and worked out in detail by the few rebelling and ardent naturalists and natural philosophers crying in the wilderness in those days of the last half of the eighteenth and first half of the nineteenth centuries, the real entrance—and for all time—of the evolution idea into the general heritage of human understanding did not come until the publication of Darwin's *Origin of Species* in 1859.

From Empedocles and Aristotle, four and three hundred years before Christ, to Lamarck and Darwin, eighteen hundred years after Christ, the evolution idea had been slowly growing, spreading, ripening, but with great resting stages and with the heavy restraining, sometimes violently repelling, hand of dogmatic theology always holding or thrusting it back. With the *Origin of Species* it burst, apparently suddenly, into full bloom. Darwin made it real and vivid to the world. He set it forth so clearly, he brought to bear on it such a wealth of detailed observation, he gave it such a reasonable and plausible basis of causo-mechanical explanation, and he found at once such valiant champions to make the necessary fight for it, that it is not surprising that the triumph of evolution has come to be generally spoken of as the triumph of "Darwinism." The triumph of evolution is at least the triumph of Darwin.

But the triumph, speedy and brilliant as it was, after the publication of the *Origin of Species*, did not come without a sharp struggle, and there have been, even as there are at this very present moment, recrudescences of that struggle. But one element of opposition is entirely gone. That is the element of opposition from scientific men, from biologists, geologists, naturalists in the widest sense. While in Lamarck's day the evolution idea was vigorously fought by the greatest anatomist and the greatest biological systematist of the time, and by other lesser but reputable and influential biologists, and even in Darwin's day had its notable and active antagonists within the ranks of the scientific men, to-day there is practically no naturalist of known achievement who does not accept organic evolution as a proved natural phenomenon. Almost all of the still existing denial of evolution, and especially of the active opposition to it, comes from theologians and mystics, lay or professional, and from a number of impressionable individuals influenced by them.

Around Darwin, in England, gathered a notable band of coadjutors and champions. In foreign countries other men lifted his banner. Evolution, the struggle for existence, and natural selection became the debated subjects of the day in scientific gatherings and churches, in books, magazines and newspapers. Dispute was loud and sharp. An Anglican bishop publicly taunted Huxley by asking him if it were through his grandmother or his grandfather that he claimed his descent from a monkey, and was answered by the quick-tongued champion of evolution to the effect that he would be more ashamed of having to recall as an ancestor a man who could behave as the bishop did than of having an ape for an ancestor.

Huxley was, indeed, the fighting Darwinian. Admitting that polemics are always more or less an evil, he believed, nevertheless, that the lukewarmness which lets error and corruption have their undisputed baneful way is a greater evil. To Huxley the questions at issue between the dogmatic assertions of clericalism and theology on the one side and the facts of nature which revealed and proved evolution on the other, admitted no indifference or compromise. In a letter to his wife, written at Baden in 1873, Huxley says:

"We are in the midst of a gigantic movement greater than that which preceded and produced the Reformation, and really only the continuation of that movement. But there is nothing new in the ideas which lie at the bottom of the movement, nor is any reconcilement possible between free thought and traditional authority."

It was well that there were Huxley, Herbert Spencer, and Haeckel to fight for evolution. For Darwin was not a fighter, and he was in no hurry. He believed he saw the truth, and if it was the truth it would prevail. The generous-minded Alfred Russel Wallace, whose name should always be associated with that of Darwin as coauthor of the theory of natural selection—for the setting out of the major lines of this theory occurred by the simultaneous presentation and publication of brief papers by both of these men—once wrote: "I was then (and often since) the 'young man in a hurry,' he [Darwin] the painstaking student, seeking ever the full demonstration of the truth he had discovered, rather than to achieve immediate personal fame."

Lamarck, a hundred years earlier, had developed and presented to the world a detailed account of the evolution idea, together with an explanatory theory of natural causation of the transmutation of species. But he had no such militant champions as Darwin's to sponsor his cause, and the world hardly even heard of his claims, let alone being won by them. True, the time was not auspicious. Other great matters claimed the world's attention then. And there was more of speculation and less of observed fact in Lamarck's account of evolution than in Darwin's. Lamarck also had injured his personal prestige by some earlier wild speculations in the field of chemistry. But if he had had a Huxley by his side the history of the triumph of the evolution idea might have been a different one.

One must always distinguish in Darwin's contributions to the evolution idea between his overwhelming accumulation of evidence for the general phenomenon of evolution and the consequent wide acceptance of evolution as a fact, and his formulation and presentation of a causal explanation of evolution, namely, the theory of natural selection (together with the auxiliary theory of sexual selection). When biologists speak or write to-day of Darwinism, they are referring specifically to Darwin's selection theories as explanations or causal factors of evolution. In popular writing and speaking Darwinism is often, perhaps usually, used as synonymous with evolution itself. Sometimes it is meant to denote simply the origin of man from apes, or from the lower animals in general. Similarly "Lamarckism," in the mouths of biologists, means the causal explanations of evolution advanced by Lamarck, namely, the modifications of individuals by use and disuse of organs, and by the influence of environment, and the direct inheritance of these modifications, or "acquired characters," so that the species also becomes modified.

I shall try, in a later chapter, to explain, in some detail, these contributions of Darwin and Lamarck, as well as those of other naturalists, to the problem of the cause or causes, of evolution. But all that we need to note just now is the fact that the evidences of the reality of evolution adduced by Darwin and made so available to common knowledge by him and by his eminent champions, most notably

Huxley, were so overwhelming, so irrefutable and hence so convincing, that, without regard to the satisfactoriness or unsatisfactoriness of the suggested causes for this evolution, the fact of evolution was established for all time. It was established by the quiet, modest master whose name will ever stand at the head of the roll of the world's greatest naturalists.

One cannot help, in closing this brief account of the origin, struggle, rise and final triumph of the evolution idea, from uttering a word of comment on the example it furnishes of a usual story in the development of human understanding and the winning of the way to truth. It almost seems, as we survey the history of the human conquering of knowledge, as if mere ignorance were the least of the obstacles that have to be overcome. Human nature seems to indulge in a perverse and malicious pleasure in setting up unnecessary difficulties in our way to the light. We put up barriers of inertia, we encourage active antagonisms to advance, we tolerate and bow to traditional authority, we brutalize the spirits of independence and cry out against the man of vision, in such perverseness as to magnify inconceivably the difficulties, serious enough in any case, of wresting truth from nature. And this, despite the fact that, after all, we mostly recognize this wresting of truth from nature to be the greatest and most useful task to which we can set our hands and minds.

Before Darwin and Huxley could make the final winning in the struggle for the evolution idea, Lamarck and many others had to be sacrificed. If the naturalists and natural philosophers could have worked in the light of evolution since Lamarck's time instead of since Darwin's time, one hundred years later, how wonderfully much farther would our beneficent knowledge of nature stand to-day. Lamarck saw evolution almost, if not, indeed, quite, as clearly as Darwin did. But the world would not see it until it had exhausted its brutal pleasure of martyrizing the too forward minds. The story of the struggle and triumph of the evolution idea is but an example of the usual story of any great advance in human understanding. But each example saddens one.

CHAPTER III

WHAT EVOLUTION MUST EXPLAIN

One does not have to make a long voyage on the ship *Beagle*, or to penetrate tropical forests, or to live in a laboratory filled with microscopes to learn of evolution. Darwin saw artificial selection going on in the barnyard; Mendel did his epoch-making work on heredity, one of the chief factors of evolution, with peas in a cloister garden; variation, another major evolution factor, can be seen by closely comparing any two individuals of any plant or animal kind; adaptation is apparent in the teeth and claws of the house cat; the struggle for existence and survival of the fittest is going on actively in any neglected corner of your garden. Matters that evolution must explain, the evidences of evolution and the results of evolution are all obvious anywhere where plants and animals are.

The wood in which the little green cottage, where I am writing, nestles so inconspicuously—because of its protective coloration, to use the naturalist's phrase—is composed mostly of Monterey pines, interesting Californian near relatives of the widespread familiar yellow pine, itself abundant in the state. The Monterey pine has an extremely restricted natural distribution, being found only in a very narrow north-and-south stretch along the middle California coast, a region embracing altogether not more than a thousand square miles. Yet this tree when artificially distributed grows readily in many places outside of its natural range.

Another strictly Californian conifer, the Monterey cypress, of which I can see specimens from my cottage, has an even more restricted natural range, existing, at present, to the number of only a few hundred, or, at most, a thousand or so weather-beaten individuals on two exposed rocky points projecting into the Pacific Ocean near Monterey. Yet this tree is one of the most abundant and flourishing of planted ornamental trees in the whole West Coast region and is familiar in European gardens. I stumble here, at once, then, even as I merely glance out of my cottage windows, on one of the most interesting of evolutionary problems, that of the geographic and topographic distribution of plant and animal kinds.

To face another problem—in these open, sunlighted woods there are many birds of numerous kinds: hawks, owls, jays, flickers and woodpeckers; titmice and chickadees; flycatchers, sparrows, vireos, russetback thrushes, warblers and humming birds; each with its characteristic size and shape and color pattern. On the edges of the wood are quail and meadow larks and along the seashore pelicans, grebes, cormorants, gulls and terns, all differing from the woods birds and all differing among themselves. I hear all day their various cries and songs, from the scream of the hunting hawks and the harsh loud calls of jays and woodpeckers to the liquid trilling of the thrushes and the staccato cheeping of the sparrows. I see them busy with food-getting, each, in its own way, seeking for its special dishes. Their nests, on ground or in bushes or trees, are, for each, of a particular kind. I can recognize each species by its particular mode of flight, or, at least, I can say—"that is a woodpecker, that a flycatcher, that a humming bird."

There are these differences, but also there are likenesses among them. The various woodpeckers not only have a common manner of flight, but also are similar in food habits, in nesting, have similar cries, and cling to tree trunk or branch in a characteristically similar way. If we examine their bodies, we note a commonness of general form and special parts, of bill, tongue, wings, tail, feet. Even if we don't know the different species of woodpeckers, we can know any of them as a woodpecker; just as we can know the various flycatchers as a group, or the hawks, or the gulls. And finally we can know any bird as a bird, not to be confused with the toads and frogs, the lizards or snakes, or rabbits or gophers or foxes that are also all here in the woods; or the fishes that are in the streams and ocean near by.

But all these groups of animals that I have mentioned have something in common, namely, a backbone and certain other correlated parts, which gives them a certain likeness in make-up and readily distinguishes them from the earthworms and insects and spiders of the land and from the sponges, sea anemones, and starfishes of the ocean tide pools. There are two great groups of animals, the vertebrates and invertebrates, and within them there are distinct major branches and then within each branch a number of classes, in each class a number of orders, in each order a number of families, in each family a number of genera, and in each genus one or more species or kinds.

There is something recognizably common in all the species of a genus, all the genera of a family, all the families of an order, and so on up the scale of classification. Although every kind of animal differs from every other kind—each individual differs even from every other individual of the same species—yet there are likenesses which group them together—obvious likenesses among the members of the more immediate groups, less obvious but more fundamental likenesses among the superficially very different-appearing members of the major groups. These likenesses are facts that evolution must explain, that evolution does, in fact, explain. At the same time they are proofs of evolution. But we shall come to this in a later chapter. I want to consider further, just now, the differences, especially the adaptive differences, among the birds around my cottage, which also are facts that evolution must explain.

All the birds belong to a single class of a single great animal branch, the vertebrates. They are all distinguished by certain common structural and physiological characters which make them differ from the fishes, the amphibians, the reptiles and the mammals, which are the other great vertebrate classes. About 10,000 living kinds of birds are known in the world, of which about 1,000 occur in the United States. Almost 500 of these can be found here in California. California has within its political boundaries such a great geographical, especially north and south, extent, and such a variety of topography, including plains, valleys, mountains and desert, streams, lakes and ocean shore, and is so favorably situated with regard to the great coast-line migratory routes, that there occur within its borders an unusually large number of bird kinds, including all-year residents, summer residents, winter residents, occasional visitants and regular migrants of spring and autumn. Kansas, a typical inland plains state, with little diversity of topography, but in the line of the great Mississippi Valley migratory route, has 350 kinds, of which nearly one third are migrants. Only fifty species are permanent, or all-year, residents. Variety of environment seems to mean variety of life.

It is not difficult to learn to know all, or most, of the birds of a given region; for that matter to know all the birds of the whole of such a well-explored and readily accessible land as ours. There is no limit, except the natural one of the period of life, to the years that one might devote to studying birds, their structure and habits, their likenesses and differences, and their relations and adaptations to their environment, especially, in working out the significance or meaning of all these observed facts. That would be to study the evolution of the birds, which would be, in effect, to study evolution as a whole, using bird kinds and bird adaptations as a basis.

I could put in a long time studying the birds which may be found about and within easy walking distance of my cottage. But a short time will reveal much. Let us confine our attention to just a few things about these birds. Let us look first at their feet. These feet tell a story, a story of adaptation, a story of evolution. Note the foot of a sparrow, a warbler, or a thrush. It has three unwebbed toes in front and a long hind toe perfectly opposable to the middle front one. This is the perching foot. These birds when not in flight or on the nest, perch on branches. Note the foot of a woodpecker. Two toes partly yoked together project in front and two similarly yoked project behind. The woodpeckers can perch, as thrushes do, but they can also cling firmly to the rough bark of tree trunk or large branches. Note the webbed swimming foot of the aquatic birds; note the different degrees of webbing, totipalmate where all four toes are completely webbed, palmate where the three front toes only are bound together but the web runs out to the claws, semipalmate, where the web runs out only about halfway. Note the unwebbed but lobate swimming foot of the coots and phalaropes where there are simply expanded separate weblike pads on each toe. Note the long, slender, wading legs of the sandpipers, snipe and other shore birds; the short, heavy, strong legs, set far back, of the divers; the small weak legs of the swifts and humming birds, almost always on the wing; the stout, heavily mailed foot of the scratchers, such as the hens, grouse, quail and turkeys; and the long grasping talons, with their sharp, curving nails, of the hawks and owls—birds of prey. In all these cases the adaptation or fitness of the foot and leg to the special habits of the bird is apparent.

Or we may examine the bill. Note the strong hooked and dentate bill of the birds of prey; they tear their victim to pieces. Note the long, slender, sensitive bill of the sandpipers; they probe the wet sand for worms. Note the short weak bill and wide mouth of the nighthawk and whippoorwill and of the swifts and swallows; they catch insects in this wide mouth while on the wing. Note the firm chisel-like bill of the woodpeckers; they drill into hard wood for insects. Note the long, sharp, slender bill of the humming birds; they get small insects from the bottom of flower cups. Note the peculiarly crossed mandibles of the crossbills; they tear open pine cones for seeds. Note the long, hook-end bill of the pelican with the large pouch on the under side; they scoop up fish from the water. One could go on tiresomely but always suggestively.

These differences in the bills of birds are related intimately and advantageously to differing special ways of feeding; just as the differences in feet and legs have their plain relation to differing special uses. One might also thus catalogue the varying types of wings and show their relation to needs and habits of flight; the long, narrow, perfect wings of the great albatrosses which spend most of their time in the air and take only an occasional rest on the uneasy surface of the ocean; the broad, soaring and hovering wings of the eagles and larger hawks; the short but strong wings of the swiftly flying ducks that make long, thousand-mile flights of migration;

the flipperlike wings of the penguins which use them for swimming under water. And then there invites us the fascinating study of the color and pattern of the plumage, with their obvious relation to protective coloration and camouflage; although the extraordinary display of the peacocks and male pheasants and others, as well as the brilliantly colored crests and long plumes of the herons, ostriches and birds of paradise demand another explanation, which Darwin tried to provide by his theory of sexual selection.

Or the manner of study might change to an intensive consideration of a single kind or group of birds. Take the woodpeckers, searching for all the various adaptations of external parts to the whole manner of their life; the short, broad wings sufficient for the limited flights from tree to tree; the strong clutching feet and the stiff, pointed tail feathers applied to the tree trunk or branch as a support when the bird is drilling its holes with the hard, sharp, chisel-like bill; the heavy neck muscles to give the bill driving power; and the usually black-and-white or gray color pattern that merges concealingly into the color of tree trunk or branch. This kind of study leads inevitably, or used so to lead, to the question: Have the woodpecker's habits led to the gradual development of its adaptively specialized structure from a more generalized bird form, or is the manner of the woodpecker's life determined by its originally having such structural characters? Evolution answers this question one way; special creation the other.

But let us leave the woods and the birds for a swift glance at the life in the near-by tide pools of the ocean shore. The creatures here, except the little fishes we may see, belong to other branches of the animal kingdom, lower branches, we are accustomed to call them. They are not vertebrate but are representatives of half a dozen invertebrate branches. The fundamental differences in body make-up among these various lowly animals are radical and important, and these differences depend primarily on the wide genetic separation of the various kinds. But, inside of a single group belonging to any one branch, there may exist a wide variety of forms, and we can recognize in this variety much that is plainly adaptive.

As we approach the rocks at low tide we hear a lively scratching and catch glimpses of a host of crabs, mostly small, scurrying into hiding places. They are equally at home on the rocks or in the water and despite their apparently awkward movements they get quickly into narrow crevices or hide under seaweed. If followed to their hiding places they face the enemy, with their strong pincer claws brandished threateningly in front of them. Their bodies are incased in a strong spiny covering, which, in some species, is of such color and general appearance as to make the crab hardly distinguishable from the rocks and seaweeds. But some crabs do not have such armor. A whole group, comprising numerous species, called hermit crabs has the hinder part of the body unprotected by any horny covering but substitutes for this the shell of some mollusk. A discarded shell is found, or in some cases the rightful inhabitant is dragged out and eaten. The crab then twists its soft hinder body into the shell with only the horny head, pincer claws, and jointed legs protruding. It has two hooks at the posterior end of its body by which it holds itself in the shell. When the crab outgrows its first shell it selects a larger one, thrusting itself into the new one with extraordinary rapidity. Some of these hermit crabs have small seaweeds and hydroid polyps growing on their shells. In fact, observers have seen them carefully tear off from the rocks and "plant" on their shells these small polyps, whose stinging tentacles help repel any crab enemies. The polyps get the advantage of being carried about and of sharing bits of food from the finds made by the crab. This is an example of a form of interrelation between two animal species called commensalism, or messmatism. Other crabs showing a special adaptive relation to other animals are the little oyster crabs, the females of which live a protected life within the gill cavities of oysters. These females have a thin, soft skin and weak legs and claws, trusting for safety to their unusual situation. The males, however, which do not live with the oysters but swim about freely, have their bodies protected by a horny covering. A similar small crab lives in the cavity of the shell of the common mussel and the scallop.

Most abundant of all animals on the tide rocks are the various mollusks that form a bewildering variety of shells composed of lime, some of a single piece and some, like those of the oysters, clams and mussels, of two opposed pieces, or valves. All mollusks are soft bodied and are much sought after by many sea-rovers, but their hard shells are their protection. A few kinds, the sea slugs, or nudibranchs, have no shell, but they appear, from their extraordinary shape and color pattern, so much like ragged bits of seaweed that they are very hard to distinguish, and thus find protection in loss of identity.

On the other hand, there is no difficulty in perceiving the many thick-skinned, varicolored starfishes and the incased sea urchins which cling to the rocks in all the tide pools. These starfishes and sea urchins, by means of hundreds of small, suckerlike tube feet, move slowly about or cling very firmly to the rocks when disturbed. Some sea urchins bore little cavities in the solid rock, in which they remain, trusting to the dashing water to bring sufficient food to them. They feed chiefly on bits of seaweed, but the starfishes feed on various mollusks, barnacles and sea worms. They fold their arms over a clam or oyster; and hundreds of the tube feet fasten themselves to the valves of the shell so that finally the mollusk yields to the constant pull of the starfish, and the shell opens. Then the starfish protrudes its stomach, inside out, through its mouth, and engulfs the soft body of the mollusk. It has been found by experiment that a large starfish can exert a steady pull of over two and a half pounds and that this is sufficient in time to open the valves of a clam or mussel.

Other tide-pool and seashore creatures, representing still lower animal branches, are the various plant-like sea anemones and hydroid polyps, called by the older naturalists "plant animals," although they are true animals, resembling plants only in general appearance when in their fixed, adult condition. These animals have a very simple body composed of a sort of short, thick-walled tube fastened, at its base, to a rock and with a single opening at its free end. This opening is surrounded by a ring of sensitive movable contractile and stinging tentacles which can grasp and paralyze small aquatic animals, and then thrust them down into the tubular cavity to be digested. The opening serves both as mouth and vent and the tubular cavity serves as stomach. There is little or no nervous system, no special sense organs except those of touch, and, indeed, none of that obvious differentiation of the body into organs and parts familiar in the bodies of the higher animals. The coral polyps, which produce the extensive coral reefs of tropic and subtropic oceans, are sea anemones of a special kind that secrete a hard skeleton of lime salts which is the dead substance we know as coral.

We can find still simpler forms than the sea anemones, in the sponges, a few kinds of which are to be found in every tide pool. They are, in fact, the lowest of all the many-celled animals. The commonest kinds are in the form of thin reddish incrustations on the wave-washed rocks or on the shells of oysters and mussels, looking more like lichens than animals. Other kinds, more typical of the real sponge shape, are like little vases fixed at the base, each with one large opening at the upper end and many small openings in the side walls. Sponges feed simply by constantly drawing in sea water through the numerous small openings, and throwing it out through the large one. Any small organisms suspended in the water are taken up by cells which line the small openings and the inner wall of the vase. The sponge as we know it in the bathroom is the dead tough "spongin" skeleton of large sponges which live in warm oceans. Some sponges secrete skeletons of lime or of a glassy substance; the delicate "glass sponges," such as the "Venus basket" found in the China Sea, being very beautiful. Sponges of the same species often vary greatly in form, adapting themselves to the situation in which they grow, and they possess so little individuality that two sponges growing side by side will often fuse into one large mass. Live sponges may be cut into pieces and each piece will grow into a perfect sponge.

There are still other kinds of animals to be seen in our tide pools, but I have mentioned enough to indicate both the wide variety, the range in complexity and the suggestive adaptations of these lowly forms of marine life. They are all living there side by side, meeting the same fundamental necessities of breathing, food-getting, protecting themselves, producing young and generally doing the same vital things with the same general means, but with special forms of body and special manners of behavior characteristic of each and particularly adapted to particular environmental conditions and relations to other living things.

This matter of the ecologic interrelations of living things is one of the most fascinating and suggestive subjects which the biologist can study. In recent years much attention has been given to it and a great many facts have been revealed about the intimate ways in which the lives of different kinds of animals and plants are associated with the lives of other kinds. Under any particular set of physical conditions, climatic, topographic, or other, there develop particular "associations" of animal and plant kinds which show how intimate and continuous is the web of life, and how intimately related it is to the environment in which it exists. We can see a good example of this by turning again to the Monterey pines that form our little wood by the sea.

From the branches, especially the dead branches, of many of these trees there hang the gray-green streamers of a lichen which finds the pine branches convenient for support and free exposure to the air and to its frequent, thirst-relieving summer fogs and winter rains. The lichen (often mistakenly called moss) does not live parasitically on the pine trees, as does the mistletoe, which one sees occasionally in the tree-tops. Nor is it, indeed, a single kind of plant, but an extraordinary combination of two low kinds, a fungus and an alga, which live all intermixed in a close commensal or symbiotic connection. This condition is true of all lichens, of which there are hundreds of known species. The fungus, which derives carbonaceous food substances from the algal cells, is the predominant part of the combination and cannot live apart from the alga. On the other hand, the alga, which derives some benefit from the fungus in the way of protection and moisture, and probably some nitrogenous foodstuffs, can live apart from the fungus, and sometimes does.

If we examine our pine trees carefully for other inhabitants, we can readily find an imposing array of insects which are entirely at home in the trees and make their living at the trees' expense. Different insects take up their abode in different parts of the tree. First, there is a tiny midge which lays its eggs at the bases of the outgrowing new pine needles. From these eggs hatch minute grubs without wings, legs, eyes, feelers or even mouth, which, lying bathed in the abundant plant sap which the tree provides to nourish the growing needles, absorbs this sap or food from it through its skin. The needles, thus robbed of their food, make only a stunted growth, and since the needles are the foliage of the pine tree which converts carbon dioxide absorbed from the air, under the influence of sunlight, into food for the tree, if there are too many pine midges the tree starves.

On the needles also may be found numerous small whitish scale insects, so called because the female covers its degenerate, flat, wingless, legless, eyeless adult body with a protecting flat scale of white wax which it secretes from pores in its skin. It has a delicate, flexible, sucking beak which it thrusts into the needle to suck sap from it. The adult male of this pine-scale insect differs from the motionless female by having wings, legs, eyes, but no sucking beak or mouth. It takes no food in its adult life, having fed sufficiently as a wingless but actively crawling larva, provided with sucking beak and mouth.

Leaving the pine needles and examining the upper branches and trunk of the tree we shall find two or three kinds of bark-boring beetles the adults of which burrow in through the outer dead bark to the live bark or cambium, and lay their eggs there in little niches along a short tunnel. When the beetle grubs hatch from the eggs, each burrows a short tunnel for itself in the live bark, living on the abundant food provided by the cambium. Farther down the trunk are the burrows of other species of bark borers, and close to the base still others, each part of the tree being reserved, as it were, to certain beetle species. The tunnel of the adult beetles and the tunnels of the grubs which branch off from it have a characteristic extent and arrangement for each species of bark borer. When the tree is felled and the outer bark is stripped off we can read the story of how many and what kinds of beetles have lived in it. There on the now dead and dry inner bark are the curious engravings which, like the hieroglyphs of ancient peoples, can be read by those who have the code.

There are other insect species that live exclusively in the Monterey pine trees—to their benefit, and the trees' hurt. There is a moth, called the resin moth, which lays its eggs on the outer bark from which hatch caterpillars that wound the tree so that resin flows out and forms a protecting mass in which the caterpillar lives. And there is another moth whose caterpillars form a community web of silk stretching over a number of small branches, underneath which silken web the caterpillars devour the pine needles. There are beetles whose strong-jawed grubs burrow into the heartwood of the trees. But it would be tiresome to catalogue all the insects that live in the Monterey pines. It is sufficient to know that there are many, and that their ways of living are various. Some of them do not rely exclusively on the Monterey pine for habitat and food, being able to live on other pine trees. But some have become so habituated to this particular kind of pine, and so specialized in their adaptations to it, that they have cast in the lot of their species as to success or nonsuccess in persistence, with the lot of this one species of pine tree. This surrender of general possibilities for the sake of the advantage of a very precise and successful fitting to specific conditions is an oft-repeated story in biology. It is especially common in connection with parasitic life.

Now, the general implications of our cursory study of some of the living creatures, and some of the ways of life accessible to observation near our cottage in the pine woods by the sea, are plain. It is the abundance of kinds of animals and plants and the variety of form and habit among these kinds and the interrelations among them which are the very first things to catch the attention of even the most casual observer. And hence these are the things that evolution, the solver of riddles about life, is first called on to explain.

If we let our study run out from our cottage and embrace the whole world, we find in it three quarters of a million different living species of animals and plants. We may be sure, from the rate at which new ones are being found—meaning by "new" only previously unknown, not newly come into existence—that there are quite as many more, probably twice as many. And we are faced, as we recognize these many different species, with an amazing variety in their size, color, form, complexity of structure, habitat and manner of life. At the same time we see the immediate connection of much of this variety with the varying conditions under which the different forms live. Nor is it difficult to see that many of the differences among living kinds are of an obviously adaptive sort. To the persistently inquiring student of nature these adaptations come almost to obsess his attention, they are so many, so ingenious, so elaborate, so precise. They affect not only the form and structure of the animal or plant but its whole way of living. These adaptations and all this variety of life cry aloud for explanation. Evolution must explain them.

But, perhaps, to most persons, the word "evolution" first suggests genetic, or blood, relationships among organisms; a genealogical tree of animal life with amœba at the base and man at the tip of the highest branch. That is, it suggests, primarily, the fundamental identity and continuity of life and the similarity and relationships of organisms, the likenesses rather than the unlikenesses. It emphasizes the presence of common characters in different organisms, as, for instance, the rayed body of all the starfishes and sea urchins, the feathers and toothlessness of all the birds, the milk glands of all the mammals. And it is quite true that this is the basic conception in organic evolution. It is on this basis that we account for fundamental likenesses. But the very fact of this recognition of identity in life makes the first glimpse of all its variety the more puzzling. We demand, straightway, that evolution explain both of these conditions.

Such an attitude toward evolution as I have just outlined may seem to reduce it from a great conception guiding our manner of thought, a great philosophy determining our attitude toward all of nature, including human nature, to a smaller and more specific principle of biology, an idea primarily of use to the student of the structure and behavior of animals and plants and of their classification. It is hard to turn our attention from ourselves; from the significance which evolution has for our understanding of our origin and place in nature; from our endowment of mind and reason, out of which endowment comes the very conception of evolution; it is hard, I say, to divert our attention from ourselves and apply it to insects, starfishes, and the flowering plants, and the problem of their variety and ingenious adaptation to their varying environment.

We are, entirely understandably, essentially anthropocentric in our interests. What has evolution to do with or for *us,* is our natural first question. But we shall best undertake to answer it with some confidence in the answer, by trying to find out what evolution offers in explanation of the problems of the simpler forms of life. Man is so hopelessly complex. He is so much more than a starfish. Although he is, perhaps, just another form of an elaborate chemical and physical phenomenon, or group of phenomena, called life he is at least quantitatively so much more than a starfish that he presents all the difficulties, to any one who would analyze and understand him, of a qualitatively different object.

With all my conviction of man's blood relationship to the lower animals, and with all my recognition of the essentially similar chemical and physical phenomena which go on in starfish life and human life, I do not admit at all that I am simply a magnified or better starfish. Believing firmly that man is of and in nature, and not out of or beyond or above it, I nevertheless recognize that included in the great deal that naturalists do not yet know about nature there is especially much that they do not know about the nature of man. Even a very full knowledge of the ways and possibilities of starfish life can be but a beginning in knowing the ways and possibilities of human life. But, and this is important, it may really be a sound beginning.

CHAPTER IV

EVIDENCES OF EVOLUTION: COMPARATIVE ANATOMY AND EMBRYOLOGY

We have, so far, rather taken evolution for granted. But that is to assume a too easy and general acceptance of something that has excited much antagonism and not infrequent indignant repudiation and denial. The indignant deniers do not really care to listen to evidence for evolution; their attitude is determined more by emotion than reason. But the unprejudiced may ask for the evidences of evolution. What are the proofs of this grandiose conception of the natural production, by transmutation, of all the kinds of animals and plants, of the blood relationship of all living things, of the identity and continuity of all life stuff? If evolution is going on all the time we should be able to see it at work. If it has been going on for ages we should be able to see its results, and as results not explicable by other causes, or, at least, more reasonably explicable by evolution than by any other cause. These are, indeed, precisely the questions and remarks made to me within the day by a young lady of high-school age. She has been hearing and reading something about science, and that word "evolution" has kept jumping out at her from all sorts of hiding places. She wants to know what it is and how we know that there is any such thing. She wants evidences of evolution.

Most of these evidences are commonly grouped, in the textbooks that are written about evolution and by the scholars who present them in lecture rooms and laboratories, under four heads: the evidences from comparative anatomy, the evidences from embryology, those from paleontology, and those from the geographical distribution of plants and animals. But there are some that do not fall readily under any of these heads; for example, some, such as blood tests, that might be called physiological evidences, others, as those of mental reactions and behavior, that may be called psychological evidences, and still others that come under such general categories as adaptations and ecological relations. In fact, there are so many of these evidences and they are of such a wide variety of character as to make it a puzzling matter to select the few that can be set out in such a little book as this. A whole book could well be devoted to an account of those available in each of the groups I have named.

Comparative Anatomy

As we are all more interested in human evolution than in the evolution of other creatures, perhaps the few cases of evidence from comparative anatomy to which we can give space may advisably be chosen from the animals instead of the plants and from that single branch of animals, the vertebrates, in which humankind finds its zoölogical place. Take, for example, the familiar case of the vertebrate skeleton. We all know something about the number and character and arrangements of our own bones and of the bones of fishes, frogs, snakes, birds and mammals.

If any of us do not, those of us in this sad condition should hasten to the nearest museum of natural history and stand a few minutes before the case containing mounted skeletons of representatives of the five great vertebrate classes, and then before the one showing a group of skeletons of different mammals, say a dog or a cat, a horse, a porpoise, a seal, a bat, a tailed monkey, an ape, and a man. Then make some comparisons among all these skeletons and enjoy the pleasure of rediscovering what other observers earlier discovered, namely, the fundamental identity in character and arrangement of the bones which form the framework of the vertebrate bodies, even though these different bodies are those of animals which vary much in their habits of life. Some walk and run, some leap, some crawl, some swim, some burrow, some fly. Each kind correspondingly shows a modification of skeletal make-up to adapt it to the special requirements made by each type of locomotion. But that modification is clearly only a special change rung on a skeletal motive common to all.

Fasten your attention to certain parts. The vertebrate skeleton consists typically of an axial portion comprising the vertebral column and the head, with two pairs of appendages or limbs, rising from or connected with the axis by a shoulder girdle and a pelvic girdle. These limbs are variously developed as fins, wings, legs and arms. In a few of the lowest fishes there is no trace of limbs, and in various amphibians, reptiles, birds and mammals, one or both pairs may be quite rudimentary. But precisely in these cases of rudimentary limbs, the lack of development obviously corresponding with special manners of locomotion not requiring functioning fins or wings or legs, we get an illuminating illustration of the persistence of the basic common type of vertebrate skeletal make-up. Where all the limbs are present in functional condition but used differently as with the bat, the seal, the dog, and an ape or man —cases within a single vertebrate class, the mammals—we see how the fundamentally similar make-up, the very same bones, indeed, appropriately modified, have been made effectively to serve various purposes. We see what the evolution idea calls for, namely, basic identity with gradatory, usually adaptive, modification.

Since our own body especially seizes our attention, examine the human skeleton in the museum case before you with particular care, and then compare it with the skeletons of the chimpanzee or orang-utan or gorilla which will be next to it if the museum is properly arranged, and also with the skeleton of a tailed monkey which will also be close by. In a detached and temporarily disinterested attitude, carefully go over these skeletons, part by part, bone by bone. Draw your own conclusions. Take nobody's word for this extraordinary identity. Take nobody's explanation for it. Let your own eyes and your own reason satisfy themselves.

If you want more of this kind of evidence for evolution go over any or all of the other systems of the vertebrate and mammal body, including our own; the muscular system, the nervous system, the circulatory and respiratory systems. They all repeat the story of the comparative anatomy of the skeleton. Or, the evidences from comparative anatomy can be obtained in another way than by taking up one body system at a time. We can run through the story of a special category of anatomical facts, as those relating to the presence in various animals of rudimentary or, as they are often called, vestigial structures, such as the rudimentary limbs in various vertebrates to which we have already referred. Other examples of vestigial structures are the reduced eyes in various cave-dwelling animals, the "thumb," or rather index finger, of birds, the splint bones or reduced side toes of the horse's foot, the appendix vermiformis and the reduced ear and skin muscles in man. Indeed, the anatomist Wiedersheim has recorded 180 vestigial and retrogressive structures in man's body alone. They occur in all his systems of organs, the skin and hair, skeleton, muscles, nervous system, sense organs, digestive, respiratory, circulatory, and urino-genital systems. Some of these rudimentary structures are to be found completely developed in other mammals or other vertebrate groups. Eleven of them are fully functional organs in fishes, four in amphibians and reptiles. Sometimes they appear in more developed condition in particular human individuals. Now and then a person can use his skin muscles to move his ears slightly, or shake the skin of his forehead or scalp. Many of these vestigial structures, the tail, for example, are better developed in embryonic life but become more and more reduced as the body grows and develops. The tail is longer than the leg in early stages of the human embryo, but gradually becomes more and more reduced, until at birth there is no external sign of it, although the bony rudiments of it—the coccyx—are present all through life.

These vestigial structures are evidences of gradual evolutionary change. In them one sees evolution actually in process. One sees evolution at work. Why should a special creator put useless and disappearing parts into the human body? Why should these parts be the remnants of parts useful and used by lower vertebrates in their kind of life, but useless and sometimes harmful in man, if the explanation is not that with his changed manner of locomotion, his modified food habits, his new artificial methods of defense against enemies, his protection against the cold and wet by clothing instead of hair, he has no longer use for certain parts with which he has been endowed through his relationship to lower vertebrates and that they are, consequently, by slow evolutionary change, gradually disappearing? What other reasonable answers can be given to any of these questions except those given by the evolutionist?

Embryology

This presence in the embryonic stages of man, and of other animals and of plants, of various structures which are present in the adult stage only in reduced or vestigial condition, or are perhaps not present at all, is one of the most striking things revealed by embryological study. And it is a peculiarly strong bit of evolutionary evidence. But it is only one of the suggestive revelations that come from the detailed study of the life history of any individual organism. In the development of any individual plant or animal we can find a swift, much condensed and often much modified but, on the whole, very enlightening recapitulation of the general evolutionary history of the species to which the individual belongs. Embryonic stages occur which are essentially similar to stages in the embryology of other animals, and also stages are passed through, rapidly and incompletely but recognizably, which repeat and thus represent, in many characteristics, the adult stages of other lower animals or plants. This "recapitulation theory" is one of the greatest generalizations that has been made in biological study. It was first formulated by Karl von Baer and later made more specific—too specific, indeed—by Haeckel, who, with characteristic optimism, saw in it more than the actual facts warranted, and, by his overemphasis of its significance and his too detailed interpretation of the evolutionary history of various animal kinds and groups on a basis of it, brought it into some disrepute. But it contains, without any doubt, a large residuum of truth, and is one of the strongest of the evidences of evolution. The human body in its growth and development from single fertilized egg cell to complex trillion-celled adult condition, with its many differentiated tissues and its elaborate systems of organs, tells us much of the history of the evolution of man.

The first steps in the development of an individual human being from a fertilized human egg cell, which, like all egg cells, has a remarkable power of multiplication and differentiation, are the division of this cell into two, then the division of these two into four, and of these four into eight, and so on until a small solid spherical mass of cells is formed, called the morula stage. Some of these cells soon become specially massed on one side, and here two cavities, or beginning sacs, are formed. One of these becomes a sac which gradually incloses the embryo, and the other forms the yolk sac, part of which eventually becomes the alimentary canal. Some of the cells of the two sacs which lie adjacent and are destined to form the actual embryo, form two layers, known as the ectoderm and endoderm, or the external and internal embryonic membranes. Later, through the repeated division (multiplication) of the ectoderm cells, an elongated area, called the primitive streak, is formed, and this indicates the fore-and-aft axis of the embryo.

Along this primitive streak, to follow a recent authoritative account by Professor Ferris, professor of anatomy in Yale University, a third layer, known as the mesoderm, is formed between the outer ectoderm and the inner endoderm layers. There are now in the region where the embryo is developing in the mother's body, three layers of cells, each having its own distinctive characteristic. These are known as the primary germ layers, and from them all the organs and parts of the body are later derived. From the outer layer, or ectoderm, are formed the outer layer of the skin, or epidermis, including its various appendages, such as the hair and sweat glands, the cells lining the mouth, the enamel of the teeth and the entire nervous system, including the sensory portions of the sense organs. From the middle layer, or mesoderm, are formed the skeleton and other supporting tissues and the muscles, the vascular system and the sex cells. From the innermost layer, or endoderm, are developed the cells lining the alimentary canal and the essential secreting cells of the various organs which develop as outgrowths from it, such as the thyroid gland, the lungs, the liver and the pancreas. In general it may be said that the endoderm supplies the alimentary system; the mesoderm, the locomotor apparatus and the sex cells necessary for the persistence of the race; and the ectoderm, those structures which are placed in control of the body and put man in touch with his environment. This particular course of embryonic development, both in its manner and in its relation to the origin of different tissues and organs, is *essentially similar in all many-celled animals,* invertebrate and vertebrate.

Up to this point the human embryo appears as a rather simple multicellular animal of the invertebrate type. The first indication that it is to become a vertebrate is the development of a dorsal, longitudinal, rodlike axis, called the notochord, which eventually extends posteriorly from the base of the brain through the length of the body. In the lowest forms of aquatic vertebrates (the tunicates and lancelets) this is the only longitudinal supporting axis the body ever possesses, but in the higher fishes and all other vertebrates (amphibia, reptiles, birds and mammals) where a more stable axis is necessary, the notochord is replaced by a more rigid, segmented, bony structure, the vertebral column.

We have not space to follow, in any detail, all the stages in the development of the embryo, but may notice simply a few special stages or happenings which are particularly significant in the evolutionary history of man. One of these is the segmentation of the embryo, initiated in its mesodermal part, by a series of horizontal clefts which result in a linear series of segments extending the whole length of the body of the embryo. This primitive segmentation, which undoubtedly repeats the adult condition of some segmented ancestor of the vertebrates, persists in a modified form in adult man in the serial arrangement of the vertebræ, ribs and the spinal nerves. In the lateral mesoderm a cavity develops which is the beginning of the body cavity, called the cœlom, which later contains the heart, lungs, and abdominal viscera. This cavity splits the mesoderm into two layers. The outer layer joins with the ectoderm to form the body wall, and the inner layer with the endoderm to form the wall of the alimentary canal which, in time, becomes entirely inclosed by the mesoderm and ectoderm of the body wall. The human embryo at this stage has acquired the characteristics of a typical vertebrate. *All vertebrate animals are essentially alike in the course of their embryology up to this stage.*

The brain in the vertebrate embryo develops at the anterior end of a hollow neural tube which expands here into three sacs corresponding to the fore, mid, and hind brains. From each side of the forebrain sac another sac grows out which expands in all directions, but especially backward, spreading over the other brain sacs and ultimately forming the cerebrum which is so large in man in comparison with the lower animals. All of this sac, except the lower part, as well as the parts of the adult brain formed from it, is known as the mantle or pallium, of which that part which forms the major part of the cerebrum is known as the neopallium. Now, the early condition of the neopallium in the human embryo represents about the whole extent of the pallium in the adult fish. As it grows further backward it represents first the extent of the pallium in the next higher class of vertebrates, the amphibians, and later the extent in the reptiles. Finally, as it begins to cover the cerebellum, the human embryonic pallium is like that found in the adult stages of the lower mammals, and not until it covers the cerebellum completely do we have the fully developed human pallium.

Thus the forebrain of man passes, in its development, successively through the various stages represented in the adult forms of the various major vertebrate groups, starting with the fish and terminating with the most developed form of the mammalian type. Similarly, the structural unit of the nervous system, the nerve cell, or neurone, passes, in its development in man, from the very simple neurone of the fish through the increasingly complex forms in the various vertebrates, to its greatest complexity in man.

The embryonic development of the vertebrate alimentary canal and the organs that arise from it, presents some equally interesting and suggestive conditions. The canal begins as a closed tube, later open, folded off from the yolk sac and lying under the notochord of the embryo. At the anterior end of the early embryo on each side of the neck, four crevices appear, which in the fishes open directly into the pharyngeal region of the alimentary canal and form the gill clefts. In man, however, these crevices do not go on to the formation of gill clefts, but soon disappear. Their presence, however, is indicative of a fish stage in his development. The lungs develop from the upper end of the alimentary canal by the formation of a single hollow sac, which later bifurcates to form the right and left lung sacs, which by repeated branchings develop into the highly ramified tubular structure of the adult mammalian lungs. The early, saclike lung of the human embryo is similar in structure to the permanent saccular lung of the adult amphibians.

The heart differentiates from a portion of the mesoderm lying underneath the pharynx in the head end of the embryo. It consists at first of two straight tubes which soon fuse for part of their length to form a single tube bifurcated at each end. At this stage of development the human heart resembles that of the adult of the lowest vertebrates. Later, this single tube of the developing heart becomes partially subdivided into two successive chambers, the auricle and the ventricle, and it now resembles the adult heart of the fishes. The auricle next divides into two cavities, and now this embryonic human heart of three chambers resembles the fully developed heart of the next highest vertebrate class, the amphibians. Later, the ventricle is also divided into two cavities, and thus the four-chambered heart characteristic of the highest vertebrates and man is reached. The red blood cells of the human embryo, are, when first formed, large and nucleated. In this stage they resemble the red blood cells of adult fishes and amphibians. Later, the embryonic human blood cells are similar in structure to those of adult reptiles. Finally, before birth of the human embryo, these blood cells become, as they also do in all mammals, nonnucleated and biconcave. Thus, it is evident that the human heart and the cells of the human blood, in their embryonic development, pass through stages representing the different adult conditions of the heart and blood in successively higher vertebrate classes.

At the seventh month of prenatal life the chimpanzee and gorilla have well-developed hair on the scalp, eyebrows and lips, and the rest of the body is covered with fine hair. This is also true of the human embryo of the same age, and the hair slopes and lines are very similar to those of the apes. But before birth the human embryo loses the fine body hair. The developing nose of the early human embryo goes through a series of stages which represent the adult nose of first the gilled fishes, second the lung fishes, third the amphibians and finally (in the third month) the mammals. In fact, the embryonic history of almost any human part recapitulates more or less clearly, and more or less nearly completely, a series represented by the adult condition of this part as possessed by the various vertebrate classes beginning with the fishes and ending with the mammals.

This embryonic recapitulation of the evolutionary history of the species is necessarily much condensed and much modified. Numerous stages of the evolutionary history are dropped out, and various adaptive stages or characters, which fit the young to carry on an independent life while still developing towards maturity, may be interpolated. But the ancestral stages actually repeated in the embryonic development of the individual are too obvious to be overlooked. Equally obvious is the similarity in development, up to very late embryonic stages, of any two kinds of animals or plants which are genetically closely related, but in adult condition may be superficially very unlike in appearance, because of adaptive modification of the body to fit the animals for life under different conditions. For example, a barnacle fixed to a tide-washed rock is a very different-looking creature from a crab crawling actively about on the same rock, but barnacle and crab are closely related and the barnacle passes through a stage in its embryonic development when it is an active, free-swimming larva much like the similar larva of the crab.

An important part of the evidence for evolution which embryology adduces, is that implicit in the character of the diagram which one could trace to illustrate the manner in which different animals (or plants) run along together as regards their embryonic development, or early separate from each other in this respect.

A starfish and a sea urchin, a beetle and a butterfly, a snake and a turtle, a horse, a chimpanzee, and a man, all start as single fertilized egg cells. Each of these single cells begins its development by a series of simple divisions, forming, in each case, a little subspherical group of similar cells. Then each group of cells begins to become modified in character by foldings and differentiation of continually forming new cells. The groups representing the starfish and sea urchin, which both belong to one branch of animals, change in one way; those representing the beetle and butterfly, which both belong to another branch, in another way; those representing the snake, turtle, horse, chimpanzee and man, which are all vertebrates, in still another way. In their later development, the starfish and sea urchin for some time go through similar changes, as do the beetle and butterfly, and as do also the various vertebrates; but these changes become more and more unlike in the different groups. At the same time it is obvious that the snake and turtle, which are both reptiles, follow paths more like each other than either is like the path of the horse, chimpanzee or man, which are all mammals and which follow paths similar among themselves. These two sets of paths continue to diverge more and more. Finally, within the mammal group the chimpanzee and man go on along paths much more like each other than either is like the path of the horse. It is, indeed, hard to distinguish the embryonic chimpanzee from the embryonic man until well along in their developmental paths.

To generalize from these instances, we can say that animals closely related to each other follow similar embryonic paths until late in their development, while animals less closely related diverge earlier and more markedly. This divergence is the earlier and the more marked, the less closely related are the animal kinds. A diagram illustrating graphically the facts concerning the embryonic development of all, or many, animals, would, therefore, have the form of a repeatedly branching tree. The same would be true for plants. Biologists believe that if this tree could be correctly worked out it would correspond with the tree of relationships worked out by comparative anatomy.

CHAPTER V

EVIDENCES OF EVOLUTION: PALEONTOLOGY, GEOGRAPHICAL DISTRIBUTION

THE "Emporia Mineral and Fossil Club" was composed of a group of scholarly young gentlemen of the late grammar and early high school ages who had had an earlier organization known as the "Osage and Cheyenne Pony Riders"—that "bunch of young Indians," the townspeople called them. The transformation came about as the result of a discovery made during the enlargement of the headquarters cave of the Pony Riders. This cave was in a sandstone outcropping near the river bank about a mile from town, and was a perfect cave for wild Indian purposes except that it was too small. In making it larger the Pony Riders were astonished to find pieces of the sandstone which they broke out stamped with the impress of leaves, and these leaves were of a kind different from any to be found on the growing plants or trees of the neighborhood. The father of one of the boys called them "fossil leaves," and suggested writing a letter to the state geologist about them. This worthy man, being human as well as scientific, sent back such an answer as immediately changed the wild Osages and Cheyennes into an enthusiastic band of geologists and paleontologists as devoted to pony riding and roaming as before, but bringing back as booty bits of stone and fossil leaves and shells, and flat rings from crinoid stems, instead of imitation scalps. Especially did the crinoid rings, scattered so abundantly on the slopes and crest of a low limestone hill near the cave, rivet their attention and wonder. For they soon learned that crinoids are a kind of marine animal related to starfishes and sea urchins, but fixed and plantlike in appearance, and hence called sea lilies, which lived in great numbers of kinds and individuals in ancient oceans. This meant that the Kansas limestone hill, now nearly two thousand miles away from any ocean and a thousand feet higher than present sea-level, had been sometime part of the bed of an ocean. The state geologist guessed this time to be about three or four million years ago!

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In Huxley's words, "fossils are only animals and plants which have been dead rather longer than those which died yesterday." Each fossil animal or plant is a record of prehistoric life, absolutely authentic, so far as it goes, admitting of no doubt or question. But, as Lyell, the great geological champion of evolution in Darwin's time, so expressively stated it, it took one hundred and fifty years of argument and dispute to persuade even learned men that shells and teeth in the rocks were actual remains of actual animals, and another hundred and fifty years to demonstrate that the shell-bearing rocks were not masses of débris from Noah's flood. Nothing in the history of science is more extraordinary than the story of the efforts, directed against the first students of fossils, to show that these structures were mere sports of nature, whimsicalities of creation, or freaks developed in the fatty matter *(materia pinguis)* of the earth by the entangling influence of the revolving stars!

Of the four "ancestral documents," anatomy, embryology, paleontology and distribution, which contain so much evidence for the reality of evolution and so much of the record of plant and animal descent, paleontology is at once the most certain and the most incomplete. It is the most certain, for each fossil is the remains of an actual prehistoric organism which has been one of the links in the long and ages-old chain of descent from lowest and oldest to highest and most recent of organisms. Fossils help prove evolution, for they help fill the spaces in that continuous and branching tree of organic genealogy which is called for by the evolution idea. But paleontology is the most incomplete of the evolutionary records because comparatively so few—

although absolutely many—of the myriad plant and animal kinds which have lived on this earth have left fossil traces for us to examine. No animal or plant is preserved as a fossil except as the result of an unusual combination of circumstances, of which perhaps the most important is that the body of the dead organism must have in some way become caught in sediment slowly being deposited at the bottom of a lake or ocean and which, hardening, formed slowly into solid rock. With few exceptions, then, only in the sedimentary or stratified rocks of the earth's crust do we find fossils. And while these rocks, such as limestone, sandstone, and shales, form much of this crust, there are in it, also, large masses of other rocks, igneous or granitic in nature, in which no fossils can occur. In some places, too, the sedimentary rocks have been so subjected to pressure and heat after their deposition that all the fossils in them have been destroyed. Finally, recall what a sadly small fraction of the unmodified sedimentary rocks of the earth has been explored for their contained fossils, or can ever be so explored.

It is obvious that under the conditions necessary to the forming of fossils, the plants and animals living normally in the ancient lakes and oceans had a very much better chance to leave their remains as fossils than the animals living on land. Thus, the insects, which at present comprise about three fifths of all known animal species and have undoubtedly been abundant through several geologic ages, are represented by few fossils compared with the aquatic mollusks and crustaceans. It is obvious, also, that the hard parts of animals, such as shells, bones, teeth, are much more likely to be preserved as fossils than the soft parts. We are likely, therefore, to have an undue proportion of our discovered fossils representing such animals as vertebrates (with bony skeleton) and mollusks (with shells) rather than such animals as sea anemones, jelly fishes, spiders, and others (with soft bodies).

We get from the rocks, then, a most incomplete picture of the plant and animal life of the earlier ages, but what there is of it is indubitably authentic. This picture has been in course of painting by the master artist, Nature, for millions of years. Here and there, and representing different times, it is drawn and colored in much detail. In other places, or representing other times, it is merely a blank. And in many spots it is sadly marred by time and accident. We have to face the plain facts that the prehistoric plants and animals have had a hard time of it in their pleasant intention of presenting to future inquisitive man an easily readable picture or story of the succession and kinds of life of the geologic ages. Yet, after all, we have been able to read much of this fascinating tale of who, and when, and where were the ancient inhabitants of the earth.

These inhabitants did not all live at one prehistoric time, nor in any one part of the earth. In fact, the earth has suffered great changes through the ages; where at one time there was ocean, at another there was land, and this reversal might be often repeated in one and the same part of the earth, with consequent radical changes in the kinds of organisms which lived there. The whole time of the earth's existence, in such condition that life might endure on it, is unknown in terms of years; we may say millions—for it has certainly been millions—and let it go at that. But the geologists and paleontologists have divided this long stretch of time, for convenience of reference, into geological eras or ages, then each of these ages into shorter parts called periods, and these periods into epochs. Each epoch and period and era is more or less sharply distinguished from every other by the different kinds of animals and plants which lived while its rocks were being deposited. Of course some animal and plant kinds persisted from one epoch to another, and even from one period or era to another. There are various species of one-celled plants and animals now living in the oceans which can hardly, if at all, be distinguished from species which have been found as fossils in the earliest (oldest) stratified rocks. But each new geological epoch and period and era is distinguished by new kinds and groups of organisms as compared with those of the preceding geological time unit. The fossils found in the oldest rocks—which, in parts of the earth's crust that have not been distorted by foldings and breaks, are the lowest of the stratified series—represent the oldest or earliest animals and plants, those in the upper or newest rocks chiefly the newest or latest animals and plants.

Now, an examination of a whole series of rock strata shows that the more highly organized and specialized kinds of plants and animals did not exist in the earliest epochs of the earth's history but that the organisms of these epochs were all of the simpler or lower kinds. For example, in the older (lower) stratified rocks there are no fossil remains of the vertebrate animals; there are only invertebrates. When the vertebrates do first appear in the less old (higher) rocks, there are none but fishes, the lowest vertebrate class, for several epochs. In a later period, the amphibians appear; in a still later period, the reptiles; and last of all, the birds and the mammals. No human fossils have been found below the uppermost, that is, most recent, geological strata. Of course "recent" used in connection with geologic time may mean anything from a few thousand to half a million years. As a matter of fact, the oldest of human fossils so far known are somewhere between three hundred and five hundred thousand years old. We shall pay special attention later to these fossil relics of prehistoric man.

The paleontological history of the plants tells a story similar to that of the animals. The oldest fossil plants are simple types of algæ. Ferns appear later and are abundant in the coal-bearing rocks. The lowest types of seed-bearing plants also appeared in the later coal measures. Still later, coniferous trees appeared and some species of these early conifers have persisted to the present time. Thus, the bald cypress of the southern states seems to be of the same species as a tree which occurs as a common and widespread fossil in a geological era before mammals appeared. The famous giant Sequoia and its first cousin, the redwood, which now occur only in the mountains of California, were common a few million years ago in various places scattered over nearly the whole of the northern hemisphere. They are the disappearing relics of an older geological period. Of the flowering plants, only the simpler types are represented by the oldest fossils; the more specialized types are represented by fossils of only later periods.

The following table shows the succession of the various major geological periods together with their characteristic plants and animals.

GEOLOGIC CHRONOLOGY

(*Adapted from Pirsson and Schuchert*)

Eras	*Periods and Epochs*	*Advances in Life*	*Dominant Life*
Psychozoic	Recent (Alluvial or Post-Glacial)	Rise of world civilization The era of mental life	Age of Man
Cenozoic	Quaternary (Glacial or Pleistocene)	Extinction of great mammals	Age of Mammals and Modern Floras
	Tertiary		
	Pliocene	Transformation of man ape into man	
	Miocene	Culmination of mammals	
	Oligocene	Rise of higher mammals	
	Eocene	Vanishing of archaic mammals	
Mezozoic	Epi-Mezozoic Interval	Rise of archaic mammals	Age of Reptiles
	Cretaceous	Extreme specialization and extinction of great reptiles	
	Comanchian	Rise of flowering plants	
	Jurassic	Rise of birds and flying reptiles	
	Triassic	Rise of dinosaurs	

Eras	*Periods and Epochs*	*Advances in Life*	*Dominant Life*
Paleozoic	Epi-Paleozoic Interval	Extinction of ancient life	Age of Fishes
	Carboniferous Permian	Rise of ammonites, modern insects, and land vertebrates	
	Pennsylvanian	Rise of insects and primitive reptiles	
	Mississippian	Rise of echinoderms and ancient sharks	
	Devonian	Rise of amphibians and first known land floras	
	Silurian	Rise of scorpions and lung-fishes	Age of Higher (Shelled) Invertebrates
	Ordovician	Rise of land plants, corals and armored fishes	
	Cambrian	First known marine faunas and rise of shelled animals; dominance of trilobites	
Protoerozoic	Great Epi-Proterozoic Interval		Age of Primitive Marine Invertebrates and Unicellular Life
	Algonkian		
	Neo - Laurentian		
	Paleo-Laurentian		

In some cases the paleontological record is so nearly complete that the transformation of certain animal kinds can be followed through the ages with remarkable detail. The horse is the classic example. Its paleontological history is largely revealed by a series of American fossils gradually discovered in rocks of the Tertiary and early Quaternary ages. These fossils are the remains of about thirty different kinds of horselike animals.

The Eohippus, the earliest of these, found in the oldest Tertiary rocks (Lower Eocene epoch) was little larger than a fox, and its forefeet had four hoofed toes, with the rudiment of a fifth, while the hind feet had three hoofed toes. Next, in higher strata (Middle Eocene), are the remains of Orohippus, also small, but with the rudimentary fifth toe of the forefeet gone. Next appear, in the higher strata of the Lower Miocene, the fossils of Mesohippus, about the size of a sheep, in which the fourth toe of the forefeet is rudimentary and useless, and of Miohippus, of similar size, in which the rudiments of the fourth toe is almost gone. Also the middle toe and hoof of the three usable toes in each foot are larger than the other side ones. In the Upper Miocene and Lower Pliocene appear the fossils of Protohippus, a horse about the size of a donkey, with three toes, but with the two side toes on each foot reduced in size and probably no longer of use in walking. In still higher Pliocene rocks comes Pliohippus, an "almost complete horse," with hoofed toes reduced to one (the middle one) on each foot and the side toes reduced to mere splints. Finally, in early Quaternary time, comes Equus, type to which the present horse belongs, with splint bones still smaller and middle toes with rounder hoof. It also differs from Pliohippus somewhat in shape of skull, length of molar teeth and other details.

Similar series of fossils representing the gradatory development of the elephants and the camel family have been beautifully worked out by the paleontologists. The earliest animal, called Moeritherium, recognized as belonging to the elephant series, lived in Egypt in early Tertiary time, and was about three feet high. Between this small elephant type and the huge mammoths, recently extinct, and the elephants of the present day, runs an illuminating series represented by fossils of Paleomastodon from Tertiary strata in Egypt and India, Trilophodon from still higher rocks in Africa, Europe and North America, Mastodon from more recent strata in Asia, Europe and North America, and Stegodon from the Pliocene of Southern Asia and North America.

The camel family presents another interesting series. It now has two main subdivisions, one including the true camels of the Old World, the second, the llamas, guanacos, and others of South

America. But for a long geologic time the family was entirely confined to North America, where there are now no native representatives of it at all. Its oldest known members were small animals hardly larger than a jack rabbit which lived in North America in Upper Eocene time. They had four hoofed toes on each foot.

Another less familiarly known but even more striking example of the gradatory appearance of successive animal kinds—which in itself means transmutation and line of descent—is that which has been provided by certain paleontologists who have studied intensively the ammonites. This group of curious cephalopod mollusks first appeared in Silurian time, flourished for several geologic ages, and then became extinct, except for one genus of three or four species, in the Cretaceous Age. This exception, the only living example of this once large and highly developed group of mollusks, is the pearly nautilus, the many chambered spiral shell of which, with its inner surface lined with beautiful nacre, is a familiar curio. The other nearest living relatives of the ammonites are the squids and octopuses.

By assiduous study of the abundant fossils of the shells of the many kinds of ammonites found in the rocks of the geologic ages in which these animals flourished, the paleontologists have worked out a series of forms, beginning with simple straight shells, going on to curved ones, then on by gradations to elaborately spiral ones. These shells, of which several hundred fossil species have been found, vary from half an inch to a yard in diameter, and present, in addition to the gradatory steps in shape, a closely continuous series of types of sutures between the different chambers running from simple straight lines to wavy, and then on by readily distinguishable steps to most complexly frilled ones. These steps appear successively in different periods of geologic time and enable the paleontologists to trace the various evolutionary lines within the group.

But the most striking and informing result of this intensive study of the fossils of a group of animals which, but for the exception of one representative genus, has been extinct for several million years, is the discovery that by carefully taking apart the fossil shell of one of the more complex, or higher, types of the ammonites, and examining closely the sutures and the shape of the successive shell chambers, which are characters perfectly preserved in the fossils, the *embryology* of this type, at least as regards shell formation, can be worked out. For each ammonite, beginning as a larva, developed its shell by the formation and addition of successive chambers, living always in the outer or latest chamber. The revelation of the course of descent of ammonites, derived from this embryonic history of a more recent complex ammonite, confirms that derived from the paleontological history of a series of adult types.

Altogether the outstanding character of the tale of the history of the earth and of the plants and animals which have lived on it, which is the tale of paleontology, is that it reveals, just as comparative anatomy and embryology reveal, the fundamental identity of life, and of its steady continuity and gradatory progress, and of the genetic relationships and the adaptations to changing environment of organisms. This is evolution. The great plan of life has been slowly and continuously unrolled. The great possibilities of life have been steadily unfolded. And this unrolling and unfolding is evolution. In the paleontological record we see evolution in action during the ages. Paleontology is a perfect proof of evolution. Evolution is the perfect, and only perfect, explanation of paleontology.

The Geographical Distribution of Plants and Animals

Paleontology treats of the distribution of organisms in time; plant and animal geography of their distribution in space. These two matters are intimately connected, for changes in geographical distribution occur with the passing of time. A map showing the distribution of a certain kind or kinds of animals or plants in one geologic age may not be true for another. For example, the earliest camels, those absurd little camel creatures of the size of a jack rabbit, which lived in early Eocene time, were limited to North America, while the various present-day members of the camel tribe live, as natives, exclusively in the Old World and South America. Even the map of the world itself as the geologist would draw it for the Tertiary Age would not be a true map for the present age. There have been upheavals and subsidences of great land masses during the earth's history. Where now is the wide dry desert west of Great Salt Lake, there was once a great inland ocean. England and Europe were once a continuous land mass. The Mediterranean Sea has changed shape and position very materially. In comparatively recent times America and Asia were joined by continuous land where now are the Aleutian Islands and Bering Strait.

With the differences in the configuration of the earth's crust in different geologic times there were also great differences in temperature and climate of specific land regions. In Miocene times Greenland, Iceland and Spitzbergen were covered with a luxurious temperate vegetation, as revealed by the fossil plant remains in these countries. In the late Glacial period the polar ice sheet extended south to 40° North latitude in America and 50° in Europe, so that the temperate plants of Greenland were pushed south to the shores of the Gulf of Mexico and the Arctic plants which line the border of the polar ice sheet were pushed to the middle of Europe and America. Of course many species of plants and animals were killed out by these great world changes, so that plant and animal geographic distribution to-day is partly the result of great happenings in the geologic period just preceding our time.

But the distribution of the living plant and animal kinds of to-day has been determined not alone by earth changes in earlier times but by present earth conditions. Practically all plant and animal species tend to be pressing out in every direction from their center of distribution, and are only restrained from spreading indefinitely by the existence of various barriers. These barriers may be oceans or great lakes, mountain ranges, deserts, forests, marked differences in climate, or the influences exerted by the presence and activities of humankind. Sometimes animals and plants are helped across these barriers by artificial means, most notably by the unintentional or intentional aid of man, and thrive perfectly well and spread rapidly in their new homes. The black rat of Europe was introduced into America about the middle of the sixteenth century and throve so that it almost crowded out the native American wild rats, only to be itself nearly exterminated by the Old World brown rat which was introduced about 1775.

These rats were brought across the Atlantic unintentionally in ships. But the mongoose was introduced intentionally into Jamaica, the rabbit into Australia and the English sparrow into the United States, all with similar results of such a rapid and enormous increase as to make each a pest. A majority of the worst insect pests now in America are of foreign origin, brought unintentionally to this country on introduced nursery stock, plant cuttings, bulbs, etc., all of them finding America an excellent breeding ground. Now American entomologists roam the world over seeking the natural predaceous and parasitic insect enemies of these pests in their native lands, and attempting to introduce them here to keep them in check. On the other hand, repeated attempts to introduce the desirable nightingale, starling and skylark from Europe have been failures.

Thus the present natural distribution of animal kinds is determined partly by actual physical barriers, such as oceans and mountains, and partly by unfavorable living conditions outside of the natural range of a given kind. This applies also to plants. Man alone has special means of crossing barriers and special means of adapting himself to all varieties of world conditions. Hence man has found his way to all regions of the earth and can persistently maintain himself in these regions. Yet, as we are familiarly aware, the variety of these conditions have had their effect in modifying him, so that there is on the whole a recognized natural distribution of the various human races. The races of the tropics differ markedly from those of the temperate zones, and these from those of the arctic regions.

The present natural distribution of plants and animals presents an interesting and often puzzling lot of conditions. But many of these can be brilliantly explained by evolution, and thus become impressive evidences of evolutionary reality. It was, indeed, especially because of their observations on the puzzling distribution of various animal kinds and groups that both Darwin and Wallace were first so insistently driven to an evolutionary explanation of this distribution. No other explanation yet offered, least of all that of specific creation, has such a satisfying reasonableness.

Just as the paleontologists divide earth history into a series of geologic and biologic ages and epochs, so the students of the geographical distribution of organisms divide earth regions and their faunas and floras into a number of great realms, with subsidiary regions within each realm. These realms are called the [1] Arctic, North Temperate, South

[1] Other divisions by realms with more or less different realm names have been made by various students of distribution.

American, Indo-African, Patagonian, Lemurian (or Madagascarian) and Australian. Of these, the Australian realm alone is sharply defined. The others have outlines rather hazily marked, there being much overlapping along their boundaries. The general outlines of these boundaries are sufficiently indicated by the realm names.

The distribution of plant and animal kinds among these realms, and their subdivisions has obviously been determined by several factors; some of these are paleontological in character, some strictly geographical and topographical, and some adaptive. David Starr Jordan, who has given much attention to these problems, has formulated certain interesting generalizations concerning the distribution of animal kinds, and these generalizations apply equally well to plants. They are as follows:

"Every species of animal is found in every part of the earth having conditions suitable for its maintenance unless:

"(*a*) Its individuals have been unable to reach this region, through barriers of some sort; or,

"(*b*) Having reached it, the species is unable to maintain itself, through lack of capacity for adaptation, through severity of competition with other forms, or through destructive condition of environment; or, "(*c*) Having entered and maintained itself, it has become so altered in the process of adaptation as to become a species distinct from the original type."

It is the situation referred to under (*c*) that presents especially brilliantly the evidence for evolution derived from distributional conditions. Take, for example, the conditions presented by the plants and animals on oceanic islands, conditions which, as already said, were of especially large influence in leading both Darwin and Wallace to their belief in evolution as the only reasonable explanation of the peculiar facts of animal and plant distribution. In fact, biographers of Darwin find reason to believe that his study of the fauna of the Galapagos Islands first fastened his mind on the evolution idea and convinced him of the reality of evolution. These islands, situated in the Pacific about 500 miles west of the South American coast, are of volcanic origin, and there are no evidences of their ever having had a land connection with the American continent, certainly not in recent geologic ages. The depth of the ocean around them varies from 2000 to 3000 fathoms or more. Their animals must have been either specially created on them since their upheaval from the ocean as volcanoes, or derived in some other way. There is such a way which appeals strongly to our knowledge of distributional methods as we know them by actual observation. It is a way in perfect line with the assumptions of the evolution idea. Let us follow Darwin himself in his observations and reasoning in connection with the Galapagos fauna.

"Here," he says, "almost every product of the land and of the water bears the unmistakable stamp of the American continent. There are twenty-six species of land birds; of these twenty-one, or perhaps twenty-three, are ranked as distinct species, and would commonly be assumed to have been here created; yet the close affinity of most of these birds to American species is manifest in every character, in their habits, gestures and tones of voice. So it is with the other animals and with a large proportion of the plants, as shown by Dr. Hooker in his admirable *Flora* of this archipelago. The naturalist, looking at the inhabitants of these volcanic islands in the Pacific, distant several hundred miles from the continent, feels that he is standing on American land. Why should this be so? Why should the species which are supposed to be created in the Galapagos Archipelago, and nowhere else, bear so plainly the stamp of affinity to those created in America? There is nothing in the conditions of life, in the geological nature of the islands, in their height or climate, or in the proportions in which the several classes are associated together, which closely resembles the conditions of the South American coast; in fact, there is a considerable dissimilarity in all these respects. On the other hand, there is a considerable degree of resemblance in the volcanic nature of the soil, in the climate, height and size of the islands, between the Galapagos and Cape de Verde archipelagos; but what an entire and absolute difference in their inhabitants! The inhabitants of the Cape de Verde Islands are related to those of Africa (these islands lie 300 miles off the west coast of Africa) like those of the Galapagos to America. Facts such as these admit of no sort of explanation on the ordinary view of independent creation; whereas in the view here maintained it is obvious that the Galapagos Islands would be likely to receive colonists from America by flight, on and in floating logs, etc., and the Cape de Verde Islands from Africa; such colonists would be liable to modification—the principle of inheritance still betraying their original birthplace."

Since Darwin's time, the fauna and flora of these islands have been more intensively studied, with results expanding, but wholly confirmatory of Darwin's observations. Of the birds, more than two thirds are species peculiar to the islands and almost all the nonpeculiar species are strong-flying and swimming aquatic birds capable of crossing wide distances of ocean. The true land birds are all, with but few exceptions, of species peculiar to the islands, while more than half of them are of peculiar genera. But all these birds are unmistakably allied to South American kinds, and they present most beautiful series of gradations from perfect identity with continental species to genera so distinct that without the existing gradatory kinds it would be difficult to determine to what continental forms they are most nearly allied.

Other volcanic groups of oceanic islands, as the Azores, the Bermudas, and the Hawaiian Islands, all have an animal and plant life that tells a similar story: almost no native terrestrial vertebrates except birds, and these of genera and species peculiar to each group, but most nearly allied with the bird kinds of the nearest continent; the aquatic birds mostly of the same kinds as those of the general realm in which the islands lie; the familiar animal and plant species that travel with man, common to all the island groups; the more isolated the island group the fewer and the more strictly peculiar the animal and plant kinds present; series of gradatory forms present in more or less approximate completeness revealing the changes from original immigrant from the continent to latest and most dissimilar related species or genus developed from it.

Australia, which, although continental in area, may be looked on as a great island which has been separated for a long geologic time from its nearest continent, Asia, presents an interesting case of mammalian distribution. The only known living representatives of the lowest order of mammals, the curious duckbills and echidnas (Monotremes), are found only in Australia and the near-by islands of Tasmania and New Guinea. And all of the marsupials (kangaroos, wallabies, opossum), constituting the next lowest order, are, with the exception of the opossum, similarly restricted to Australia and neighboring islands. The additional fact that these lowly organized mammals are, with the exception of various rats, mice and bats, almost the only native mammals found in Australia, makes the Australian mammalian situation a very interesting one. The explanation, reasonable and consistent with the known paleontologic facts, seems to be that Australia became separated from all other land masses not later than in the Jurassic or Cretaceous Age, at which time there yet existed in the world no other mammals than various small and most lowly organized ones. After the separation, the ocean barriers prevented the migration into Australia of the higher mammalian types, which were later developed in the great land masses of the Old World and America with their wide and stimulating diversity of climate, topography and living conditions in general, and hence the Australian marsupials have had no competition, have flourished, and have developed a considerable variety of forms. Some of these show adaptive, although not fundamental, likenesses to such higher forms as rodents and carnivores. The ancestors of the present rats and mice and bats which are now abundant in Australia must have arrived from the Asiatic shore in later—probably late Tertiary—times, by being carried on floating logs, or, in the case of the bats, by flight. But the large Asiatic mammals have been unable to reach Australia. The rapid multiplication of rabbits and foxes, introduced recently by man, show how easily other mammals might have flourished in Australia if they had not been shut out by the ocean barrier.

With so much space given to the interesting distributional conditions presented by ocean islands we cannot refer in detail to any of the special features presented by continental distribution. Such problems, however, are all around us. The meadow lark, for example, which we have here in California, seems, at first sight, to be just like the meadow lark of the East. But closer attention to it shows that it has certain slight but positive differences in color pattern. Its song, too, is recognizably different. The pair of woodpeckers which have a nest in a pine tree by my cottage are like a familiar Eastern species —but with noticeable slight differences. The flicker has reddish instead of yellow wing shafts. Why these differences? Californian life conditions are somewhat different from those of the East. The birds here respond in one way or another to these differences. They are not yet different species of birds; but they are on their way to be. They are called different varieties or subspecies, which is an evolutionary step toward being different species.

If one traverse a continent in the Northern Hemisphere from south to north, from tropic or subtropic regions to north temperate and on to arctic regions and then cross it from east to west, he will notice greater differences among the plants and animals as he moves across the latitudes than are evident in moving from east to west. The reason is that differences in latitude mean greater differences in living conditions than do differences in longitude. If we climb a high mountain situated in a southern region we can mark out by the distribution of plant and animal life on it a series of zones corresponding in some degree with differences in latitude. At the bottom there will be a subtropic zone, above it a temperate one, above that a transition zone and at the summit an alpine or arctic zone. Different kinds of plants and animals fitting the different zones form a gradatory series of organisms in a gradatory series of life conditions.

But we must make an end of this discussion. Perhaps we can most usefully do it by quoting a short statement recently published by Professor Newman of the University of Chicago, summarizing the evidence for evolution based on geographical distribution:

"On the hypothesis of special creation, or on any other hypothesis except evolution that has ever been suggested, the extremely intricate patchwork of animal and plant distribution remains an unsolvable picture puzzle, without rhyme or reason. When this puzzle is attacked with the aid of the evolutionary idea, the key to the whole maze is furnished, and the difficulties clear up with remarkable ease. The whole hodgepodge makes sense and we can understand many previously irreconcilable facts. In no field does the working hypothesis of evolution work to such advantage as in this field.

"On the basis that a species arises at one place, spreads out over large areas, becoming modified as it goes, that new species are formed from old through modification after isolation from the parent stock, how do the facts of distribution look when examined in detail?

"1. Cosmopolitan groups, those with the widest distribution, are those to whom no barriers are sufficient to check migration, for example, strong fliers, man, earthworms carried by man.

"2. Restricted groups are usually those to which barriers are readily set up and are frequently the last remnants of a formerly successful fauna or flora, which continue to survive only in some restricted area where the conditions are rather more favorable than elsewhere.

"3. The study of the distribution of species belonging to a single genus reveals that the more primitive or generalized species occupy a central position, and the most specialized species are at the outer boundaries of the distributional area.

"4. The faunas and floras of continental islands are just what we should expect on the basis that there was at one time a land connection with the nearest continent; that at this time the faunas and floras were the same on both island and continent; that, later, the continent and island were separated by an impassable barrier of ocean; and that the inhabitants of the two bodies evolved separately.

"5. The faunas and floras of oceanic islands are like those of the nearest mainland and are of those types, for the most part, that might most readily have been blown or carried on floating débris.

"6. The conclusions arrived at by students of geographic distribution, past and present, as to the existence of former land connections, now broken, are borne out by the independent findings of geologists and geographers."

CHAPTER VI

CAUSAL EXPLANATIONS OF EVOLUTION

PERHAPS it is not a bad thing that Mr. Bryan and the Fundamentalists are stirring up matters about evolution, and hence stirring up the evolutionists to interrupt for a moment their evolutionary research in order to take stock of their present knowledge and to tell the public, in more or less intelligible language, just where evolution now stands. What has been learned about evolution since Darwin? What are the special things that still need to be learned?

The principal thing needing now to be known about evolution, is to know what causes it. This has, indeed, been an outstanding need all along. Biologists have, for a long time, had no doubts at all about the reality of evolution, but they have always had doubts about the validity of the various causes that have been suggested to explain it from the times of the Greeks to those of the mutationists and the Mendelians—which are the times of to-day. Oddly enough the antievolutionists have taken little advantage of this uncertainty among the evolutionists concerning the causal explanation of evolution. They have mostly devoted themselves to affirming dogmatically, or trying to prove, that there is no such thing as evolution; at least, and particularly, no such thing as the evolution of man. They could have made more trouble if they had stressed more the differences of opinion among the evolutionists regarding the causes and control of evolution.

I carefully say causes, not cause, for it is quite certain that there is no one thing alone that causes evolution. There are certainly several or many causal factors, that work together in combination. Some of these factors we know, and we understand something of the coöperative relation among them. But some of the secrets of the combined working of the known factors we do not know, and, in addition, we almost certainly do not know some of the factors themselves. The "unknown factors of evolution" are the biologist's great riddle to-day.

But—let me repeat—because the biologists do not know, or only partially know, the causes of evolution, to assume from this that they have any doubts at all of the reality of evolution, would be to assume what is not true. I do not know of a single living biologist of high repute—and I do not determine repute on a required basis of a belief in evolution!—who does not believe in evolution as a proved part of scientific knowledge. It is as well-proved a part as many other parts of this knowledge that we all readily accept.

Since Darwin's day much has been added to our knowledge of the facts about the manner and the effect of evolution, but only two important new alleged factors have been presented for consideration as primary causes of evolution; these are mutations and Mendelian inheritance. There is no general agreement among naturalists that either is a sufficient, or is even a chief explanation of either species forming or adaptation, which are the coördinate fundamental problems of organic evolution. In this same post-Darwinian period, also, the two most important explanations of evolution current in Darwin's time, namely, Lamarckism, based on the inheritance of acquired characters, and Darwinism, based on natural and sexual selection, have been weakened rather than strengthened as sufficient causes of evolution. Hence we are in the curious position of knowing now much more about evolution than was known a half-century ago, but of feeling much less confident that we know the whole story of the causes of evolution. If this is ammunition for the antievolutionists let them make what use of it they can. We can afford to be honest.

The two basic coördinate phenomena which any causal explanation of evolution must explain satisfyingly are, as has been pointed out in earlier chapters, first, the great number and variety of plant and animal kinds (species) together with their genetic relationships, and, second, the adaptation, often remarkably precise, of these species, in both structure and function, to their special environment and ecologic relations. Any satisfactory explanation of evolution must explain both of these actually existing phenomena. Both Lamarck and Darwin faced this necessity squarely. As much cannot be said of the mutationists and Mendelians.

Lamarck's explanation is simple and plausible. It bases itself on the familiar fact that plant and animal individuals do become adaptively modified during their lifetime in response to environmental conditions. It assumes that such individually acquired changes or characters are passed on, in some degree, by heredity to the offspring which in turn, granted a similar environment, further change in the same direction and similarly pass on their changes by heredity. So on through succeeding generations, until new types of form and behavior, and increased degrees of adaptation or fitness result.

A plausible explanation, but one wholly dependent on the "inheritance of acquired characters," which, unfortunately, does not seem to happen. Both extensive observation and intensive experimentation unite in shattering this absolutely essential assumption in the Lamarckian explanation of evolution. The germ plasm from which new individuals arise is so distinct from the rest of the body in the parent individuals, so protected from the influence of external conditions or of local changes in other body parts, that there seems to be no means for causing it to produce in its development into new individuals a replica of the local changes suffered by the parent body in its lifetime. And this conclusion, arrived at by modern study of the germ plasm and heredity mechanism, is confirmed by the observed results of completed development. Acquired characters, in the Lamarckian sense, are not inherited.

Darwin's explanation of species change and adaptation is based, like Lamarck's, on both certain observed facts and certain assumptions. Small, spontaneous, fortuitous variations appear in all new individuals born—this is an observed fact—and there is an overproduction of young in every species—another fact. Hence, Darwin assumed that there will be a severe struggle for existence by these young for place and food among themselves and in competition with the young of other species. In the course of this struggle these small variations will play a life-preserving or life-losing rôle, depending on whether in the face of the environment they are advantageous or disadvantageous. Those young which are better, even very slightly better, equipped for this struggle, by virtue of their variations, this "better" being, therefore, in the direction of fitness, will win in the struggle and leave offspring varying as themselves—assuming these variations to be inherited—while the others will be extinguished together with their disadvantageous variations. By cumulation through generations this "natural selection" through the "survival of the fittest" will result in species change and increasing adaptation.

Also a plausible explanation, but weakened, if not shattered, as far as species forming is concerned, by the results of modern biological study, which have shown that many of these small variations are not inherited. They are merely fluctuations around a mean, to which mean the offspring tend constantly to return. Besides, it is asking too much to ascribe a life-or-death-determining value to these minute variations, despite any conceivable intensity of the struggle for existence. Indeed, most of the species differences—let alone the individual differences—among such animals as the insects and others represented by large numbers of species, are of a kind which demand a very lively imagination to be recognized as of life-and-death-determining value. There is a large family of little beetles called ladybird beetles, among which some of the species are distinguished from each other by very slight differences in the number of size or color of minute spots on the wing covers. Similarly many little flies are distinguished by the number and size of small bristles on the back and small differences in wing venation.

One often needs a hand lens to discriminate between them. Now, are these differences, which we have to reinforce our eyes to see, going to decide whether a toad or lizard or insect-eating bird sees and devours, or does not see and devour, individuals of one rather than another of these insect kinds—or, even more fantastic, one individual rather than another, both belonging to one species and differing from each other by even more microscopic variations?

Mutations are larger variations which are undoubtedly heritable. They were recognized by various earlier students of evolution as possible factors in the origin of new species, and were not unfamiliar to plant and animal breeders, under the name of "sports," as the actual beginnings of new races or varieties of domesticated plants and animals. But it was not until the results of the long and painstaking observations and experiments of Hugo de Vries, the Dutch botanist, on the large-flowered evening primrose *(Oenothera lamarckiana)* and certain other plants, were published in 1901, that mutations were seriously considered by any considerable number of biologists as possible chief elements in species forming. Before De Vries, and only ten years after Darwin published the *Origin of Species,* von Kölliker, the great German zoölogist, in criticizing the assumptions on which species forming by natural selection was based in the Darwinian explanation, especially the use of the small fortuitous fluctuations as handles for selection, proposed an alternative theory of species forming by leaps (saltations). These saltations, von Kölliker held, need not be large, but must be changes definite and fixed. Later, Korschinsky, a Russian botanist, outlined in some detail and with greater emphasis a theory of species forming by "heterogenesis" or mutations. Darwin himself referred to certain well-known sports which had given rise to new races of domestic cattle and sheep (hornless Paraguay cattle, short, bent-legged, Ancon sheep; extra long, smooth, straight and silky wooled Mauchamp-merino sheep). And the well-known and now widely spread cattle race called Polled Hereford originated comparatively recently from one or more hornless bulls which appeared as sports in the horned race. But these were all looked on as exceptional cases, playing little part in the general evolution of species.

Since the work of De Vries, and the growing dissatisfaction with the Darwinian explanation, the mutations explanation of evolution has gained a considerable following. But mutations are, so far as much careful observation goes to show, not abundant, nor can they be assumed to be adaptive in character. They may be so pathologic or abnormal as to insure early death to the individual showing them, and to that extent are "selected out." That is, the very bad ones get extinguished, but if not too bad they may persist and really establish a new species. That they actually do this is a proof that it is not merely the fittest which survive: it is just the sufficiently fit that survive. But to explain the extraordinary precise adaptations of orchids and other insect-pollinated flowers to their insect visitors, and the equally extraordinary adaptations of these visitors to their plant hosts, or the remarkable adaptations of parasites, or of protectively colored and patterned butterflies and moths, mutations are simply hopeless.

Then, there is the offered explanation of the origin of new species through hybridization in nature, and the juggling of characters and character combinations in these hybridizations through the Mendelian formula of heredity. This Mendelian inheritance will be discussed in the next chapter, but here again it is only the origin of new kinds of plants or animals, and not adaptations, which are explained—if anything at all in the way of species forming is explained. Thus only one half of the evolution problem is even approached by the Mendelian explainers.

An explanation, more auxiliary than replacing in its character, was especially urged by Moritz

Wagner, an explorer and German naturalist, and by Romanes, the brilliant student and upholder of Darwin, and has been strongly championed by David Starr Jordan, the eminent American zoölogist. This explanation has received much support from field naturalists and students of systematic botany and zoölogy and of geographic and topographic distribution. It is that based largely on the element or factor of isolation, both geographical and physiological. Its special strength lies in its great usefulness to the natural selection explanation. Indeed it seems self-evident to many naturalists that natural selection is impotent as an actual cause of species forming without some effective sort of isolation factor to assist it.

Whenever the individuals of a species move evenly over an area, its members freely interbreeding, the character of the species remains substantially uniform. Whenever freedom of movement and consequent freedom of interbreeding is checked by some barrier or other means, the character of the species is rapidly altered. It is changed even though external conditions seem to be practically identical on both sides of the barrier, and if there is no visible distinction in the original stock on the two sides. Presumably there are differences in the variations which become perpetuated in either group.

If, therefore, individuals of a plant or animal species are able in some way to cross a barrier and are then isolated from the rest of the species, or are segregated in any way so that free interbreeding with the bulk of the species is prevented, a gradual change occurs in the isolated group.

One of the most striking examples of such species and varietal change, accompanying sharp localization of groups of individuals, is afforded by certain land snails of the Hawaiian island of Oahu. The naturalist Gulick, in a classical study of the distribution and changes of these snails which inhabit a series of adjoining but rather sharply separated valleys in the wooded part of the island, has shown that they have become split up into about 175 species, including between 700 and 800 varieties or subspecies. In all cases the valleys that are nearest each other furnish the most nearly allied forms of the snails, while a full set of the varieties of each species presents a minute gradation between the more divergent types found in the more widely separated localities.

Romanes pointed out that such a segregation of a group or groups of individuals of a species can come about by other means than geographic or topographic isolation. Anything that could lead to exclusive or discriminate breeding among certain individuals of a species would result in the isolation of these individuals as effectively as their actual separation from others by a geographic or topographic barrier. Now, there are various influences or conditions that might conceivably bring about such a state of affairs, and some of these have been actually observed to exist. In the case of plants, for example, slight differences in the time of flowering and hence pollination among groups of individuals in the same region might determine a certain physiological segregation of groups within the species.

The evolution explanation by isolation is not without importance, but, as already said, is more of an auxiliary than an independent causal explanation. Without question, isolation is an important factor in helping to effect species modification. But it is a condition, rather than an active force, making for species change.

Many naturalists have called attention to the existence of long series of related plant or animal kinds which show a succession of small gradatory steps along some particular line of modification, these steps being of a character which it is not reasonable to interpret as of selective value. Some of these naturalists have become convinced that the explanation for this condition must be found in some subtle controlling environmental influence or some inherent capacity in the organisms to change in a given direction—or, at least, they say when such change is once begun by reason of some extrinsic influence, there must be some force to keep it up even to a point where it may prove disadvantageous to the more recent and largely modified species and hence be arrested by selection. Many paleontologists, especially, are convinced that this is a common phenomenon, and explain the extinction of various lines of plant and animal evolution on this basis. This phenomenon is called orthogenesis, or development in straight lines, and is explained by assuming the possibility of determinate variation within a given line of related organisms.

Paleontologists see in this orthogenesis and its results the explanation for the extraordinary development in size and character, and final extinction of the great Jurassic and Cretaceous reptiles, dinosaurs, ichthyosaurs, mosasaurs, etc., which were the largest land animals that have ever lived, but nearly all of which became extinct before the next geological epoch (Tertiary). The famous horse series (described in an earlier chapter) with its persistent evolutionary increase in size and functional and structural reduction of toes is another example. So, also, is the classic series of species of the fresh-water snails *(Paludina)* of Slavonia. They extended from Tertiary times to the present, and show a persistent increase in size, addition and roughness of whorls and modification of shape of the aperture. But all these differences follow by such small gradatory steps that one cannot reasonably attribute a selective value to them, and hence cannot accept an explanation of the evolution of these snails on the basis of natural selection.

But this orthogenetic or determinate variation itself calls for a causal explanation. This has led to the rise of two schools of orthogenesists, one of which assumes some as yet unexplained environmental influence capable of setting up and continuing such variation, while the other assumes internal influences which determine this particular kind of persistent variation. It is easy to see, however, that these explanations are confessions of ignorance of evolutionary cause or causes, and readily lead to a form of mysticism which is not conducive to the advancement of a scientific explanation of evolution. In fact, the assumption of determinate variation and orthogenesis has already led to the development and too wide uncritical acceptance of such an evolution explanation as Bergson's *evolution créatrice,* presupposing an internal *élan* in life stuff which compels it to move ever on toward complication and specialization along particular lines. But it must be admitted that the proposal and more or less general acceptance of such semimystic types of evolution explanation is an evidence that the other types such as Lamarckism, Darwinism, and mutations, are not generally satisfactory. The plain truth is, as pointed out at the beginning of this chapter, that a satisfactory causal explanation, or a sufficient number and combination of causes of evolution, has yet to be worked out. Evolution is a fact, obvious to any one who will see it, and accepted by all scientific men; but its explanation is incomplete.

CHAPTER VII

FUNDAMENTAL FACTORS IN EVOLUTION

(Reproduction and Development, Variation, Heredity)

EVEN though the full explanation of evolution is incomplete, certain inevitable elements in it, however it may be formulated, are plainly recognizable. In all the various causal explanations of evolution which have been offered by different men at different times, there figure certain fundamental phenomena and conditions common to all life, such as variation, heredity, segregation, selection, plasticity and adaptive response to environment. Antecedent to any evolution, and even to these fundamental factors in it, there must be life itself, and the capacity of living creatures to reproduce themselves and develop from egg to egg-producing stage.

Students of organic evolution are not necessarily concerned with the actual origin of life. They are concerned with the origin of the great variety of form and manner which life assumes. Yet they cannot help asking themselves, just as all of us ask, the ultimate question: If evolution explains the unfolding and outrolling of life with its myriad variety, what explains the beginning of life? Who, or what, breathed life into nonlife, and when and how was it done? Did life come to this earth from elsewhere in the solar system, as the meteors come? Did the Creator of matter and energy create life as a special act at a special time? Or were the created inorganic matter and energy able to create life some time in their own evolution?

As we trace life down from its manifestation in the form of the highest, most complex living creatures to its character in the lowest, simplest organisms, and at the same time trace inorganic matter up from its simplest or elemental forms to its most complex combined forms, we find a very suggestive approach. Much of the form and behavior, the detail of make-up and activity of the simplest organisms, the microscopic one-celled plants and animals, are determined by familiar physical and chemical laws. Small masses of oil foam made in the laboratory with a viscosity and colloidal structure similar to that of protoplasm, imitate in surprising manner the physical appearance and simple movements of the simplest organisms. The students of biophysics and biochemistry are daily taking some of the mystic "vitalism" out of life.

But nobody has yet made an amœba in a test tube, nor infusoria in a sterilized hay infusion. Pasteur and Tyndall long ago exploded the naïve claims of the believers in spontaneous generation. *Omne* *vivum ex vivo*. It is only life that produces life. The amœbalike bit of oil foam, with all of its realistic imitation of amœba's movements, the most complex molecules created by the organic chemist, with all their identity of chemical elements with protoplasm, are all of that long way from amœba and protoplasm which is measured and defined by the phrase nonlife and life. There is a great gulf between what is living and what is not. And that gulf creates the great question for evolutionists and nonevolutionists alike; the question of the origin of life.

The thoroughly logical evolutionist, or transformationist, who sees the whole world, inorganic as well as organic, with all its present variety of matter and form, as the result of slow continuous transmutation and evolution—a view greatly strengthened by the recent revelations in radioactivity and atomic structure and behavior—simply says, sometime, somewhere, some way, living matter, in its simplest form, arose from nonliving matter, probably in its most complex form. But he has not seen that happening, nor does he attempt to say when, where, or really how, it happened. He does occasionally amuse himself by guessing at possible "hows," but that is chiefly because of the pressure of his consistency.

Variation

But in whatever way living matter, with its capacity for self-reproduction, was, or, possibly, is, produced, it exists. Evolution has it ready at hand. But there could be no evolution of organisms unless this life stuff itself varied in its reproduction. Whether this variation, slight or large, is imposed on reproducing life stuff by the inevitable variability of the conditions under which reproduction takes place—there can certainly be no identity of such conditions in two succeeding instants of time or two different points of space—or whether this variation is something inherent and spontaneous in the complex physico-chemical phenomenon we call life, the observed fact is that such variation does always occur. As I have already said, there are no two animal or plant individuals, whether of different or the same species, whether the offspring of different or the same parents, whether usual twins, or even so-called identical twins, which are alike. This unlikeness begins with their beginning as separate organisms. Variation is a fact. It is the basic factor of evolution. It is a basic element in any causal explanation of evolution.

In Darwin's explanation of evolution, variations, small, spontaneous, fortuitous variations, as well as larger ones called sports, were the building stones with which he began the erection of his explanation of species forming and adaptive change by natural selection. He took these variations as given by nature, and assumed their heritability. He then incorporated into his explanation the further observed fact of overproduction of young by all parents. All parents normally produce either at one time or at scattered intervals more than enough offspring to replace themselves. The female codfish has been known to produce 9,000,000 eggs in one year; the Columbia salmon produces 4,000, and then dies. Some seabirds lay but one egg a year, but they continue to produce eggs for several years. The elephant, reckoned the slowest breeder of all animals, does not begin to produce young until thirty years old, but it continues breeding until ninety, producing an average of six young in the interval.

On the basis of this overproduction, which would lead, should all produced young survive to maturity, to the filling of the sea by codfish and the covering of the land by elephants, Darwin predicated a sharp struggle for existence by the young of any species. This he saw as a struggle among themselves for place and food, a struggle between them and the too many young of other species needing the same place and food, a struggle between them and their predaceous and parasitic enemies, and a struggle with cold, and heat, and wet, and dryness and inclement nature generally. He then assumed that those individuals with variations, however small, that were of advantage to them in this struggle would live to produce more young, while those with disadvantageous, or not so advantageous, variations would be snuffed out. He then further assumed that those individuals that lived would hand on their favorable variations by heredity to their young. Thus he used in his structure of explanation another fundamental phenomenon of life and basic factor of evolution, heredity, to which we shall recur in a moment. Among the young there would be further variation, in both right and wrong directions, with further success in living and reproduction on the part of those with advantageous variations, and extinction on the part of those with disadvantageous variations. So, by cumulation, there would come about a gradual modification of species in an adaptive or fit direction; the "survival of the fittest."

Now variations, which do actually occur and are undoubtedly the basis of evolution, have been the subject of much study among biologists since Darwin's time. They have found out that there is much variety among variations with special regard to their heritability. This is an all-important matter in connection with their relation to evolution. Some are heritable, and some are not. Especially are those spontaneous, fortuitous, small variations on which

Darwin placed so much reliance in building his evolution explanation, not directly inherited in full measure. They turn out to be simply an ephemeral fluctuation of size, of color, of any character at all, around a mean according to the law of probabilities, and are not handed on by inheritance in their own particular degree of variance from this mean.

Further, as already suggested, they are so slight that they seem unable to act as handles for natural selection, even were they directly heritable and thus capable of cumulation. I have studied the variation in color pattern in a species of small ladybird beetle which has typically twelve little black spots on its two red-brown wing covers. Now, among a thousand of these beetles, collected in the spring just after their emergence from pupæ and not yet exposed as full-fledged beetles to all the struggle for existence, there were individuals with no spots, individuals with one spot on each wing cover, individuals with two spots on each wing cover, and so on up to beetles with nine spots on each wing cover, or eighteen altogether. A large majority, however, had the typical twelve spots. Among another thousand collected in the autumn, after a full season's exposure to the struggle for existence, in which struggle the character of color pattern should cut an important figure according to the natural selection explanation of evolution, there were also individuals with no spots, with two, four, and so on up to eighteen spots, and in almost exactly the same proportions as among the spring collection. In other words, although twelve black spots on the red-brown wing covers are the normal color pattern of this ladybird beetle, its individuals may vary materially as regards this conspicuous character and yet come through a season's struggle for existence none the worse for it.

Lamarck, too, depended on variations as the basis of his causal explanation of evolution, but they were not the so-called Darwinian variations. They were rather the differences between offspring and parents which were produced during the development of the offspring by special use or disuse of its parts; by modifications directly induced in the developing individuals by the influence of varying environment, by adaptive reactions to the external conditions of life. These are the so-called "acquired characters" of Lamarck. They were assumed by him to be handed on to the next generation by inheritance, and to be cumulated by further modifications and their inheritance through successive generations until an effective and often most extraordinarily precise adaptation to environmental conditions was reached. It is these extraordinary adaptations which so impress us in any examination of plant and animal life. But these "acquired characters" do not seem to be heritable; they certainly are not in the manner of

Lamarck's conception. Mutilations produced experimentally, like the cutting off of the tails of mice during many succeeding generations, or produced by conformity with some custom, as the binding and deforming of Chinese women's feet, leave no trace in heredity. Valley plants carried up to Alpine gardens and grown there for several generations become dwarfed in size and otherwise modified as the result of the high mountain conditions, but their seeds sown again in the valley produce plants of the usual valley type. I have reared silkworms on a starvation ration and produced moths but half of the usual size, but the descendants of these moths, fed normally, produced full-sized moths.

These nutritional, or climatic, or otherwise environmentally produced changes, these individually adaptive modifications, or so-called acquired characters are not directly inherited. From the days of Weismann, who began the destructive criticism of the reputed instances of such inheritance, up to the very present time, there has been a steady attack on the fundamental assumption in Lamarck's most plausible and attractive evolution explanation—and the Lamarckians have had the losing side. Yet they do not give up. They cling to some of their instances. New experimentalists offer new alleged cases of the inheritance of acquired characters. Even as I write, the Austrian experimentalist Kammerer is exciting anew the hopes of the Lamarckians by accounts of his experiments in inducing changes by environmental influence in the mode of reproduction of various salamanders and in the color of various amphibians and reptiles, with a claimed definite hereditary transmission of these changes in later untreated generations. Also, recently, two American zoölogists of repute, Guyer and Smith, have reported the positive inheritance of certain eye defects induced in rabbits by a toxic serum. The unusually carefully conducted experiments of these men and their elimination of alternative explanations give their claims a very serious importance. Perhaps even more arresting are the claims of Pavlov, the great Russian physiologist, for the direct inheritance of certain conditioned reflexes as the result of his experiments with white mice. He was able to train some mice after 300 lessons to run to their feeding place on the ringing of a bell. But it required only 100 lessons to train similarly the offspring of these mice, only 30 lessons to train their offspring, only 10 lessons to train their young and only 5 lessons to train the next generation. He believes it "very probable that after some time a new generation of mice will run to the feeding place on hearing the bell, with no previous lesson." No matter how many carelessly claimed instances of a modification of a species character by an inheritance of acquired characters can be proved to be uncertain, and thus to be useless as evidence for the Lamarckian explanation of evolution, any single one that cannot be otherwise explained will have a grave consequence in the search for the actual causes of evolution.

There is a great reasonableness and a strong attraction about the Lamarckian explanation of species change and adaptation. If its assumptions could be substantiated it would offer a direct method of adaptive change and it would satisfactorily explain a fact that seems to me to be the strongest logical argument which can still be made for species adaptation growing out of individual adaptation. This is that so many of the species adaptations are precisely identical with those adaptations that are produced in individuals during their lifetime in response to environmental conditions. This situation presents an important problem not yet explained away by the anti-Lamarckians.

But they assume the offensive. They ask how, in the light of all we know about the mechanism of heredity, and about the sharp and early setting off and isolation of the germ cells from the body cells of the parents, the Lamarckians are going to find the means by which their acquired characters can so modify the germ cells that they will produce in the new generation a replica of these changes in the body cells. There is no doubt that anything inside the body or extrinsic to it which can directly affect and modify the germ cells will modify the new individuals. Experiments of various kinds prove this, and it is, besides, something quite in harmony with modern knowledge of the mechanism of heredity. But how the enlargement of the right biceps of a blacksmith, or the callousing of the heel of a barefoot negro, or the storing away of an unusual mass of information in the brain, is going to affect the germ cells in such a way as to cause them to develop into children especially muscled or calloused or educated does not readily appear. Certainly all the new knowledge of the material basis and mechanism of heredity, which has been acquired in the last sixty years, and which is more than we had acquired in all time before, does not reveal how.

Heredity

But there are heritable variations, small ones as well as larger ones, mutations, sports, etc. There is heredity, or the passing on of characters and traits from generation to generation, new characters and traits as well as old. There would be no evolution without heredity any more than without variation. Heredity is a phenomenon as fundamental to life, and as important an element in any explanation of evolution, as variation. If variation is the all-important centrifugal element in evolution, heredity is the all-important centripetal element. Like produces like, although always, always, with a difference. Sometimes this difference is small—the minute variation; sometimes large—sports, saltations, mutations. But larger than the unlikeness is always the likeness. Heredity is more obvious than variation; but both are in evidence in every birth, and both are fundamental factors in evolution.

The modern knowledge of heredity began with the work of Francis Galton in England and Gregor Mendel in Austria in the eighteen-sixties. Galton studied heredity statistically and paid a special attention to the inheritance of human mental capacity and traits. His work was published in well-known scientific journals and in books which had an immediate hearing and influence. Mendel studied heredity experimentally, using garden peas and other plants for subjects, and published his results in the obscure journal of a small natural history society where they lay unregarded until 1900. In that year three famous European botanists, all working independently of Mendel and of each other on experimental problems in inheritance, discovered—each for himself and all three practically simultaneously—Mendel's papers, and made Mendel's work known to the world. Now Mendel, "Mendelism" and "Mendelian inheritance" are names nearly as familiar to biologists as Darwin, Darwinism and Darwinian selection.

On the basis of his statistical studies of heredity, Galton formulated two major generalizations now commonly known as Galton's laws of heredity. They express in summary form average results when a large number of cases is taken into account. The first of these generalizations, which may be called a general law of ancestral inheritance, is to the effect that an individual derives on the average one half of his inheritance from his two parents, one fourth coming from each; one fourth of his inheritance from his four grandparents; one eighth from his eight great-grandparents; and so on, by diminishing fractions, until the sum of this infinite series reaches 1, or the total inheritance of the individual.

He also formulated a second generalization, which he called the law of filial regression. This may be expressed by saying that the children of parents who vary from the mean of the population vary similarly, but to less extent than the parents. "The stature of adult offspring must, on the whole," he says, "be more mediocre than the stature of their parents; that is to say, more near to the mean or mid-type of the general population."

These generalizations or laws of Galton, based on the examinations and statistical treatment of many data, mark a distinct step forward in the study of heredity. But they give us little information about the probabilities of the inheritance of specific characters, and the hereditary make-up of specific individuals. They do not indicate just what special traits we may expect to derive, or may not expect to derive, from the parents, or the grandparents, or great-grandparents; nor do they tell us what will be the hereditary fate of a given individual with a given ancestry. It is precisely that kind of information that we most desire.

Mendelism makes no such broad generalizations as Galton's, but it makes much more precise ones. It does not treat of halves or quarters or eighths of one's whole inheritance, but of the inheritance of specific characters. And it treats of the inheritance expectancies of the offspring of a single pair of parents instead of those of the members of a large mixed population. Mendel's own experiments were made on various varieties of garden peas (and some other plants) which can be freely crossed, these crossings resulting in fertile offspring. Mendel chose for his crossings races of peas characterized by such readily contrasted characters as tall and dwarf stem, wrinkled and smooth seed coats and so on, and fastened his attention to the results of crossing as regards these specific or unit characters. He determined and recorded the outcome for every one of the offspring. He then mated these recorded offspring among themselves and with typical representatives of the races to which the parents belonged, and determined and recorded again the results, as regards the same special characters, for all of the offspring produced by each mating. And so on, for still other generations.

Out of all this experimentation and detailed recording of results came a surprising and important revelation of an orderly and definite inheritance behavior. On the basis of this, Mendel was in a position to state in advance just what could be relied on to happen when the same experiments were repeated. And when Mendel's work was repeated by others the same things did happen. Since then Mendel's results have been strikingly confirmed by other men studying inheritance in other plants, and also in animals and human beings.

Among the outstanding features of the Mendelian conception of inheritance, is the recognition of the body as being made up of a great number of more or less independent unit characters grouped together as a mosaic to form the whole. These unit characters can be rearranged and recombined by crossings, but not destroyed, or essentially modified. One character may be temporarily extinguished as regards bodily manifestation by the presence of a dominating contrasting character, but it persists as a germinal possession, to reappear again as a body character under favoring circumstances. That is, the germinal and bodily possessions of an individual may differ, and it is his germinal rather than his bodily character and history that is of prime importance in understanding and prophesying his hereditary possibilities and those of his offspring. His own mind may be entirely sound but his germ plasm may carry the possibility of feeble-mindedness. Let me illustrate this by recounting some of the details of an experiment in hybridization that I have repeatedly made.

If we make a cross-mating between two silkworm moths of certain different artificially developed races, one of these races producing exclusively golden silk (cocoons) and the other white silk, we shall get a family of about three hundred brother and sister silkworms. When cocooning time comes these will spin, not, as one might expect, pale yellow (color blend) cocoons, nor yellow-and-white blotched (color mosaic) cocoons, nor some golden cocoons and some white cocoons, but all of them will spin golden cocoons like the cocoons of the golden-silk-spinning race to which one of the parents belonged. And it makes no difference whether this parent was the male or the female parent. It is the hereditary trait, golden-silk-spinning, that dominates over the hereditary trait, white-silk-spinning, not one parent over the other. The dominance seems complete, and, as regards physical or bodily manifestation, it is. But let us carry the experiment a step further.

If we mate two of these golden-cocooning offspring of the golden-white cross we shall get a family of silkworms which will *not* all spin golden cocoons, as both their parents did, but three fourths of the young will spin golden cocoons and one fourth white cocoons, and this proportion will be nearly exact. If now, two of these white spinners, which are the offspring of two golden-spinning parents, are mated together, all the offspring produced by them will spin white cocoons, while the offspring of two of the golden-spinning children of the golden-spinning parents will again divide in the proportion of three golden spinners to one white spinner.

That is, although the golden-spinning trait is dominant, in bodily manifestation, over the white-spinning trait, when a pure golden race is crossed with a pure white race the germ cells of the offspring produced by this crossing will still carry the white-spinning trait, which is able again to manifest itself under certain conditions.

Mendel's results in crossing his races of garden peas differing in various contrasted traits were just like these silkworm results. On their basis he offered a theoretical explanation of this behavior which indicates what the conditions are which make the recessive trait appear again after its apparent extinguishing by the dominant trait. And this explanation so well accounts for the happenings that, with some modifications made necessary by post-Mendelian studies, it may be accepted as the true one.

It assumes that hereditary traits are represented in the germ cells by specific physico-chemical [1] determiners, or combinations of them. These are brought together in the fertilized egg cell produced by any mating, pure or cross, and handed on in the male and female sex cells produced by the offspring of the cross, without destroying or materially influencing each other. Although, when two kinds or groups of determiners representing contrasting traits, such as yellow-and-white-silk-spinning or high-and-dwarf stem of pea plant, are in the egg cells, one of these contrasting characters is dominant over the other as regards actual bodily manifestation.

Now, applying this explanation to the pea and silkworm experiments, let us see how it accounts for the results.

When a moth of the pure white-silk race is

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[1] The modern study of plant and animal cells, particularly of the germ cells, shows definitely that these determiners, called genes, are situated in small bodies called chromosomes which lie in the cell nuclei. An elaborate study of the character and behavior of these chromosomes has been made by cytologists, with the result of revealing their enormous importance in the mechanism of heredity.

crossed with a moth of the pure golden-silk race, the offspring will all spin golden cocoons, because golden is dominant over white in the struggle for manifestation. But half of the germ cells of these hybrid golden-silk spinners will carry the determiner for golden, and half the determiner for white. When these golden-spinning hybrids are mated together, the differing sex cells should meet, by the law of probabilities, in the following proportions: male cell carrying golden with female cell carrying golden in one fourth of the cases; male carrying golden with female carrying white, or female carrying golden with male carrying white, in one half of the cases; and male carrying white with female carrying white in one fourth of the cases. Now, the results of these junctures in the fertilized egg cells from which the young develop should be that, in all the cases where golden meets golden, the developing young should spin only golden cocoons and produce sex cells containing only golden determiners. In all the cases where white meets white, the young should spin only white cocoons and produce sex cells containing only white determiners. But in all the cases where golden meets white, the young should spin only golden cocoons (because golden dominates white in bodily manifestation where the two traits meet), but these young should produce sex cells, one half carrying golden and one half carrying white determiners.

That is, although all of the young produced by mating a moth of the pure golden race with a moth of the pure white race should spin golden cocoons, only three fourths of the young produced by a mating of these hybrids should spin golden cocoons. One fourth should spin white, and these whites mated together should produce young spinning only white. But the goldens mated together should produce again a certain proportion of whites, because only one third of these goldens are germinally pure, the other two thirds possessing both germ cells representing white and germ cells representing golden. Which is just what happens.

This is only the beginning of the new-heredity story. In some cases, the first hybridization produces a blend between the crossed characters, because neither character is actually dominant over the other. But crossings of the blend generation result in a breaking-up among the offspring into some (actually one fourth) showing one of the original traits, some (another one fourth) showing the other, and the rest (one half) showing the blend again. The one fourth showing one of the original traits are germinally pure for that trait, and, mated together, produce offspring showing only that trait; and similarly with the one fourth showing the other original trait. But the blends are germinally impure, that is, they produce in equal numbers sex cells carrying one trait and sex cells carrying the other, and, when mated together, they produce offspring, one fourth manifesting only one trait and germinally pure for that trait, one fourth manifesting only the other trait and also germinally pure for it, and one half showing blends and germinally impure.

But it would take too long, and lead us into too much detail, to go on with the story. It is sufficient to affirm that the facts of Mendelian inheritance and their explanation have carried us a long way in our attempts to reach the goal of being able to prophesy, with a high degree of confidence, what will be the specific hereditary outcomes of matings of plants and animals and men in which contrasting specific traits are involved. The principles and the mechanism of Mendelian inheritance are well determined. But the behavior of each trait has to be worked out for each species of plant or animal, or for man. Golden color may be dominant over white in the silk of silkworms; but because we know this, we cannot say that golden is dominant over white in flower petals. It may be in one kind of flower, and the reverse may be the case in another.

The actual determinations can be fairly easily worked out in plants and in those animals susceptible to experiment. In the case of man, however, planned and controlled experimentation is impossible. Here advantage must be taken of unplanned experiment (miscellaneous matings), and of family (genealogical) records which have paid attention to physical and mental characteristics.

Much has already been done in this way. The hereditary behavior of a number of human pathological conditions, like six-fingeredness, web-fingeredness, dwarfism, color-blindness, night-blindness, and the like; and a number of diseases, and especially disease diatheses, as diabetes and Huntington's chorea; and some less important but interesting physical characteristics, as eye color and hair form; and finally, and very importantly, several mental traits, as certain types of feeble-mindedness, have been pretty clearly worked out and found to be typically Mendelian. But only a beginning has been made. And, despite the sweeping claims of the Mendelians, there is undoubtedly much heredity that is not Mendelian in character.

CHAPTER VIII

FUNDAMENTAL FACTORS IN EVOLUTION

(Selection, Segregation, Response to Environment)

Selection

Another fundamental factor in evolution is selection. Various forms of selection have been either actually observed or assumed, such as natural selection, artificial selection, and sexual selection. The first and third of these will always be closely associated with the name of Darwin, for their detailed elaboration as explanations of evolution was Darwin's peculiar contribution to the evolution idea. In fact, the word Darwinism when used by biologists means the natural and sexual selection theories of evolution explanation, and not evolution itself, for which Darwinism is popularly much used as a synonym. Darwin also called wide attention to artificial selection and was undoubtedly much strengthened in his belief in natural selection by the obvious processes and results of the plant and animal breeders.

The essential elements of observed fact and logical induction that go to make up Darwin's conception of natural selection as a causal agent in species forming have been noted in previous chapters (Chapter VI and VII). And I have referred, too, to the fact that most biologists now refuse to believe in its capacity to serve as such agent. But this lack of acceptance of natural selection as a competent cause of the origin of new species must not be confused with a disbelief in the reality of natural selection as a general evolutionary factor, exercising a definite influence on the determination of major lines of evolutionary movement. There is a general—although not unanimous—acceptance of natural selection as that factor in life which accounts for the nonpersistence of too unfit lines of plant and animal evolution. Perhaps it would be sufficient simply to say that only such organisms can exist as are sufficiently fitted to exist under the actual conditions on the earth. The nonpersistence, then, of any others—and it is certain that such others do come into being—may need no further explanation, and the phrase "natural selection" might have, from this point of view, no sufficient meaning to keep itself alive.

However, there is a real place for the idea of natural selection in our understanding of evolution, for it indicates a group of special conditions, incidental to the life of plants and animals and to their arrangement in evolutionary lines, which gives us some understanding of how it is that some lines persist and some do not. A line of gradual development and modification may go on for some time and distance and yet come to a forced ending. The conditions which bring about this forced ending may be summed up under the name natural selection.

Sexual selection as conceived and expounded by Darwin may be roughly defined as a selection in mating brought about by the exercise of a choice by the males or females of an animal species among the varying individuals of the other sex which offer themselves, or are available as consorts. This choice can be made on grounds of superior size, or virility, or striking character, or beauty of color pattern, or loudness or melodiousness of song, or what not else. As a result of this choice in mating, young would be produced inheriting the special characters of the parents. Darwin would thus explain the existence and high development of the striking color pattern and plumes and the curious dancing and mating-time antics of many male birds, and the songs and decorations of many male insects, the females of the same species being plain and quiet.

Such a theory was necessary to account for the numerous cases in which these striking possessions of the males would seem to expose them dangerously to their enemies, a condition not at all compatible with Darwin's assumption in his natural selection theory of a rigorous struggle for existence. Indeed, it was the incapacity of the natural selection hypothesis to account for the various highly developed secondary sexual characters that exist in so many animal species that led Darwin to the formulation of the sexual selection theory.

But this theory faced difficulties in its necessary assumption of a highly developed æsthetic sense on the part of such animals as the insects and birds. Also, in the fact that in most species of animals about equal numbers of males and females occur, so that after all the more beautiful males or the louder singers had been chosen there would still be mates left for all the others, and hence a reproduction of the less adorned as well as the more adorned. But the major difficulty is that much close observation and some ingenious experimentation have failed to substantiate the sexual selection hypothesis. The late Dr. A. G. Mayor, the brilliant biologist in charge of the Carnegie Institution's laboratory in the Dry Tortugas Islands, cut off the strikingly patterned wings from the males of the large Promethea moth, and fastened the plainer wings from females on them. He found no hesitation on the part of the females to accept these males, robbed of their special attractions as consorts, even in the presence of unmutilated males. Other similarly crucial experiments have had similar results.

Darwin's sexual selection theory may be said, therefore, to be largely discredited. It ought, however, to be said at the same time, that no other more satisfactory theory to explain these strange and striking secondary sexual differences which occur in many animal species has yet been presented.

The phrase artificial selection may be used to sum up the methods, or it may also be used to denominate the results of man's work in domesticating and modifying various plants and animals for his advantage. From the standpoint of self-dependence in nature, these changes, especially in the case of animals, constitute usually a sort of retrogression.

It is certain from the records of history, and from ancient pictures and carvings, and still more ancient bones and relics, that man has had domesticated animals for the last ten thousand years. How long before that he made a practice of taming and using and perhaps breeding his animal companions of prehistoric times, we may never know. In the caves where are found the bones and rude implements of early man, that primitive man of the Glacial epoch, there are also found the bones of various animals, but these seem to be the remains of kinds that were either his victims or his conquerors in the raw struggle for existence of those ancient times. However, when the prehistoric Egyptians and Cretans emerged from the Stone Age into the earliest light of history, they appear with cattle, sheep, donkeys and dogs, already fully domesticated.

The domestication of animals is the result of several different factors—and similar factors enter into the domestication of plants. First, there may be the simple capture and taming and using of individuals of a wild species. Then comes the rearing in captivity of young of this species, and the easier taming of these home-reared individuals because of their earlier acquaintanceship with man.

But in this rearing in captivity a new element enters almost at once. That is the choosing, or selection, of certain of these young to be allowed to grow up, and again the choosing among these when grown up of those to be the parents of more young. This selection may be almost unconscious, or it may be made intentionally and carefully, so as to preserve the most desirable individuals and have them give birth to others like themselves. Then there comes the crossing of special individuals, or the hybridizing with other races in the hope of adding or combining in the offspring the desirable qualities of both kinds of parents.

It is easy to see, as Darwin saw, the striking analogy between artificial selection and an assumed natural selection in which man's place is taken by an overproduction of young, and a struggle for existence. But the weakness of the argument for natural selection on the basis of the reality of artificial selection lies in the assumption that the slight variations among the too many young will determine their life or death. In the case of artificial selection, this life or death determination among the young is made by man, using all his powers of discriminating among the slightest differences in individuals. I have seen Luther Burbank, one of whose special qualifications for plant breeding is an unusual capacity for such discrimination, crawling about on his hands and knees among the thousand little seedlings in a plant bed all derived from a single crossing, and selecting the few that he wishes to live and reproduce themselves, while the others go to the bonfire.

It would be interesting to trace, if space permitted, the origin and lines of modification of some of our more familiar domesticated plants and animals. The dogs, for example, undoubtedly the oldest domesticated animals, as they are also the closest and the most nearly universal animal companions of man, and represented now by about fifty breeds ranging in character and size from the tiny toy dogs of Paris that a lady can carry in her muff to the great Danes and St. Bernards that stand three feet high and weigh one hundred and fifty pounds, are believed by most zoölogists to have descended from several different wild species of wolves and jackals of various lands. The house cats, on the contrary, as various and widely distributed as are their present thirty or more breeds, all seem to be descended from a single wildcat *(Felis maniculata)*. It is a native of northeast Africa and was domesticated in Egypt at least 1,300 years before Christ.

The horses of modern times can be traced back to two wild ancestor species, *Equus przewalski*, of northern Asia, from which all the Oriental, Mongolian, Arabian, North African and East European races have sprung, and *Equus caballus fossilis*, or the diluvial horse of Europe, from which the German, Norman, English and West European horses generally have arisen. The existing horses in America have been derived from Europe, although a remarkable series of fossil horses dating back to the beginnings of the Tertiary Age have been found in this country. Remains of horses are associated in Europe with human relics of the Bronze Age, and figures of the wild horse are abundant among the drawings made by prehistoric man on cave walls in Spain and France.

The many races of domesticated cattle also seem to trace back to two sources, the wild banteng (*Bos sondaicus)*, of Java and South Asia, from which are derived the zebus, the old Egyptian longhorns, and many of the races of Europe, such as the Spanish, Albanian, Sardinian, Polish and brown Alpine cattle; and the primitive wild ox of Europe (*Bos* *primigenius*), from which have descended most of the English, North German, and Holland races. This wild species persisted in Germany until the twelfth century, and in Poland up to the eighteenth century. The races of domesticated hogs are also descended from two wild races, the European wild boar (*Sus scrofa*), and another species (*Sus vittatus*) from eastern Asia. From this latter the swine of China and those of the Romans, and indeed most of the European races have descended. The lake dwellers of Switzerland had domesticated hogs, and pig remains have been found with prehistoric relics in Denmark. China has had domesticated swine for thousands of years. The domesticated races of sheep seem to have had three original wild sources, *Ovis musimon* of South Europe, *Ovis arkal* of Western Asia, and *Ovis tragelaphus* of North Africa. Most of our present European and American races come from the second named of these wild kinds. The earliest certain remains of tame sheep appear in the Stone Age. In the Bronze Age, sheep domestication was well developed. The oldest Assyrian drawings picture domesticated sheep, among which the still persisting fat-tailed race appears. The Egyptians had domesticated sheep in the times before the Pharaohs.

Of birds there are domesticated races of doves, chickens, turkeys, ducks, geese, swans, peafowls, pheasants, canary birds, ostriches, cormorants and others. Of these, the doves and chickens are represented by the most varieties. Brown, an English authority on domestic birds, lists more than seventy races of chickens now living, thirteen races of ducks, ten of geese, and eight of turkeys. Of pigeons there must be nearly as many domestic races as there are of chickens. Yet all of them, with their extraordinary variety of crests, and ruffs, and tails and plumage pattern, and all their various special manners, such as tumbling, dancing, and the like, are descended from a single wild species, the common rock dove (*Columba livia*), of Europe, Asia and North Africa.

The domestic races of chickens are by some naturalists also held to be descended from a single wild species, the jungle fowl (*Gallus bankiva*), which ranges from Hindukoosh to the Chinese island of Hainau and through most of the Indonesian Islands. But other naturalists believe that one or two other wild species of fowl are concerned in the ancestry of our barnyard hen. The domestic ducks are derived from the wild duck (*Anas boschas*), and have evidently originated from this ancestor independently both in China and in Europe. The domestic geese seem to have an older origin than the ducks; in fact, geese are probably the oldest of domesticated birds. The ancestor of our races is the wild species *Anas cinereus.* The Chinese races, however, are descended from *Anas cygmoides,* and the early Egyptians seem to have tamed and used the Nile goose *(Chenalopex egyptiaca).*

There are even two species of insects that have a right to be called domesticated animals, namely, the honeybee and the mulberry silkworm. Man has long used the honeybee *(Apis mellifica)* to obtain honey, but only in modern times has the species been the subject of true "breeding." However, already several distinct races have been produced. The bee is native to Europe and Asia, and "wild" honeybees in America are only communities established by wandering swarms from hives, or from other "wild" communities which have descended from such escaped swarms.

The silkworm *(Bombyx mori)* has, on the contrary, been an artificially bred animal for five thousand years, and scores of races, with differently colored and shaped cocoons, exist. The actual wild species from which the domesticated races are descended is not known, but it is most likely some one of the several wild species of northern India. The cocoons of certain of these wild Indian species are to-day still collected for the silk and sold under the commercial name of "Tussoor" silk. The ancient breeding and care of silkworms was mostly done in China and Japan. To-day it is also carried on extensively in France, Italy, Syria and the Levant.

Segregation

Finally, there remain to be considered two other fundamental factors in the life of plants and animals which have a positive influence in helping to determine the lines, or directions, of evolutionary movement. These are the factors of segregation, or isolation, and that of the response of living matter to environment. But both of these factors have been briefly discussed in a preceding chapter, and need for the purposes of this elementary treatise to be only a little further elaborated here.

Under the natural conditions of life, as it exists to-day and has existed for many geologic ages, it is inevitable that a certain geographical segregation of plant and animal kinds should occur. For example, the present flora and fauna of Australia are largely isolated from the floras and faunas of other parts of the earth, and this has a directly determining effect on the possible lines of plant and animal evolution that can exist in Australia. Similarly, although not by ocean barriers, the plants and animals of a desert are segregated more or less nearly completely from other groups of organisms. And this is also true of those of a great forest, or of a great marsh, or of the upper altitudes of a mountain range. The important matter of "associations" of plants or animals, or plants and animals, produced by such geographical, or topographical, or other environmental conditions, is attracting much attention at present; and the evolutionary importance of segregation of groups of plant and animal species is becoming more and more apparent.

But there can be, and often is, a segregation not of species but of individuals of species. A number of individuals of a given species may, by one means or another, escape from their habitual home and thus be forced to mate with each other, without opportunity of mixing with the bulk of the species. This results in a special perpetuation and cumulation of the particular heritable variations possessed by the members of this segregated group of individuals. Such a segregation of individuals can also be produced even within the usual range of a species by special physiological or environmental conditions which bring about a restricted instead of a general interbreeding on the part of certain individuals.

It is this segregation and forced interbreeding of a few individuals in a different environmental setting from that of the bulk of the species which has seemed to some biologists to give "isolation" a considerable importance as a causal factor in the modification of species, or, in effect, in the origin of new species (see Chapter VI).

Response to Environment

The remaining important factor which we should not overlook, is that of the response of life stuff and of individual organisms to their environment. The plasticity of life is notorious. But we are too much given to seeing fixity in individuals and kinds of plants and animals, especially animals. We see more of this plasticity in plants. Differences in nutrition and other environmental conditions so readily affect plants that the botanists even recognize "nutritional varieties" in their classifications of plant kinds. But animals are also extremely plastic, and individuals of a given species can reveal very considerable differences directly traceable to differences in environmental conditions during their development from egg to adult. Dr. Stockard is able to cause certain kinds of fishes to develop with only one eye, or with no eyes, by giving them, during their growth, an environment somewhat different from their usual one. In fact, it is very important for us to hold always in mind the fact that even what may be termed normal development depends not alone on influence of heredity, but also on environmental influences. For the normal development of any individual organism, certain definite environmental conditions, constituting what may be called normal environment, are as necessary as normal heredity.

Without any doubt at all, the plasticity and individual response to environment is a very important factor in evolution. Here we are using the word "environment" in a very generous sense to include the active or limited exercise of body function, use and disuse of parts, as well as external or internal influences or conditions affecting either directly or indirectly the whole individual or special parts of it. It must be confessed, however, that in the present state of our knowledge of heredity, and especially of the inheritance of acquired characters, we cannot understand just how this individual response to environment plays the rôle in modifying species that many of us believe it simply must play. There is undoubtedly a growing belief in the importance, as a fundamental evolutionary factor, of the adaptive response to environmental conditions on the part of individual organisms. And one of the reasons for this is the conviction of biologists generally that the natural selection, mutations and Mendelian explanations of the origin and adaptation of species are insufficient explanations.

Osborn, the paleontologist, and others, have made familiar to us the phrase "the unknown factors of evolution." It is a suggestive and useful phrase. We have yet much to learn before we shall have a full understanding of the fundamental factors and the effective causes of evolution.

CHAPTER IX

THE EVOLUTION OF THE PLANTS

THE plants which grow about my little green cabin in the Monterey pine wood near the Pacific shore are many and various, and they represent a considerable number of the major groups into which botanists conveniently divide all plants in order to indicate the likenesses and unlikenesses among them. But this grouping does more than simply that; it gives a general picture of their relationships, their genealogy, their evolution.

First, starting with the higher types, there are the flowering, or seed plants. They are commonly divided by botanists into two principal classes: those with inclosed seeds and usually well developed, brilliantly colored and variously shaped flowers, like the yellow monkey flowers and dandelions, the blue asters, orange poppies and delicate creamy white fairy lanterns that are all blooming so abundantly now about me; and those with exposed or "naked" seeds, which include our Monterey pines and the various other pines, as well as all the firs and cedars and cypresses and larches and redwoods and other cone-bearing trees. Among the naked-seeded plants, too, are a few strange trees called cycads, of which the "sago palm" of the florists is the most familiar example, as well as the curious maidenhair tree or ginkgo, the sole survivor of an ancient race which was represented by many species in older geologic times. Indeed, the whole class of naked-seeded plants is an older and much more primitive plant group than the flowering plants. It is also much more limited in number of kinds, being represented by perhaps not more than 500 living species to the 100,000 or more of the flowering plants known to exist now. However, some of the conifers have such myriads of individuals, and these individuals are, as great trees, so imposing and important and so useful to us as plant kinds that we are likely to think of them as the crown of plant evolution. Indeed, the greatest plants we know are the cone-bearing ancient Sequoias of the Sierra Nevada in California, represented now by comparatively few individuals, some of which are 300 feet high and more than thirty feet in diameter at the base, and are of an age of 2,000 years and more. In earlier geologic times the Sequoias grew in abundance over most of America and even in the Old World.

But it is really the closed-seeded flowering plants with their manifold kinds, from the tiny and tender white violets in the near-by forest, to the aspiring and hardy alders and sycamores of the stream side, and sturdy oaks of the open hills, which are the crown of plant evolution.

It is among these flowering plants that those marvelous adaptations of stem and leaf and flower and seed, and those extraordinary relations with other plants and animals, reach their culmination. To them belong the strange array of desert plants: the water-storing, leafless cactuses, with their animal-repelling spines and prickles and their minimum of evaporating surface to bulk of body; the small leaved, resin-covered creosote bushes, and the slender-stemmed ocatillas, which swiftly put out tiny leaves in the short rainy season, and let them as promptly wither away when the scanty rains cease. Among the flowering plants, also, belong various pond kinds with special adaptation to aquatic life, like the floating, small-flowered duckweed, the anchored, long-stemmed, flat-leaved, large-flowered pond lilies, and the completely immersed pond weeds with their hidden flowers lacking all petals.

To the more developed of the flowering plants belong those many kinds with strangely shaped and strikingly colored and patterned flowers that are cross-pollinated by insects. The insects, attracted by the scent and colors of the flowers, visit them to gather nectar and pollen, and are compelled by the intricate pattern and shape of the flower cup and ingenious mechanical devices of stamens and pistils to carry a load of pollen from one flower and deposit it in the next similar one visited. The orchids attain the extremest cases of these cross-pollinating devices, accompanied by such specialized conditions that the flowers of some orchids are absolutely sterile unless visited by particular kinds of insects. This means that not only are the plants specially adapted to their insect visitors, but the insects are specially adapted in structure and habit to their flower hosts. When Wallace discovered a great sphinx moth in Madagascar with a sucking proboscis twelve inches long, he prophesied that there would be found in the same region a kind of plant with flower cups twelve inches deep, and his prophecy was realized. In the warmer parts of the United States there grow several species of the plant genus Yucca, showy lilylike plants of which some are grown in gardens. These plants depend for pollination on the visits of a small moth *(Pronuba)* whose larvæ live on the seeds of Yucca. The parent moth lays her eggs in the ovary of a Yucca flower, and then collects a small mass of Yucca pollen and forces it down the central part of the pistil, thus insuring fertilization of the Yucca ovules and consequently a supply of developed seeds to provide food for the moth larvæ. The larvæ do not eat all the seeds, some remaining to produce new Yucca plants. The Pronuba thus generously pays for the seeds eaten by its young!

There are various flowering plants which have developed a parasitic life at the expense of others. A well-known example is the dodder, which twines its leafless stems about other plants, sending suckers into its host, from which it derives all its nourishment. The various species of mistletoe are partly parasitic, but get some of their needed carbon from the carbonic dioxide of the air. Of another type are the carnivorous insect-catching plants, such as the sundew, and Venus's flytrap, whose leaves are modified into traps which catch small insects and afterward digest them by means of digestive ferments not unlike those secreted by the alimentary canal of animals. In the pitcher plants and bladder weed the leaves also trap insects, but there is little digestive effect, the products of the decomposing bodies of the dead insects being simply absorbed by the leaves. Certain tropical trees, especially of the genera Cecropia and Acacia, have developed extraordinary symbiotic relations with certain kinds of ants, harboring colonies of these ants in their hollow stems or thorns, and putting out certain peculiar growths much relished by the ants. When the marauding leaf-cutting Aztec ants come to these trees they are repelled by the friendly ants living in them, and thus their foliage is saved.

But the adaptations of the flowering plants are altogether too numerous and various to be catalogued here. These plants range from minute, almost microscopic, herbs living but a few weeks, to stately trees which outlive man; from plants with soft, succulent stems to those with rigid trunks of the hardest wood; from plants living in salt and fresh water, to those living in deserts or on mountain summits and soil-covered arctic glaciers. In form and habit plastically fitting themselves to all sorts of conditions they yet show a remarkable homogeneity in their essential structure and fundamental manner of life and self-reproduction. They reveal readily their mutual relationship to each other; they show a fundamental identity of form and function through all the changes rung on their basic plan. They are a beautiful example of evolution making variety out of identity.

But we must pass to other kinds of plants, to simpler and older types, for the flowering plants are, as geological time goes, very modern. They did not appear on the earth until the Cretaceous epoch, millions of years after that period known as the Carboniferous, when lower types of vegetation ran riot over the earth and laid down those inconceivable masses of plant remains which we delve now from the earth's crust as coal. In those Carboniferous forests and marshes and land regions there were no flowering plants, even no true conifers. Ferns were the most abundant plants of the Carboniferous Age both as to variety of species and numbers of individuals. Ferns and some strange trees called Lepidodendrids, Sigillarids, and Calamites, whose remains form most of the coal, were the characteristic plants that gave the great swamps of the Carboniferous Age, the age dominated by plants, their peculiar character. There were fishes and amphibians and a few reptiles, but as yet no birds or mammals—and of man, no whisper.

As one moves down the evolutionary ladder of the plants from the true flowering plants at the top, and the conifers forming the next rung below, one comes next to the ferns. They differ from the flowering plants in general structure and characteristic appearance, but especially and most importantly, from the evolutionist's point of view, in the reproductive parts and methods. Although the ferns are land plants—they, with the mosses and liverworts, were the first land plants—they do not produce seeds but spores, and the male germ cells are not pollen grains but motile sperm cells, which must find their way to the female germ cells, or spores, in water. There is an existing genus of fernlike plants called club mosses (*Selaginella*), which shows a remarkably close approach to the seed-bearing condition and reveals undoubtedly the intermediate evolutionary stage between the typical ferns and the lowest seed-bearing plants. And one of the most important botanical discoveries of recent years is that of the fact that in a number of the lowest seed plants fertilization of the ovules is still effected by large motile sperm cells very much like those of the ferns. The plants in which this condition exists are the fernlike cycads and the curious ginkgo, both of which had long been recognized by botanists as being very ancient types of seed plants—they date back to Carboniferous times—and as showing in various ways close resemblances to the ferns. In both of them the ovary and ovules are much like those of pines, and the pollen grain develops a pollen tube as it does in the pine. But this pollen tube carries an accumulation of water and two large motile sperm cells to the female organ. The fertilization and germination of the seed-bearing plants has great advantages over the aquatic method of the ferns. In the first place, a special supply of water is not needed for fertilization, and, secondly, the seed has food stored in it by means of which the young plant is able to make a good start despite the possible absence of an immediate food supply in the ground.

The beautiful bracken and maidenhair ferns which are so familiar to all of us, and which grow abundantly in my near-by cañon, are modern types adapted to the earth conditions of present geologic time. And although there is undoubtedly no such abundance of fern kinds now as existed in the Carboniferous Age, yet the ferns are by no means a dying race. "In some especially favorable regions, such as the higher mountains of Jamaica and in New Zealand," says Douglas Campbell, the Stanford botanist, "the number and variety of the ferns is extraordinary, and they are perhaps the most numerous and conspicuous plants that one encounters. From the tiny filmy ferns, sometimes less than an inch in height, to the majestic tree ferns, raising their magnificent crowns of fronds thirty or forty feet above the ground, every available spot is occupied by a bewildering variety of these beautiful plants. Moisture loving as they are, one finds that they become scarcer in the drier parts of the world, but many species have become adapted to dry regions. For instance, there are a number of ferns found in the coast regions of California, where for months during the long rainless summer they become completely dried up and apparently lifeless, but promptly revive with the advent of the first autumn rains. In the moisture and warmer regions many ferns become epiphytes and grow upon the trunks and branches of trees. These epiphytic ferns are among the most beautiful growths that one encounters in the tropics. A few species of ferns are also aquatic in habit, but the number of these water ferns is small."

Below the ferns, and lowest of the land plants, are the mosses and liverworts. Even more clearly than the ferns, these plants show their origin from aquatic ancestors (algæ) by the character of their reproductive organs. They also lack any considerable development of firm or woody tissues and thus do not assume the upright position common to most of the higher plants, but have a prostrate habit. They send out simple hairlike roots upon which, however, they depend to only a limited extent for their supply of water, as they readily absorb water through their leaves. Most of the mosses and liverworts are small plants growing flat on the ground, although a few liverworts normally float on water. If the water dries up, however, the liverwort settles upon the mud and grows very luxuriantly, the contact with the earth acting apparently as a stimulus. Roots are developed, penetrating the mud, and the plant assumes quite a different form from that of the floating condition. The behavior of these liverworts may perhaps illustrate the first step in the development of the higher plants from algalike aquatic ancestors, and the botanists are undoubtedly justified in looking at them as representing the most primitive of existing green land plants and those which have given rise to all the higher types of plant life.

A curious aberrant group of the lower plants, widespread, showing much variety of form and habit, and second in numbers only to the flowering plants, is that of the fungi, including the mushrooms, puffballs, molds, mildews, rusts, etc. We know nearly 50,000 living species of fungi, all of which agree in their lack of that green coloring matter called chlorophyll, which is so characteristic of almost all other plants and upon the presence of which depends the plant's power of breaking up carbon dioxide and rebuilding organic compounds containing carbon and water in the presence of light (photosynthesis). The chlorophyll-less fungi must, therefore, derive their needed carbon from already formed organic carbon compounds. They are commonly found growing on dead and decaying plant or animal matter or living as parasites on and in animals and other plants. Some of them, notably the wheat rust, corn smut, rye ergot, potato rot, and others, cause great injury to various crops. All fungi, whether living on dead or live organic matter, and whatever their variety of external form, have a fundamental identity of make-up. They consist of few or many ramifying rootlike filaments which penetrate the organic matter and take up food from it, and a number of special filaments which bear spores. These spores may be produced in uncountable numbers, as in the toadstools and puffballs, where they form a mass of whitish powder.

Various types of fungi are familiar to all of us. Bread exposed to warm moist air soon becomes covered with "mold" which is composed of one or more species of fungi, whose floating spores falling on the moist bread have germinated and quickly produced a tangled, webby mass of fine threads. These ramify through the bread near the surface, breaking down the starch by means of the ferments or enzymes secreted by the fungus filaments, and using this broken-down starch as food. Later, special short erect filaments are sent up and from them are given off many minute spores. A mushroom or toadstool as we see it above ground is merely the spore-producing part of the fungus rising quickly at fruiting time from a mass of underground filaments which take up food from the decaying organic matter in the soil. A familiar parasitic fungus is that which often kills house flies in autumn. It causes the dead flies to stick to the windowpane, where each is surrounded by a whitish ring composed of tiny spores. These are shot off from the ends of filaments protruding from the body of the fly, within which the feeding filaments have abundantly ramified and broken down the tissues of the fly for food.

The fungi evidently do not lie in the direct line of evolution from the simplest green plants (the algæ), through the generalized liverworts and mosses and ferns, to the modern, highly developed and specialized flowering plants. They are a sidewise line with a kind of specialization of their own. It is a successful line as evidenced by the host of species and their great variety and wide distribution. And it is probably a fairly recent line, for some of the parasitic fungi occur exclusively on flowering plants and hence must have developed since their hosts came into existence. Very few fossil fungi have been discovered—the habits are against ready fossilization—and these few throw no particular light on the evolution of the group. It is, however, generally assumed by botanists that the fungi are descended from plants containing chlorophyll, although it is conceivable that they represent a series of plant forms which never developed chlorophyll. There are a few fungi, like the water molds, whose resemblance to certain algæ, both in general structure and in method of reproduction, is sufficiently close to suggest a real relationship. The lichens, those curious plant combinations of fungi and algæ living together in a symbiotic or unusual parasitic relationship, constitute a highly specialized group of plants, which are quite outside the general line of plant evolution. It is a successful special kind of adaptation, which involves both fungi and algæ of several different groups.

In our further descent of the evolutionary plant ladder we find ourselves now facing a series of plant groups, all of which are aquatic. We take leave of land plants when we get below the ferns and mosses and liverworts and the aberrant fungi. All of the lowest and simplest plants live in the water or under such conditions of wetness as are nearly equivalent to strictly aquatic conditions. Even in the ferns and mosses we found strong indications, especially in the structure and habits of their fertilizing cells, of their evolution from aquatic ancestors; and our next step down the plant ladder gets us definitely into water. There is no doubt, indeed, that land plants have developed from water plants—just as we shall find in tracing the evolution of animals that they, too, originated as aquatic organisms. In fact, we shall find that both plants and animals trace their ancestry back to a few groups of very simple, one-celled acquatic organisms that are difficult, if not impossible, to differentiate clearly either as animals or plants. They are just simplest organisms from which both great branches of life, plant and animal, developed. Many years ago, the German evolutionist Haeckel proposed founding, for the sake of a discriminating classification of living creatures, a third great branch of organisms called Protista, to include the simplest and oldest creatures representing the evolution of life before it had become definitely differentiated into plant and animal life.

The plants below the mosses and liverworts are called algæ, and are divided into three main groups, known as the red algæ, the brown algæ and the green algæ. The red and brown algæ are almost all marine plants and are familiar to us as the kelp and seaweeds abundant on any ocean shore. I see dozens of kinds of them each time I go down to the near-by tide pools. They mostly live attached by rootlike holdfasts to rocks or shells, although a few, like the famous Sargassum or gulfweed of the Caribbean Sea and South Atlantic, can live as floating masses far out from land and far above the bottom of the ocean. The green algæ, examples of which are the familiar green pond scums, are mostly fresh-water forms, but a few live in the ocean.

The red algæ compose the majority of the seaweeds, but, because of their usually small size and their habit of living in deeper water or under the shelter of the larger brown seaweeds or rocks, are not so well known to casual observers as the brown algæ. A few forms, however, like the Irish moss, which grows where it is exposed to the action of the waves and becomes large, and the smaller, curious corallines, which deposit carbonate of lime in their softer tissue and thus come to look like delicate corals, are familiar to any seaside visitors. The red seaweeds contain chlorophyll, but it is hidden by the red pigment which characterizes most of these rather specialized algæ. A few of the fresh-water forms are, however, greenish or olive or even blackish rather than red.

The brown algæ, owing their color also to brownish and yellowish pigments which hide their chlorophyll, include a number of very large and conspicuous species. Largest and most remarkable of all are the giant bladder kelps of the Pacific coast. These are characterized by a long, hollow axis with fleshy walls, tapering from the smaller end, which is attached to the ocean bed by strong holdfasts, to the swollen bulbous floating end, which is furnished with long, flat, leaflike projections. Some specimens grow to a length of 300 feet or more, thus rivaling in linear dimensions those greatest land plants, the giant Sequoias and redwoods. Sometimes these giant kelps grow in such thick beds as to form veritable offshore breakwaters, as they do at Santa Barbara and near Monterey. Various other brown algæ, like the "devil's aprons" of the New Zealand shore, are broad and flat with tough leathery skin, while yet others, as the curious sea palm of the Pacific coast, growing on rocks exposed to the full attacks of the heaviest surf, resemble small palms in appearance. The bodies of all these brown algæ have a gelatinous tough covering, and are capable of resisting not only the beating of waves but exposure to the dry periods of low tide. They have their own peculiar and necessary adaptations, and though simple in make-up compared with the land plants, are a considerably specialized group.

The green algæ bring us almost to the very bottom and beginning of the plant series. Most of them live in fresh water, but a few live in the ocean, especially on coral reefs in the tropics. Some of these marine forms have fan-shaped, flattened bodies; others are jointed and much branched with the ends of the branches tipped with bright green tufts of hairs looking like the tentacles of the coral polyps. Like the corals, too, they secrete a calcareous skeleton and help to build the coral reefs. Some of them have been found as fossils in rocks as old as those of the Silurian Age. But these marine green algæ are specialized forms and very unlike the simpler fresh-water forms, which abound in ponds and slow streams. Many of the green algæ are unicellular in structure, but some, like the green pond scums, have bodies consisting of chains of similar simple cells floating free in the water. Closely related to the pond scums are the beautiful little unicellular desmids, familiar to microscopists who study the microcosm of a drop of stagnant water.

Usually classed with the algæ, as their lowest types, but by some biologists treated as a separate group of lower organisms probably related to the bacteria, are the so-called unicellular "blue-green algæ." These, together with the bacteria, also one-celled in structure, are known as the fission plants because their only form of reproduction is by simple division of the body into two (or more) parts, each of which becomes a new individual. The blue-green algæ occur in stagnant water or on damp earth and possess chlorophyll and can thus live independently, but some apparently live as parasites or messmates in the bodies of higher plants and animals. Some species have been found in hot springs like those in Yellowstone Park and, like many of the bacteria, are able to endure temperatures fatal to most plants and animals. The bacteria, which include many species, some of which are the cause of putrefaction and of numerous animal and plant diseases, seem to lack a definite nucleus in their minute one-celled bodies, and may be closely related to the very oldest and simplest of living creatures.

But there are other simple organisms that claim this distinction. The one-celled nucleated monera, claimed also by zoölogists as the simplest animals, and the curious slime molds, also claimed by both botanists and zoölogists, are mere naked masses of soft slimy protoplasm, which can move slowly by a sort of flowing of their viscous bodies, and reproduce themselves by simply breaking up into small nucleated bits. The slime molds are terrestrial, but are active only under conditions of dampness, contracting and secreting a protective covering when dryness comes on. The best known of these slime molds live on old tanbark, where they may be found in damp weather on cloudy days or in the shade as slowly moving, light-yellowish soft masses of naked protoplasm.

But of all these simplest living creatures an aquatic group of microscopic, one-celled organisms, called the Flagellata, are the most interesting to the evolutionist, as they seem to be the living representatives of the immediate ancestors of both plant and animal branches alike. They get their name from the delicate whiplashlike flagellæ that project from their minute one-celled bodies and by the lashing of which the microscopic creatures can swim freely about in the water. To them are closely related another group of organisms called Volvocales, which are small colonies of similar cells living in fresh-water ponds or puddles. They are especially significant because they seem to reveal the manner in which many-celled plants and animals have evolved from the one-celled types. These two groups are composed of active, free-swimming organisms, some of which possess chlorophyll, while others lack it. The chlorophyll-bearing flagellates closely resemble many of the simplest green algæ, while the chlorophyll-less species show a close resemblance to the cells of such low animal types as the sponges. It may, indeed, very well be that, as already suggested, from the flagellates have developed, and branched off from each other, both the plant and animal lines of life.

Related, perhaps, to the flagellates, are two groups of microscopic simple unicellular organisms, the diatoms and the Peridineæ, which occur in enormous numbers in the surface waters of the sea —the diatoms include many thousand species. They form the greatest part of the so-called "plankton," or floating life of the ocean, on which all marine animals ultimately depend for food. For all of the smaller animals and even some of the larger ones feed directly on these minute organisms, while the other marine animals feed in turn on these plankton-fed kinds. The diatoms are especially abundant in the colder oceans, and the Peridineæ in the tropical seas. The diatoms secrete delicate and beautifully marked siliceous shells, which, constantly falling to the ocean bottom as their minute makers die, build up great beds. Upheavals of ocean bottoms in various geologic periods have lifted some of these beds to be part of the present land, and in various parts of the world thick strata of this diatomaceous earth or rock have been found.

This swift survey of the major plant groups, arranged in a descending series from highest, most specialized and most recent groups to lowest, simplest and oldest, has, I hope, revealed a glimpse, at least, of the general course of plant evolution and some of the major kinds of adaptations characteristic of it. Various as plant kinds are, and amazing as are some of their adaptations, they show, on the whole, no such extremes of specialization as do the animals. Nor are there as many diverging lines of evolution, nor perhaps more than half as many species, as among the animals. But for this very reason one can see in the plants with perhaps more clearness than in the animals, the outstanding general course of their evolutionary development and the limits of their adaptations.

Plants are different from animals in structure and in physiology; but they are less different than the definitions in the old textbooks would indicate. Most of them are fixed, a general characteristic of plant life; but so are many animals; while some plants, mostly lower aquatic ones, swim freely about. All of them have certain powers of movement, shown by the moving of the protoplasm in the cells, and the "nutation," or twisting movement, of the growing apex. Some of them have twining tendrils; some keep their flower faces to the sun. While in their photosynthetic method of obtaining carbonaceous food from the air, plants do "take in carbonic acid gas and give off oxygen" as stressed by the textbooks, yet they also have a true respiration like that of animals, that is, they take in oxygen and give off carbonic acid gas. And although all of them which contain chlorophyll can and do get food directly from inorganic materials, which animals cannot do, all of the fungi as well as various other higher and lower forms live on already formed organic substances as animals do. Also, if the flagellates and volvocales are animals, as the zoölogists strenuously claim, then there are some chlorophyll-bearing animals which can obtain food directly from inorganic substances.

But most plants do differ markedly from most animals, both physiologically and in structure. The power of photosynthesis possessed by all green plants is, perhaps, the most important and fundamental distinction of plants, as contrasted with animals. Plants are less specialized in their parts and in the interdependence of these parts. Plant cells are usually well set-off from each other by walls; animal cells are not. Although the usual method of reproduction is by means of fertilized egg cells, as in animals, most plants, even the higher ones, can reproduce themselves from other parts of the body. They can regenerate parts, and make new wholes from small pieces. This is true of only a few animals, mostly low in the evolutionary scale. Plants are less individualized; indeed they may almost be looked on as colonial organisms. They are very plastic, and respond individually in very marked degree to environmental influences; a beech tree in the temperate zone may grow to be fifty feet high and have widely spreading branches; in arctic regions or near the top of a high mountain it may never reach more than a few inches in height. The power of individual adaptation in plants is, in general, much greater than that of animals.

Like the animals, many plants have been domesticated by man and greatly modified by changed environment, selection and hybridization, and the distribution of many has been much affected by man. The United States Department of Agriculture maintains a bureau entirely devoted to the search for, and importation and domestication of, foreign plants. Man has played a great modifying rôle in relation to the forests, grasses, grains, edible vegetables, fruits and nuts, and ornamental flowering shrubs and trees. Quite as true is it that these plants have had a large influence on man. Much of the pattern of man's present spread over the earth has been determined by forests and by agriculture; so, although plant evolution has no such intimate relation to human evolution as has animal evolution, nevertheless it has had its influence in determining human evolution, especially that part of it which we call social or societal evolution—a very important part indeed.

CHAPTER X

THE EVOLUTION OF THE ANIMALS: THE INVERTEBRATES

When we speak or hear of evolution, our first thought is likely to be of the evolution of man—our view of the world is naturally anthropocentric. The next thought is of the evolution of the animals—we recognize their kinship to us. And only the last thought is of the evolution of the plants—they stand farthest from us. In the fleeting survey, however, of the evolution of the various groups of organisms, begun with the last chapter, I have, for various reasons, arranged the consideration of the evolution of man, the animals, and the plants in inverse order to that of our interest. One reason is precisely that of this relative difference in our interest in human, animal and plant evolution. By taking up the plants first we avoid too much self-interest, too much prejudice, perhaps. Another reason is that the plants have gone less far, less widely, and less variously in their evolution than the animals, and we are, therefore, rather easily able to comprehend the general course of their evolution. Thus, we gain a certain amount of confidence in our capacity to trace evolutionary lines, a confidence that we need more and more as we approach the almost baffling evolutionary complexes and extremes met with in the higher animals and man.

Just as the plants are divisible into two great groups, of different evolutionary rank, namely, the higher, or flowering plants, and the lower, or flowerless plants, with some uncertain and perhaps linking forms on the border line between them; so the animals are divided into the two major groups of vertebrates, including the higher forms, and invertebrates, which include a great host of lower kinds, some, however, of extrème and very successful specialization. It is of interest to note that the higher group of plants, the flowering kinds, contains nearly as many living species as all the various groups of flowerless plants together, while among the animals the higher vertebrates are greatly outnumbered by the lower invertebrate kinds. Indeed, the class of insects alone includes nearly three fourths of all the known living animal species.

Although recognizing the plants as a group inferior in specialization and general evolutionary rank to the animals, we must not think of the plants and animals as constituting a linear evolutionary series, the lower animals rising from the higher plants. The plants and animals constitute two separate, or, better, divergent lines of evolution, which arose from simple, generalized, common ancestors in the early history of the earth. For just as the lowest plants are aquatic, motile one-celled kinds of very simple structure and behavior, so it is, also, among the animals. Indeed, as we have already noticed, there are at the bottom of the plant and animal ladders a considerable number of living kinds of organisms which are claimed by the botanists as the simplest plants, and by the zoölogists as the simplest animals, or are looked on by less self-interested biologists as constituting a separate ill-defined group of primitive organisms in which the two great living kingdoms of plants and animals find a common origin.

The simplest animals comprise a large and various group called the Protozoa, and are almost all microscopic in size. The bodies of most of them are composed, for their whole lifetime, of but a single cell. A few, however, sometimes called colonial Protozoa, have the body made up, for a part of their life, at least, of from a few to many similar cells, some of which may become modified to form special germ cells. But even in these colonial Protozoa there is no organization of cells into tissues or organs. By cell is meant simply a small unit bit of protoplasm, with a nucleus that is also protoplasm, but of somewhat different character from that of the rest of the cell body. The single cell of some protozoan bodies, as those of Amœba and similar forms, is quite naked, and has no more definite shape than has a droplet of any thick viscous substance. In others, the protoplasm forms a thin but firm outer covering, or even secretes a tiny calcareous or siliceous shell, which give the little creatures a definite fixed shape. These shell-secreting Protozoa remind one, by this character, of the diatoms (one-celled plants with siliceous shells). Like the diatoms, also, they occur in immense numbers in certain ocean regions and their shells accumulate on the ocean bottom in thick beds of great extent, some of which have been upheaved in past geologic times to form part of the earth's crust. The great chalk beds and cliffs of England, France, Greece, Spain and America are composed of countless numbers of tiny shells of lime-secreting Protozoa, while the rock called Tripoli found in Sicily, and the Barbadoes earth from the island of Barbadoes, are composed of the minute siliceous shells of other ancient Protozoa.

Although the one-celled Protozoa have a body of great simplicity compared with that of any of the many-celled animals—our own bodies have been estimated to contain about three trillions of cells—the single cell body of some of these Protozoan bodies shows a good deal of differentiation and specialization. In amœba and other similar generalized forms any part of the tiny naked protoplasmic body can do what any other can, that is, help in locomotion by slowly flowing out into temporary fingerlike projections (pseudopodia), take in food by flowing around it, digest this food, secrete wastes, breathe, and take part in reproduction, which consists simply in the dividing of the body into two parts (as in the fission plants). But in the more specialized Protozoa the body has a fixed shape, with a definite number of projecting flagellæ, or cilia, for swimming organs, a definite mouth opening and an opening for discharging waste, special contractile parts, and an accessory nucleus besides the regular larger one. Also, reproduction may involve the permanent or temporary fusing of two individuals before division takes place.

The first step in the evolution of the many-celled from the one-celled animals is illustrated by the make-up of those interesting small creatures called volvocales, which are common in fresh-water ponds, and are claimed by botanists as the simplest multicellular plants, and by the zoölogists, under the name of colonial Protozoa, as the simplest multicellular animals. There are several kinds of these interesting links between strictly one-celled and true many-celled organisms, but all agree in having a body composed of a few (sixteen or thirty-two) to many similar cells which hold together (usually in a gelatinous envelope) in a flat or spherical group, until the time for reproduction arrives. Then each cell divides into a small group of daughter cells (new colony), or a few of the cells become modified to act as quiescent egg and active sperm cells while the rest of the cells die, thus ending the old colony. Each of the cells of the old colony is like every other cell and can do what any other cell can do, at least until the time for reproduction comes. Each one of these colonies is thus an independent organism, with its make-up resembling, in its essential character, that early embryonic stage in the life of all many-celled organisms which is produced by the repeated division of the fertilized egg cell.

From the one-celled and colonial Protozoa the first step up the existing evolutionary animal ladder brings us to the sponges, the least complex of all the strictly multi-cellular animals. They possess so little differentiation of cell character and such a lack of individualization that they are hardly more than larger, and somewhat more complex, colonial Protozoa. The body contains no such systems of organs as characterize the higher animals; there are no heart, no lungs, no alimentary canal, no nervous system, or eyes or ears or other organs of special sense, no organs of locomotion. It is simply an aggregate of cells, arranged in two layers, with a gelatinous substance between them in which protoplasm ramifies and a number of separate cells lie. The whole is supported, usually, by a skeleton of horny fibers or siliceous spicules. It is of a simple vase shape, or of hardly any definite shape at all, without front or back, right or left, growing attached to a rock or shell in the ocean, or, in the case of the few fresh-water kinds, to a stone or piece of wood in pond, river or canal. There are numerous small openings scattered all over the body surface, lined by cells with waving flagellæ, and a single larger opening at the free end of the body. By the waving of the flagellæ, currents of water are drawn into the small openings, bringing oxygen to be breathed and tiny organisms to the cells to be captured and digested. These cells also give up carbon dioxide and food wastes to the water, which passes from the lateral openings into the central cavity or cavities of the sponge and on out through the large opening at its free end. The one necessary condition for the life of a sponge is the streaming of water through its body.

The sponges reproduce themselves, both sexually by fertilized egg cells, and asexually by small budded-off groups of body cells which either swim away, become attached to a firm object and grow into a new sponge, or remain attached to the mother body and develop there, thus producing an irregular colony with the general appearance of a branching plant. In the sexual mode of reproduction, male and female germ cells are developed in the same individual, and the motile male cells swim about in the canals and cavities of the sponge body until they find the egg cells, which they fertilize. The fertilized egg cells then begin to develop and pass through their first stages in the sponge body. Finally the embryo sponge, which is usually a tiny oval mass of similar cells, with cilia on the outer cells for swimming, escapes from the body of the parent into the outer water where it swims about for some time, then comes to rest on the ocean floor and attaches itself to some rock or shell, and begins to take on the form and character of the parent, leading, from this time on, a fixed sedentary life.

"Sponges," as most of us know them, are merely the horny sponge skeletons of a few species. But other sponges are found in almost all oceans, from the tide lines to the greatest depths, and vary in size from a small fraction of an inch to a yard in height. They may be reddish, purple, orange, gray or even bluish in color. The horny sponge skeletons, which are the sponges we use, all belong to a few species which grow in the Mediterranean and Red seas and along the coasts of Greece, Asia Minor, Africa and the Bahama Islands.

The next step is to a large branch of animals which includes the polyps, corals, sea anemones and jellyfishes. Most of them live in the ocean (a few in fresh water) and, like the sponges, are fixed in the adult stage, and somewhat resemble plants in general appearance, hence the name "zoöphytes" (plant animals), given them by earlier naturalists. The jellyfishes, however, and the young polyps, which are jellyfishlike in make-up, swim about freely. Along any seashore we can see members of this great animal group. In some of the tide pools near my cottage there are hundreds of sea anemones of various kinds, some of them very beautiful. And after every storm at sea the cast-up, soft, gelatinous bodies of jellyfishes, from tiny "umbrellas" of half an inch to great ones two feet or more in diameter, strew the beach.

The sea anemones and polyps have a body shape and structure something like that of the sponges, but more definite, more differentiated and specialized, and more individualized. The body is a short thick tube, composed of two distinct cellular layers, separated by a thin noncellular membrane. It is attached by its base to some rock or firm object, and has a large opening at its free end surrounded by a circlet of sensitive contractile tentacles which seize objects of food and thrust them into the interior of the hollow body. The numerous small lateral openings of the sponge body are missing, water and food entering the body, and water and wastes leaving it, by the one hole at the upper end.

The exquisite jellyfishes, or medusæ, have the body in the general form of an umbrella or shallow bell. Around the edge of this bell are set numerous threads or tentacles with stinging cells (corresponding to the circlet of tentacles in the polyps and sea anemones). The mouth opening is at the middle of a longer or shorter projection which hangs down from the middle of the underside of the umbrella. The body cavity extends out into the umbrella-shaped part of the jellyfish, usually as a series of canals radiating from the center, with a connecting canal running around the margin of the umbrella, all forming a sort of special digestive cavity.

In both the polyps and jellyfishes there are the beginnings of cell specialization into muscle and nerve and stinging cells, and the beginnings of special organs, such as simple sense organs and digestive canals. Reproduction is carried on much as in the sponges, that is, both asexually by budding, and sexually by the fusion of quiescent egg cells and motile sperm cells produced by the same adult individual. But the process of reproduction and development of new individuals is carried on in more specialized manner than it is in the sponges. Some of the polyp buds develop into jellyfishlike bodies (medusæ) which swim away from the parent body and later produce both egg and sperm cells. After fertilization, the egg cell develops into a free-swimming larva called a planula, which resembles neither a jellyfish nor a polyp, but later becomes attached and develops into a polyp. With many polyp kinds the young polyps, and even also the young medusæ, remain attached to the parent body and, like the sponges, produce a colony. But this colony may show a considerable variety among its adhering individuals. The most specialized of these polyp-medusæ colonies are the extraordinary floating colonial jellyfishes, like the marine "Portuguese man-of-war" which appears as a delicate bladderlike float, usually about six inches long and brilliant blue or orange in color, bearing on its upper surface, which projects above the water, a raised particolored crest, and on its under surface a tangle of various thread-like appendages bearing grapelike clusters of little bell- or pear-shaped bodies. Each of these parts is a modified polyp- or medusa-zooid produced by budding from an original central zooid.

In these colonies we find an extraordinary condition. They are made up of many polyp and medusa individuals, each of which sacrifices all its functions except one which it performs for the whole colony. Thus, some individuals serve as swimming organs, some as feeding organs, some as sense organs, some as stinging organs, and some as reproductive organs. But each one originates as a distinct individual and not as a single part or organ of an individual.

Some of these colonial polyp-jellyfishes have for a central zooid a long upright tube with hundreds of variously shaped parts attached around it. The upper end of the tube is enlarged to form an air-filled chamber, a saclike boat, by means of which the whole colony is kept afloat. Around the central stem are many delicate bells, the opening and closing of which make the whole colony swim through the water. Each swimming bell is a modified medusa-zooid, without tentacles or digestive or reproducing organs, but retaining simply the function of swimming. Below the swimming bells, at the lower end of the central stem, are grouped many structures presenting at first sight a confusion of variety and complexity, but on careful examination revealing themselves to be polyp- and medusa-zooids modified to form at least five kinds of functioning structures. There are many flattened scalelike parts whose function is simply that of affording a passive protection, in times of danger, to the other structures. These protecting scales are greatly modified medusa-zooids, each consisting of a simple cartilage like gelatinous mass penetrated by a food-carrying canal. Under these broad leaves are a number of pear-shaped bodies which have a wide octagonal mouth opening at their free end and possess in their interior certain digestive glands. Each one is provided with a very long flexible tentacle which bears many fine stinging threads. The tentacle waves back and forth in the water, and on coming in contact with an enemy or with prey its poisonous stinging threads shoot out and paralyze or wound the unfortunate animal. These pear-shaped bodies are the feeding organs, each being a modified polyp-zooid. Scattered among these dangerous structures are many somewhat similarly shaped but wholly harmless structures, the sense organs. Each of these, too, has a pear-shaped body, but without mouth opening, and also a long, very sensitive, tentaclelike process. The sense of feeling is very highly developed in the tentacles, and they discover for the colony the presence of any strange body. These sense structures are modified polyp-zooids. Finally, there are two other groups of structures, usually arranged in grouplike bunches of grapes, which are the reproductive structures, male and female. They are modified medusa-zooids grown together, and without tentacles.

This whole colony, or this compound animal, floats or swims about at the surface of the ocean, and performs all of the necessary functions of life as a single complex animal does. Yet it is, in truth, a community in which the hundreds of parts are different individuals all of one species. It is, in effect, the same kind of communal life, with a differentiation of labor and specialization of structure among the community individuals, as is revealed by those familiar communal animals, the termites, social wasps, bumblebees and honeybees. In these insect communities, however, the individuals are all separate, while in the colonial polyp jellyfishes they are all fastened together. They are fastened together so closely, and so in the manner of the various organs of a single complex individual, that it is only by a study of the origin of each part that we find that it is, in reality, a single, much modified polyp or medusa individual.

Thus, in this great branch of lower animals, made up of the polyps, corals, sea anemones and jellyfishes, we find the plain beginnings of a specialization of cells and of simple organs and also an example of colonial, or communal life. And we find these animals, although possessing their own peculiar specializations and adaptations, clearly standing in the general evolutionary line toward the higher animals which we have seen to begin with the one-celled and colonial Protozoa, and advance through the generalized sponges to the more specialized sea anemone and polyp type. But from here on we find no such clear single line of evolution. The other great branches of animals, although showing in the character of their most generalized members enlightening indications of such a line, are so divergent and reach such extremes in their own peculiar development that they can hardly be arranged in any straight linear series. The arrangement must be of a pronounced tree-branching character.

The branch of animals which is usually treated in the zoölogical textbooks, next after the polyps and jellyfishes, is that of the echinoderms, which include the starfishes, sea urchins, sand plates, sea cucumbers and feather stars. They are all marine, the starfishes and sea urchins being among the most familiar animals of the tide pools, and are all, except the feather stars, not fixed but able to move freely, although only slowly, about. These feather stars are the living representatives of the crinoids, those widespread and abundant echinoderms of earlier geological ages. They differ from all other members of the branch in being fixed either permanently or for a part of their life, being attached to rocks on the sea bottom by a longer or shorter stalk, which is composed of a series of rings or segments.

The body shape of the echinoderms varies from the flat, rayed body of the starfish and the thin disc of the sand plate, to the thick, flattened egg-shape of the sea urchin, the melonlike sac of the sea cucumber, and the delicate, many-branched head of the feather star, with its supporting slender stalk attached to some firm object. But in all these shapes we can see, more or less plainly, a symmetrical radiate arrangement of the body. For there is always a central portion from which radiate separate arm- or branchlike parts, or about which are arranged radiately the internal body parts; although the external appearance may, at first sight, give no plain indication of the radiate arrangement. The radiating parts of the body are usually five. There is a certain degree of radiation in the body structure of the sea anemones, polyps and jellyfishes, and it is possible that the echinoderms have derived and further developed this radiate condition, so characteristic of them all now, from an ancestral polyplike type of generalized radiate character. But there is little else in the echinoderm body to suggest the polyp, or jellyfish type of structure.

All the echinoderms have specialized cells and tissues and well-developed systems of organs. They are far above the sponges and polyps in degree of specialization of these tissues, organs and organ systems. They have, for instance, a well-developed digestive system, with mouth, alimentary canal composed of esophagus, stomach, intestine, cæca and special glands secreting digestive fluids and an anal opening. This alimentary canal is not, as in the polyps, simply the body cavity, but it is an inclosed tubular cavity lying within the general body cavity. There is a well-developed nervous system consisting of a central nerve ring around the esophagus, and branches radiating from it into the various radially arranged arms or regions of the body. There is no brain as in the higher animals, but the central nervous ring contains nerve cells as well as nerve fibers. The only sense organs are special tactile or touch organs in all the members of the branch and very simply composed eyes or eyelike organs at the tips of the rays of starfishes. Some of the echinoderms breathe simply through the outer body wall, taking up, by osmosis, the air mixed with the water in which their bodies lie, but some have very simple, special gill-like respiratory organs. There is also a distinct circulatory system, but the "blood" which is carried by this system and which fills the body cavity consists mainly of sea water containing a number of amœboid blood cells. There is no organ really corresponding to the heart of the higher animals. There are distinct organs for the production of the germ or reproductive cells, and the sexes are distinct (except in a few species). All the echinoderms (except some of the feather stars) have organs of locomotion and well-defined muscles to move these organs, which are short flexible processes called tube feet. The spines of the sea urchins also help in their locomotion.

Differing from that of the sponges and the polyps and jellyfishes, the reproduction of the echinoderms is always sexual. Young or new individuals are never produced by budding, or in any other asexual way, although most echinoderms have the power of regenerating lost parts, even to such a degree that some starfishes can regenerate all the rest of a body from a single ray with a bit of the central disc. The new individual is always developed from an egg produced by a female individual and fertilized by the sperm of a male individual. The eggs are very small (about 1-50th inch in diameter in certain starfishes) and are fertilized by the sperm cells after leaving the body of the female. That is, both sperm cells and egg cells are poured out into the water by the adults, and the motile sperm cells in some way find the egg cells and fertilize them. From the eggs hatch tiny larvæ which do not at all resemble the parent starfish or sea urchin. They are active, free-swimming creatures more or less ellipsoidal in shape, and provided with cilia for swimming. Soon the body changes form and takes on a curious shape with prominent projections. From these larval stages the adults develop by changes, or metamorphoses, as striking as those of the butterflies and moths.

Of a markedly different general plan of body are all those mostly small and extremely various lower animals which the older naturalists lumped together in one great heterogeneous branch called the articulates; that is, animals with jointed bodies, such as the earthworms, leeches and other worm kinds, and the crabs, crayfish, centipedes, insects and spiders. Although modern naturalists break up this miscellaneous group into several branches, the older classification stresses their common possession of a segmented body. There is, however, a great variety of appearance among them. In the more specialized forms the segments may be so fused and modified that they are recognizable only in the younger embryological stages, but in such forms as the earthworms and tapeworms, the crayfish and lobsters, the centipedes, scorpions and simpler insects, the successive body segments are plainly visible all through life. There may be many of these segments and, except for the head and perhaps the hindmost segments, they may be much alike, as with the earthworms and centipedes. Or, they may be very few and mostly different from each other in size and shape, as with the more specialized insects and the spiders.

Corresponding to the general segmentation of the body is the segmental arrangement of external mouth parts, legs, wings and organs of special sense (feelers, eyes, etc.), which are attached, usually in pairs, to various segments. The legs may be many, or few, or none. The wings, which occur only in the insects, are never more than two pairs and, like the three pairs of legs possessed by most insects, are attached to the segments of the middle (thoracic) part of the body, these locomotory organs thus being concentrated about the body's center of gravity. The internal organs and organ systems are (except in the case of various degenerate parasitic worms) well developed and also show a distinct segmental and symmetrically bilateral condition. The more compact the body, and fused its segments, the more concentrated and less obviously segmented are the various organ systems. The general evolutionary line of specialization among the segmented animals is from an elongate, slender body, composed of many similar segments with many pairs of similar external segmental appendages and distinct repetitive segmental arrangement of the internal organ systems, to a short, compact body, composed of a few much modified and closely fused segments with few pairs of external appendages and strongly concentrated internal organ systems, with little repetition of parts. From centipede to house fly illustrates this evolutionary line.

These segmental animals show different special lines of evolution. Present-day knowledge of these diverging lines is indicated by the modern classification. This breaks the articulates up into five branches of worms and wormlike animals, and one very large branch including the crustaceans, myriapods, insects, and spiders, mites and ticks. Some of the wormlike groups are perhaps not fundamentally articulate in structure and hence should not be included in the general evolutionary line of segmental development. In the branch with the crustaceans, myriapods, insects, and spiders, and forming an interesting sort of link between them and the segmented worms, is a small group of wormlike animals called slime slugs, which show in their make-up a combination of characters of the segmented worms and the myriapods, which in turn connect closely with the simpler insects.

In the branches of flat worms and round worms there are many kinds which live as external or internal parasites on other animals, and which have developed extraordinary adaptive specializations both of structure and habit, to fit themselves specially for parasitic life. Much of the structural specialization of these parasites is along the line of degeneration, loss of parts (locomotor and special sense organs, etc.), and a retrogression toward simplicity of body make-up. This is a simplicity by specialization, however, and not by generalization; a lack of complexity, not original but acquired by evolution. Not all evolutionary movement is advance toward higher forms and higher powers; it may be toward acquired simplicity and degenerative conditions. But it is still evolution toward fitness. The parasite is often among the most fit of creatures; it is fit for its particular mode of life. But it is such a specialized and canalized kind of life that in the event of a catastrophe to host species the parasite species also faces catastrophe. It cannot change back or away from its too complete adaptation to just one set of living conditions.

It seems absurd to pass by the great insect class without even a reference to the amazingly many and various examples of evolutionary development and adaptation it presents. Greater in number of kinds than all the other animals put together, almost all the changes conceivable are rung by the insects on the basic motif of a single fundamental type of form and physiology. Adapted for life in the air, the water, the soil, the trunks of trees, the leaves of plants, the bodies of other insects and animals, feeding on leaves and fruits and seeds or hard wood, burrowing into animal flesh, eating feathers and hair, sucking plant sap or blood, taking food through a mouth, or simply through the skin, having wings and legs or no wings and no legs, clad in all the colors and patterns of a kaleidoscope, and showing such examples of protective coloration and mimicry as are to be found nowhere else in the animal kingdom, the insects, abundant in species and individuals, with long series of continuous small gradations from species to species, and yet attaining large differences and great evolutionary distances, offer a most fertile field to the student of evolution. But we cannot enter it here. In a later chapter, however, we shall have opportunity for, at least, a brief account of insect instinct. It is, above all, among insects that instinct reaches its greatest diversity and highest development.

Still of another body plan are the mollusks, constituting the last great branch of invertebrates, and including the mussels, clams, oysters, snails, slugs, cuttlefishes and octopuses, and all that host of animals we call "shells" or shellfish. We know them familiarly only by the houses which they make, live in, and leave at death to tell the tale of their existence. The variety in form, colors and markings of these shells indicates the great diversity among their makers. They live on land, in fresh water and the ocean. No depths of the ocean abysses are too great for the octopuses, no coast is without its many shells, hardly a pond or stream but has its mussels and pond snails, and in all regions the land snails and slugs abound.

The mollusks are not to be mistaken for any other of the lower animals; they have a structure peculiarly their own. In them the body is not articulated or segmented as with the worms and crabs and insects, nor radiate as in the starfishes and sea urchins, nor plantlike as with the sponges and polyps. Where the typical molluskan body is well developed, it is composed of four principal parts: a head, with the mouth, feelers, eyes and other organs of special sense; a trunk containing the internal organs;

a foot, which is a thick muscular mass not at all foot- or leglike in shape, but which is the organ of locomotion by means of which the creature crawls; and a mantle, which is a fold of the skin inclosing most of the body and which produces the shell. Such a typical molluskan body is possessed by most of the snails. But in most of the other mollusks one or more of these four body regions are so fused with some other region as to be indistinguishable. In the mussels and clams the head is not at all set off from the rest of the body, the cuttlefishes and octopuses have no foot, and the slugs have no shell.

The internal organs and organ systems are well developed. The nervous system includes a brain, and the circulatory system has a pulsating sac composed of two or three chambers which can fairly be called a heart, and there is a well-defined closed system of arteries and veins. Especially in the development of their circulatory system do the mollusks stand above all other invertebrates.

Reproduction is always sexual. In most species the young mollusk on hatching from the fertilized egg does not resemble the parent, but is a free-swimming larva which must undergo a considerable metamorphosis before reaching the adult stage.

In this respect the mollusks are like the echinoderms and many of the articulate animals, notably the crustaceans and most insects. It seems probable that this marked metamorphosis in the course of development often accompanies, and is an indication of, a high degree of specialization or divergence from the ancestral generalized type of the group. In such cases the larvæ, unless too highly modified adaptively to meet immediate needs, should give some idea of the group ancestor. For example, the caterpillar of a moth or butterfly, although itself much modified so as to meet the immediate conditions of life it faces, undoubtedly represents in some degree the segmented wormlike ancestors of the insects. The winged butterfly has come such a long distance from its wormlike ancestor that we ordinarily would never connect the two. But if we wish to visualize the far ancestors of the butterflies we have but to look at their caterpillars. What an interesting revelation of evolution at work!

CHAPTER XI

THE EVOLUTION OF THE ANIMALS: THE VERTEBRATES

ALL the thousands of animals of the great branches we have so far referred to agree in being invertebrates, creatures without a backbone and the rest of that internal bony skeleton characteristic of the vertebrates. These latter, which include the familiar classes of fishes, amphibians, reptiles, birds and mammals, we call the "higher" animals, to distinguish them from that long and confusing array of smaller creatures of sea and land which are conveniently lumped together as "lower" animals. That the higher animals have arisen by evolution from the lower ones is proved by such a mass of evidence that all biologists accept such origin as a fact. But from what particular branch or group of invertebrate animals the vertebrates have arisen is still a matter of question.

But before we reach the true vertebrates we find a few odd kinds of marine creatures, simpler in structure than the vertebrates, but yet associated with them by modern students of classification. They group them with the vertebrates to form a branch called Chordata, so called because of the notochord characteristic of all of them. This notochord is an internal, slender, gristly rod which extends the length of the body along the back and serves to support the nervous system. It is present in the young of all vertebrates, being replaced in older stages by the more highly developed cartilaginous or bony jointed backbone, but in the lowest Chordates it persists throughout life; no vertebral column is formed. In a small, delicate, almost transparent, fishlike animal called the lancelet, or amphioxus, the notochord persists throughout life, and is the only internal skeleton possessed by it. In the lampreys, a group of larger eel-like animals, the notochord also persists through life, but these creatures have a cartilaginous skull at its anterior end. Both the lancelets and the lampreys are classed by some biologists with the fishes, as the lowest members of the group, but by others they are classed as independent profish forms.

The lowest Chordates are certain curious marine creatures, called sea squirts, or ascidians. They have leathery, saclike bodies, and live singly or in colonies, or even so closely associated as to form a sort of compound animal. We might expect them to show such traces of their invertebrate ancestry as would indicate from which of the lower invertebrate branches they have arisen; but they are so degenerate in structure that they give no satisfactory clues to their evolutionary origin. This degeneration is due probably to the fact that although they are active tadpolelike creatures when hatched, they mostly soon become attached to rocks or shells, and take on the simple saclike form characteristic of their adult condition.

The lancelets, of which only about ten living, rather widely scattered, species are known, are only from half an inch to four inches in length and live chiefly in sand, in warm seas. Heretofore, they have been looked on as rather rare animals, but recently one species has been discovered to exist in great numbers in a limited region of the China coast. Although they have a well-developed cartilaginous notochord running from head to tail, with a nervous cord above it, inclosed in a special membranous sheath, they have no skull or brain. The mouth is a mere vertical slit without jaws. The circulatory system is fishlike, with closed blood vessels, but there is no heart, the blood being driven about by the contraction of the walls of the vessels. Along the edge of the back and tail is a rudimentary fin, but there are no paired lateral fins which, in the true fishes, correspond to the arms and legs of other vertebrates. In the character and arrangement of its parts, the lancelet is certainly a fish; but in degree of development it differs more from the lowest true fish than such a fish does from a mammal. Lancelets may be regarded as vertebrates expressed in the lowest terms.

Let us begin now with the true vertebrates. They are characterized by the possession of a bony internal skeleton composed of a longitudinal axis, the backbone, terminating anteriorly in a skull and posteriorly in a tail, with a smaller or larger number of ribs inclosing incompletely the main body cavity, and with two pairs of limbs connected with the axis by a shoulder and a pelvic girdle. In them we have a remarkable series of animals showing, despite much plasticity of adaptation and marked lines of lateral development, a close adherence to a general structural plan and a steady advance along a major evolutionary line. The fishes, the amphibians, the reptiles, the birds and the mammals grade with more or less clearness into each other, even the living linking forms being sufficient to establish these genetic gradations, let alone the impressive confirmatory evidence derived from past forms preserved as fossils. Comparative anatomy, embryology, paleontology and geographical distribution all offer their strong and mutually supporting evidence of the general line of vertebrate evolution, with its triumphant termination in that highest mammal, man.

Of these vertebrate classes the largest is that of the fishes, of which about 15,000 living species are known, 3,000 of them living in North America. The typical fish body is one well formed for progression in the water, being pointed at each end (the shorter point in front) and with the sides flattened, the back and belly rather narrow, and the motive power located in the tail. But from this typical form diverge manifold variations, adaptations to a wide variety of habit and specific mode of life. These adaptations affect the size and shape of the body, the character of the fins and tail, the colors and pattern of the skin and scales. In the flounders, which are flattened and lie on one side on sandy bottoms, the eye that would normally be on the under side, moves during development, around to the upper side of the twisted head. When the flounder is first hatched, the eyes are on the two sides of the head and the creature swims upright in the water like other fishes.

But whatever and however radical the adaptive modification of the body, whether flattened as in the flounders, slender, cylindrical and snakelike as in the eels, long and narrowed from side to side as in the ribbon fishes, or almost spherical as in the globefish, a fundamental plan of body make-up is always present and readily recognizable. And this body plan of the fishes is also the fundamental structural plan of all the vertebrates from the lowest fishes through to the highest mammals, always persisting and plainly to be made out. There is the internal bony skeleton with its longitudinal axis, skull, ribs, shoulder and pelvic girdles and attached limbs; the closed circulatory system with pumping heart and elaborate system of ramifying arteries and veins; a respiratory system with lungs in the land forms and gills in the aquatic forms; a digestive system with stomach, intestine and attached liver and pancreas; a system of reproduction which is exclusively sexual; and a nervous system composed of brain, dorsal spinal cord and nerves reaching all parts of the body.

The amphibians, including the cœcilians, sirens, mud puppies, salamanders, frogs and toads, stand in a fairly intermediate position between the fishes and the reptiles. Despite their difference in appearance and habits, they are really much like fishes, resembling them in all but a few essential characters, such as absence of fins, the presence usually of well-developed legs for walking and leaping, and the absence or reduction of certain bones of the head connected with the gills and lower jaw which are well developed in fishes. In their adult condition some of the amphibians are terrestrial and some aquatic (fresh water), but all have an aquatic larval life. The young, called tadpoles, are extremely fishlike in their earlier larval stages, being long-bodied, tailed, swimming freely about by means of the finlike flattened tail, and breathing by means of external gills. As the tadpoles grow and develop the legs begin to appear, the hind legs first in the frogs and toads, the forelegs first in the salamanders; lungs develop as two simple sacs with more or less folded walls, and the gills disappear (except in the cases of the few forms which in addition to developing lungs retain gills through life). The tail shortens and finally disappears in the frogs and toads; with the salamanders the tail fin only is lost. At the same time the change from water to land is made.

The body varies from a long and slender, truly snakelike form, as in the tropical cœcilians, through the familiar salamander shape, where it is more robust but still elongate and tailed, to the heavy squat, tailless condition of the toads. Legs, with five digits, are usually present, but in the few species of cœcilians they are wholly wanting. These cœcilians may have as many as 250 vertebræ and about as many pairs of ribs. The salamanders may have as many as 100, but the short, squat frogs and toads have but 10 vertebræ, and no ribs at all. The heart is always three-chambered (two auricles and a ventricle), while in fishes there are but two chambers (one auricle and a ventricle). The circulation of the simpler salamanders is essentially like that of a fish, but in the frogs and toads there is a distinct advance beyond this condition. The nervous system is well developed, although the hind brain (cerebellum) is very small. There are tactile nerve endings in the skin over the whole body, and taste organs on the tongue and lining of the mouth. The eyes have no lids in some of the lower forms, but most of the frogs and toads have an upper lid although no under one. The ears have no external parts other than the thin tympanic membranes.

The reptiles, including the lizards, snakes, tortoises, turtles, crocodiles and alligators, resemble the amphibians in general shape, but in internal structure and the more essential characters are more like the birds. They all breathe exclusively by lungs, although some kinds live in water, both salt and fresh. As among the amphibians, the body shape varies from very long and slender—some snakes have as many as 400 vertebræ—to short and squat, some turtles having only 34 vertebræ. The reptilian skull, in the number and disposition of its parts and in the manner of its attachment to the spinal column, resembles that of birds, although the cranial bones remain separate, not fusing as in the birds. Four legs, each terminating in a five-toed foot, are present in the turtles; the lizards, also, usually have four, but some have only two and some none at all; while the snakes are legless or at least without more than mere rudiments of hind legs. The lungs of reptiles are simple and saclike, but in the turtles and crocodiles they are divided by septa into a number of chambers. The reptilian heart consists of two auricles and two ventricles which are, however, usually only incompletely divided, the division into right and left ventricles being complete only in the crocodiles and alligators, the most highly organized of living reptiles. The nervous system reaches a considerable degree of development. The brain, in size and complexity, is plainly superior to the amphibian brain and resembles quite closely that of the birds. Of the organs of special sense, taste seems to be little developed, but smelling organs of considerable complexity are present in most forms and consist of a pair of nostrils with olfactory papillæ on their inner surfaces. Ears are present, but crocodiles and alligators are the only reptiles with a well-defined outer ear. Eyes are always present and are well developed, resembling the eyes of birds in many respects. All reptiles have movable eyelids, including a nictitating membrane like that of the birds. In addition to the usual eyes there is in many lizards a remarkable eyelike organ, the so-called pineal eye, which is situated in the roof of the cranium, and seems to be the vestige of a true third eye which in ancient reptiles was probably well developed, but has been lost by degenerative evolution.

Most reptiles lay eggs from which the young hatch after a longer or shorter period of incubation. Usually the eggs are simply dropped on the ground in suitable places (although certain turtles dig holes in which to deposit them), where they are incubated by the general warmth of the air and ground. However, some of the giant snakes, the pythons, for instance, hold the eggs in folds of the body, and in some snakes and lizards the eggs are retained in the body of the mother until the young hatch, but in all these cases, the young, although born alive, are in reality inclosed in an egg shell until the moment of birth. The newly hatched young resemble the parents in most respects except in size.

With the birds, readily distinguished from all other animals by the covering of feathers, we come to a distinct advance in vertebrate evolution. Yet they have many important points in common with the reptiles, and the paleontological record shows a number of striking linking forms uniting the two classes. The birds, unlike the fishes, amphibians and reptiles, have warm blood and a complete double circulation, and they have more complex lungs to provide for the increased aëration of the blood made necessary by the more active blood movement. The lungs are divided into small spaces by numerous membranous partitions, but they are not lobed as in the mammals. Connected with the lungs are a series of scattered air sacs which in turn connect with bones that are hollow and contain air. Thus, a bird's body contains a large amount of air, an adaptation connected with flight.

The power of flight is made possible by the modification of the fore limbs to be wings and the special development of large muscles attached to the breastbone which has, except in the ostriches and a few other birds which do not fly and have only rudimentary wings, a marked ridge or keel to provide space for this attachment. The fore limbs, or wings, have only three digits, while the legs usually have four, although a few birds have only three toes and the ostriches but two. This is a condition brought about by a reduction from the typical five digits. The hind limbs or legs are present and functional in all birds, adaptively varying, as pointed out in an earlier chapter, in relative length, shape of feet, etc., to suit the special perching, running, wading or swimming habits of various bird kinds. Living birds are toothless, but certain ancient forms now extinct and known through fossils had large teeth set in sockets on both jaws.

The heart of birds is composed of four distinct chambers, the septum between the two ventricles being complete. The birds have an active and intense circulation, the pulse being even quicker and the blood hotter than in the mammals. The brain is compact and relatively large and more highly developed than in the amphibians and reptiles, but the forebrain (cerebrum) has not the convolutions of the mammalian cerebrum. Of the special senses, the organs of touch and taste are apparently not keen, but those of smell, hearing and sight are especially well developed. The optic lobes of the brain are of great size relatively, compared with those of other vertebrate brains, and there is no doubt that the sight of birds is keen and effective. There is no external ear, other than a simple opening, but the organs of the inner ear are well developed and birds have excellent hearing.

All birds are hatched from eggs, which undergo a longer or shorter period of incubation outside the body of the mother, and are, in most cases, laid in a nest and incubated by the parents. The time for this incubation varies from ten to thirty days among the more familiar birds, to nearly fifty among the ostriches. When the young are ready to hatch, they break the egg shell and emerge. Either their eyes are open and the body is covered with down and they are able in a few hours to feed themselves (precocial young), as with the grouse, quail, and others; or they are blind and almost naked, and dependent upon the parents for food until able to fly (altricial young), as in the case of the perching and song birds, and others. The preparation of a nest, sometimes of much elaborateness, and the faithful care of the young for longer or shorter periods after hatching, mark a distinct psychological advance on the part of the birds over the lower cold-blooded vertebrates.

And now the mammals—and we are nearing home! Let us recall the story of the evolution of the vertebrates as we have so far tried to picture it. First, we find them in the water, as fishes, breathing by means of gills, cold-blooded, with a heart of but two chambers not separating the arterial and venous blood, small-brained, and with sense organs of dull perception, trusting for the persistence of the kind to many eggs carelessly strewn, rather than care of a few young. Then, as amphibians, half-aquatic and half-land inhabiting, with lungs as simple sacs with folded walls richly supplied with blood vessels (though this blood is still cold and mixed and pumped by a heart of three chambers), with the first legs, and a better brain and sharper senses. Next come the reptiles, mostly typical land animals, all breathing by lungs which begin to have their surface increased by membranous partitions, with blood still cold and mixed, but driven by a four-chambered heart, with nervous system better developed, the brain larger; and practicing the beginnings of nest-making for the eggs. Then, the birds, warm-blooded, active, intense, possessing a definitely double circulation with a heart of four chambers in which the two ventricles are completely separated, a brain large but compact, keen special senses, especially of sight and hearing, and capable of elaborate nest-building, and care of the eggs and young. They are animals of the free air, thanks to fore-limbs become wings; animals of highly perfected instincts and a dawning intelligence.

And now, as mammals, the vertebrates reach their evolutionary height. They reach man. But not at one leap. The mammals are of many sorts; there are 2,500 living species of them grouped into eleven different orders. They all agree in certain distinctive characters of structure and physiology: above all, they are distinguished from the other vertebrates by their mammæ, or milk glands, from which they feed, for a while, their few carefully tended young. They all, except one very small group (three genera) representing the very lowest of mammal kinds, which produce young from eggs hatched outside the body, give birth to free young. These young, as embryos, have developed in the uterus of the mother body, to which they are intimately connected by a membrane called the placenta. (In the kangaroos and opossums, composing the next lowest mammalian group, there is no placenta.) Mammals differ from fishes and amphibians and agree with reptiles and birds in never having external gills. They differ from reptiles and agree with birds in being warm-blooded and in having a heart with two distinct ventricles and a complete double circulation. Finally, they differ from both birds and reptiles in having the skin more or less clothed with hair, the lungs freely suspended in a thoracic cavity separated from the abdominal cavity by a muscular partition, the diaphragm, and in the possession by the females of milk glands.

In size, mammals range from the pygmy shrew and harvest mouse, which can climb a stem of wheat, to the great sulphur-bottom whale of the Pacific Ocean, which attains a length of a hundred feet and a weight of many tons. There is a great range of variety in external form and in habits of life. Though most species live on the surface of the earth, some, like the moles and gophers, are burrowers in the ground; some, like the bats, have the forelimbs modified to be wings; and some, like the seals and walruses, the porpoises and the whales, have taken to the water and have the limbs modified to flippers. In the dolphins, porpoises and whales, the hind limbs have been lost, and the tail ends in a broad horizontal fin, or paddle. While most mammals have the typical five toes on each foot, the hoofed mammals have from but one to four.

The bones of mammals are firmer than those of other vertebrates, containing a larger proportion of salts of lime. The spinal column varies in the number of vertebræ, this difference being chiefly due to the varying length of tail. Apart from the caudal vertebræ the usual number is about thirty. The skull is very firm and rigid, all the bones composing it, excepting the lower jaw, the tiny auditory ossicles and the slender bones of the hyoid arch, being immovably articulated together. The teeth vary in number and character, for they are adapted to varying habits of feeding and of offense and defense. The alimentary canal differs greatly in length, being very long in vegetable feeders—in the cow it is twenty times the length of the body—and short in the carnivores—in the tiger, for example, it is but two or three times the body length. The nervous system and organs of special sense reach their highest development among the mammals. In all of them the brain is distinguished by its large size and by the special preponderance of the fore-brain, or cerebrum, over the mid- and hind-brain. In man and the higher mammals the surface of the forebrain is thrown into many convolutions; among the lowest the surface is smooth, as it is in the bird's brain. Man's brain is many times larger than that of any other known mammal of equal bulk of body.

As already pointed out, all mammals except a very few give birth to free young. There are three or four peculiar creatures, undoubtedly the lowest of all mammal forms, which produce their young from eggs hatched outside the body. One of these kinds, which lives in Australian rivers and is called the duckmole, or duckbill (*Ornithorhynchus*) because of the flat sheathed snout, lays two eggs in a carefully constructed burrow nest. The other kinds, which are land animals, deposit a single egg in an external pouch on the body, and here it hatches. In various structural details these egg-laying mammals show remarkable resemblance to birds and reptiles. They are all found in those "lands of living fossils," Australia, Tasmania, and New Guinea. So different are they from all other mammals that some biologists prefer to call them promammals, and establish them in a separate class. But they agree with other mammals in that distinctive character of feeding their young a secretion from milk glands, although the glands in these low or near mammal forms are much less compact and well developed than they are in other mammals.

Another low and ancient order of mammals is that of the marsupials (kangaroos and opossums). They give birth to their young in a very early and helpless stage (the young of the American opossum is only about half an inch long at birth) and carry them about in an external pouch. This pouch is on the underside of the body, and in it are the teats to which the young cling constantly. All of the marsupials except the opossums live, as do the duck-moles, in Australia and neighboring islands.

Most of the other orders of mammals—the rodents, the shrews and moles, the bats, the cetaceans, the herbivorous hoofed mammals, and the carnivores—are more or less familiar to all nature students, hunters and frequenters of zoölogical gardens. They are all, except perhaps the seals and walruses and the dolphins, porpoises and whales, easily recognizable as belonging to the mammalian class. They are the "quadrupeds" of the older text-books, the "beasts" of common parlance.

But there is one order, the highest in the whole class and by far and away the most fascinating to us, to which a few special words must be given before we pass on to our next chapter, that on the evolution of man. This order is that of the Primates, or man-like mammals, and includes the lemurs, tailed monkeys, baboons and apes. It is in this order that the classifying zoölogists place man. He is put here on the basis of the known facts concerning his anatomy, physiology, embryology and paleontological history. He has been studied in a detached and unemotional way by the same methods and in the same manner as other animals have been studied, and the results of this study compel the zoölogists to classify him as an unmistakable member of the great branch Chordata (which includes all vertebrates), belonging in it to the class of Mammals, and in this class to the order of Primates, within which finally he finds his closest genetic relationships with the anthropoid apes, the living representatives of which are the gibbons, orang-utan, gorilla and chimpanzee. The structural resemblances of all the Primates, as well as their physiological and embryological characteristics, set them off clearly and unmistakably from all other mammals, as a group of closely related forms.

First and lowest among them are the curious, small, superficially squirrel-like lemurs of Madagascar and neighboring regions. They live chiefly in trees and feed on insects. Then come the tailed monkeys and the apes (not anthropoid) which are divided into two general groups. One of them lives in Central and South America and is characterized by having a flat nose with the nostrils far apart and directed laterally. All of the members of this group are arboreal, and many have long prehensile tails. In the other, or Old World group, the nostrils are close together and directed downward, the tail is never prehensile, and in some cases is rudimentary or even absent. These Old World apes include the baboons, mandrills, the tailless Macacus and the Barbary ape, which extends across from Northern Africa into Spain.

Finally, at the head of the order (excluding man, for the present) come the tailless anthropoid apes, whose structure is very close in almost all details to that of man. In fact, there are only two persistent and outstanding major structural differences between man and these apes, and those are the inability of man to oppose the big toe as he does his thumb—a feature associated with his erect position—and the relatively enormous size of the human brain, which is, in the adults of the higher living races of man, three times the size of the brain of any anthropoid ape. Even in an Australian bushman, who belongs to one of, if not quite, the lowest of human races, or in a four-year-old child of any of the higher races, the brain is twice the size of that of an adult gorilla, whose body is as large as that of human adults. For the rest, however, the structural make-up of the anthropoid apes is extraordinarily like that of man.

The gibbons, inhabiting southeastern Asia, stand more erectly when on the ground than the other anthropoids, but have arms of such length that they are able to touch their hands to the ground as they stand. But they spend most of their time in trees, and feed on fruits, leaves and insects. In the same region we find the orang-utan, which walks, when on the ground, on the knuckles and sides of the feet.

It also, however, prefers life in the trees, in which it builds nests for rest and concealment. The gorilla, the largest of the apes, and in details of structure perhaps most like man, attaining a height of five feet and weight of two hundred pounds, is a native of Africa, where it lives in families and subsists chiefly on fruits. Ever since the sensational tales of Paul du Chaillu, the gorilla has been popularly looked on as a ferocious animal quick to attack man. But Carl Akeley in recent intimate studies of the gorilla at home in the Belgian Congo reveals this great ape to be timorous and well disposed rather than fierce. Finally, in Africa also, is found the chimpanzee, which, in its various characteristics, including manner and mentality, taken altogether, most nearly of all the anthropoid apes approaches man. The capacity of the chimpanzee and orang-utan for being taught to imitate human behavior is well known to all frequenters of zoölogical gardens and vaudeville entertainments.

The fossil remains of several now extinct anthropoid apes have been found in Europe and elsewhere, and, most recently, in a single instance, in North America. Among these remains are those of one or more kinds which seem to have been even more closely similar to man than are any of the living anthropoids. As a matter of fact, no biologists see in any of the living anthropoids a kind which could be called a direct ancestor of human kind. Man and the present anthropoids are descendants, along distinct lines, of some now extinct common ancestor. This ancestor has yet, if ever, to be found.

CHAPTER XII

THE EVOLUTION OF MAN

In the popular use of the word "evolution" it is often, indeed, perhaps usually, made to mean exclusively the evolution of man. Man from the monkeys, that is the popular significance, and the popular damnation—when it is damned—of evolution. From the biologist's point of view that is a wrong limitation and an unfortunate special connotation of the word. But even from his point of view the evolution of man is an inevitably included part of the meaning of evolution. For practically no biologist leaves man out of the evolutionary series. It would be inconsistent and even absurd for him to do so, because he lists man in all his classificatory textbooks, as we have just expressly stated in the close of the last chapter, as a vertebrate animal belonging to the class of mammals. Within this class he puts him in the order of primates, and within this order the zoölogical classifier recognizes a special family, the Hominidæ, represented, in this geological time at least, by man alone. And he gives him a genus name, *Homo,* and species name, *sapiens,* combined to read *Homo sap-*

iens, just as he gives such a binomial to every other known animal kind. He believes, on the basis of what seems to him incontrovertible evidence, that all other animal and plant kinds listed in his register of living creatures are the results of evolution. And, on the basis of similar evidence, he must and does accept logically and naturally this particular creature, *Homo sapiens,* as having exactly the same status, as regards origin and blood relationship to other animal kinds, as have all the other animals which he knows. *Homo sapiens,* or man, may be the highest, the most interesting, the most important, the most anything, of all animal kinds, but that does not release him from his general relation to the evolutionary scheme of things.

So evolution means to biologists, just as it does to laymen, the evolution of man—even though it means also much in addition to that. And the evolution of man means to them also the most important part of evolution—for they, too, are more interested in humankind than in any other kind of creature.

Biologists might, therefore, as well frankly recognize that the interest of the great public in evolution, so far as this public has any interest in it at all, is primarily, and often exclusively, an interest in the evolution of man. Hence, any biologist writing or speaking of evolution must, if he wishes a general hearing, give a large attention to the special subject of human evolution and its influence on our attitude toward the pressing problems of individual and societal life and fate.

It is particularly this significance of evolution in its relation to our understanding of human endowment and possibilities, of human behavior and control, of the relation of the individual to society and of society to the future evolution and fate of the race, that creates and holds the interest of people. If the evolution of man merely meant classifying him in zoölogical textbooks as a vertebrate animal of the class of mammals, and pointing out for him a long history as a constantly improving creature struggling from darkness into light, the public would let the classifiers have man to list and play with as an animal species developed by evolution, as much as they liked.

But when this acceptance of man's evolution involves, as it at once does, the acceptance of such significant things as the surrender of the long-held conception of an immediate special creation of man by a special Creator, the recognition of a close genetic relationship of man with such animals as the anthropoid apes, and the control of man, in many aspects, by various natural laws to which all other creatures are subject, all of which acceptances bear importantly on our whole conception of philosophy and religion, then the public balks. Part of it simply revolts and will have nothing to do with evolution. Part of it asks, dubiously, just how assured biologists are of human evolution. Finally, part of it, accustomed to see in science a method and a means of finding out the truth, and accustomed to accept the pronouncements of science as a basis of knowledge, declares itself ready to accept the evolution of man with all its implications. But it asks, rather nervously, just what and how extensive these implications are, and just how far their acceptance will modify our conception of the high estate of man; just how far they will despiritualize and materialize our understanding of humanness. What becomes of poetry, philosophy and religion, of inspiration, virtue, and God, when we accept the evolution of man?

It would be a promise I could not fulfill, a presumption I am not silly enough to dare, if I should say that I or any biologist or natural philosopher can satisfactorily answer these questions. We cannot. But it is our duty not to dodge these questions, but to try to point out, as simply and clearly as may be, what approaches to their answers science is now in a position to make. It is especially needful to do this just now, because the public has been rather widely stirred recently by very positive anti-evolutionary statements and activities. These attacks have, as of old, mostly been made by theologians, and the evolution denied and banned by them is the evolution of man. For the rest of this book the evolution of man, therefore, will be my special subject.

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The evidence for the evolution of man is gained, just as is the evidence for the evolution of the plants and other animals, from the study of his anatomy, physiology, embryology, paleontology and geographical distribution. From all these sources there are impressive testimonies to man's oneness with all other life, to his origin by evolutionary processes from lower life forms, and to his ever continuing slow change and modification under the pressure of the always present major factors of life and evolution, such as variation, heredity, selection, and environmental influence, the resultant of whose influences determines the character and evolutionary movement of living creatures.

But there is one element in man's make-up and attributes, much more difficult to study and so far much less understood than most of his other attributes. It speaks less clearly concerning the reality and the manner of his evolution and, in fact, leaves open a most important opportunity for attack by those who would try to controvert the claims of the evolutionists. This element is his psychology; the manifestations of his mind and spirit. If man owes all that he has to evolution he has at least been able to go so far beyond all other creatures in the quantitative development of mind and all that goes with mind, that he seems, to many, to have a mind and related capacities which are really qualitatively different from those of all other creatures, even the highest among them. And this has led to the development of a school of students of human life who accept the natural evolution of man's body, but call for another and different, presumably a supernatural, explanation of his mind and spirit. This school includes some real scholars, but a larger number of laymen who wish to follow science as far as they can, but have an emotional urge to see in man's higher intellectual and especially his so-called spiritual capacities something quite beyond scientific explanation. So important is this matter of mind in any consideration of human evolution, that I want to devote a following chapter exclusively to a brief statement of the present status of the scientific man's study of the evolution of mind. Leaving this very important matter aside, then, for the moment, we may glance swiftly at some of the more or less familiar facts which reveal both the evidence for, and the character of, the evolution of man.

In an earlier chapter (Chapter IV), special reference was made to the striking similarity, indeed, fundamental identity, of the skeleton of man and that of other vertebrates; the likeness being more and more close as one passes from the lower vertebrates (fishes) on up to the higher ones (mammals). Also, among the mammals this similarity, bone for bone, both in shape and disposition, grows more and more marked as one passes from the lower orders, as the Monotremes and Marsupials, to the highest, the Primates, which includes the monkeys and apes. This story of skeletal likeness or identity is repeated by the story of each of the other great organ systems, the muscles, nerves and nerve centers, alimentary canal and tributary glands, the respiratory and circulatory systems.

There are differences, to be sure, but the very differences reinforce in one's mind the unescapable conclusion of the origin of man's structure by an evolutionary process from the structure of the vertebrate animals. For these differences are not radical, but comparative, and they are plainly associated with differences between the habits of man and the habits of these animals. Especially are many of these differences plainly associated with the erect posture of man. The gradatory steps culminating both in the change of the habit of going on all fours to that of going on the lower limbs, and in the change of structure, especially skeletal and muscular, made necessary by this change of habit, are beautifully shown by a comparison of the habits and structure of the anthropoid apes with those of the lower mammal orders on one hand and those of man on the other.

The story told by the vestigial and retrogressive structures alone in man's body is a brief for the evolution of man that is practically unanswerable. It is a brief particularly confusing to the special creationist. How can an all-wise, all-powerful, special Creator ever be held responsible for creating man with a host of useless and degenerating parts in his body? As pointed out in the earlier chapter on the evidences of evolution found in comparative anatomy and embryology, anatomists now list nearly two hundred cases of vestigial and retrogressive structures in the human body. Their explanation by evolution is a reasonable one. Man, in assuming an upright position with a body inherited from lower mammals going on all fours, and in his other modification of habits and character of functions, has not completed his adaptive structural evolution and is now in process of losing or modifying parts of his inherited body structure so that it may conform with his new habits.

In this earlier chapter, too, are told some of the striking facts of man's embryology. They reveal how each human being, in his individual development from single fertilized egg cell to complex adult body of trillions of differentiated cells associated into organs and organ systems, passes through a series of stages in which he is, as regards the character of his bodily make-up, first invertebratelike, then fishlike, then amphibianlike, then partly reptile-like and partly birdlike, then characteristically mammalian, and only finally of that particular and peculiar type of body which differentiates him from all other animals as man. He repeats, or recapitulates in his embryonic development, the major steps by which he has arisen by evolution from lower animal forms. His heart is first a single-chambered tubular organ like that of the adult lowest vertebrates. Then it becomes partially divided into two successive chambers, an auricle and a ventricle, and now resembles the adult heart of the fishes. The auricle next divides into two cavities, and now this embryonic human heart of three chambers resembles the fully developed heart of the next highest vertebrate class, the amphibians. Later, the ventricle also divides into two cavities, and thus the four-chambered heart characteristic of the higher vertebrates and man is reached. Similarly, the red blood cells of the human embryo are, when first formed, large and nucleated. In this stage they resemble the red blood cells of adult fishes and amphibians. Later, the embryonic human blood cells become similar in structure to those of adult reptiles. Finally, sometime before the birth of the human embryo, these blood cells become, as they do also in all other mammals, non-nucleated and biconcave. Thus it is evident that the human heart and the cells of the human blood pass, during the embryonic development of each human being, through stages representing the different adult conditions of the heart and blood in successively higher vertebrate classes.

Similar stories are told, in more or less detail, by the other organs and organ systems. The facts of human embryology alone are enough to indicate both the reality and the general course of the evolution of man. There is no other explanation of them but evolution which does not make human reason to be a travesty of itself.

But besides the sources of knowledge concerning the evolution of any plant or animal group, or of man, which lie in the study of embryology and comparative anatomy, there are also the sources afforded by the study of paleontology and geographical distribution. What evidences and revelations of the evolution of man do these sources afford? Are there human fossils that throw light on human evolution? Does the present distribution of the various races and types of living man help us to an understanding of the course of man's evolutionary development?

The historian speaks of modern history and ancient history. But all of the history of the historian seems to the geologist and biologist to be only very modern history, indeed. It is only the history of man during the last few thousand of his many thousand years of existence on earth. It tells the tale of what manner of man lived, and of his achievements during the five or six thousand years just preceding this year. But the paleontologist and anthropologist find irrefutable evidence that man, of one kind or another, has existed on this earth for certainly no less than one hundred thousand years, and probably for several hundred thousand years. This evidence is that of the actual remains (fossils) of these early men and of a great mass of things made by them, their tools and weapons and utensils, their ornaments and works of art. These human fossils and artifacts have been found in such relation to various geological formations and intermixed with the fossil remains of such various extinct animals well known to paleontologists, that no doubt can exist of the truly ancient period of existence of these prehistoric human beings thus revealed to our knowledge.

Although the findings of such fossils and human artifacts began as long ago as the middle of the last century, the large majority of them have been made since the beginning of this century. And since 1900 the rapidly succeeding finds have been so numerous that there is now an impressive array of material available to the student of human prehistory. On the basis of this material, most of it of indisputable authenticity, the anthropologist can picture with surprising detail the character and behavior of our human—and near-human—ancestors of the last several hundred thousand years. He can distinguish among several definite types of human creatures, living at definitely distinguishable times during the present geological epoch, called Quaternary, scattered through that first and longer part of it called Pleistocene, or Glacial time, and that latter and much shorter part of it called Recent, or Post-Glacial time. He sees a gradual change in succeeding periods from a more bestial type of man to a more human type; from an ape-man type to the present type. He sees the evolution of man as it has so far run its course.

Most of the finds, constituting the evidence so far available to students of man's prehistory, have been made in Europe and the British Isles. But one of the most important was made in Java and another in Rhodesia in Africa, while North America, from which no really ancient human or anthropoid fossil had ever before been recovered, recently has made its first contribution to the genealogy of earliest man by uncovering a relic of an anthropoid ape of unusually interesting character.

It has been for a long time a matter of some wonder to anthropologists that North America has contributed little or nothing to the history of anciently prehistoric, that is, Glacial time, man. From time to time human relics claimed to be geologically ancient have been uncovered in this country, such as the Calaveras skull, the Lansing man, the Florida man and others, and most recently and perhaps most promisingly the Lagow sand-pit man from near Dallas, Texas. But none of these relics has yet succeeded in establishing for itself an age at all comparable with that of the numerous European and English finds. The American relics seem to be only those of extra-early Indians belonging to a period well beyond the last glaciation.

It is very different in Europe. From France we know of a half dozen or more skulls and skeletons which are all of Mid or Late Glacial time. There are similar relics from Belgium, Germany, Austria, Spain and England. These are all remains of so-called Neanderthal man. Then, there is the still older Heidelberg jaw. The age of this relic may be no less than 400,000 years. Perhaps no older, but perhaps of even more primitive type, is the Piltdown man, or "dawn man," of Sussex, England. Also of very primitive type is the Rhodesian man, of which a few fossils are known. Plainly later than these, although still much older than any American relics, are the numerous skeletons and skulls of Cro-

Magnon man found variously in Central and Western Europe. This man is probably the earliest type of true present-day *Homo sapiens,* but he lived from twenty to thirty thousand years ago.

Oldest and most primitive of all the human or near-human relics are those skull parts, teeth and left femur found in 1891 in Java, and which are the basis for establishing the existence in Upper Pliocene, that is, nearest Pre-Glacial time (or, at latest, in earliest Pleistocene or Glacial time) of a low ape-man type of creature which is called *Pithecanthropus erectus.* For with all its simian characters of head, the character of its thigh bone indicates that it carried its hideousness erectly.

To add to the evidence of these human or near-human fossils of indubitable antiquity, the anthropologist has still another kind of evidence of man's ancientness on this earth, an evidence much enlarged in recent years. This evidence lies in the existence of the results of early man's handiwork, a myriad examples of which have been found in situations and under conditions that clearly prove their varying geological antiquity. So many of these artifacts of human origin have been found, and they are so characteristically various and are so consistently distributed as regards geologic time, that the anthropologists have been able to distinguish a series of definable cultural stages in human prehistory, each associated with different succeeding structural types of men.

The less ancient of these discoveries include primitive bone and stone tools—not to refer to such comparatively recent things as the handiwork of the Neolithic and Metal ages—and various carvings on bits of mammoth ivory and reindeer horn, and numerous drawings of wild horses, mammoths, and other extinct mammals, as well as of ancient man himself, on the walls of limestone caves.

The more ancient of these relics of human activity, found abundantly under conditions that show them to be contemporaneous with Glacial time and even earlier, are certain chipped flints adapted for use as simplest tools and weapons by various types of flaking in ways to produce cutting edges and convenient handholds. Some of these flaked flints have been found under conditions that seem to prove them older than any actual human fossils yet discovered. Some have been ascribed not only to Upper Pliocene time but even to older strata. If these oldest flints, called eoliths, are to be accepted as truly man-touched, they prove the existence of Tertiary man, which is to say that they carry man's antiquity back from Early Glacial time by another half million or more years.

But a certain discussion, vigorous to acrimony, rages about these oldest chipped flints. One group of scholars holds that they may have been produced by natural causes through rough contacts with each other or other larger flint fragments. But the Nestor of American paleontologists and anthropologists, Professor Henry Fairfield Osborn of the American Museum of Natural History, is convinced that the so-called Ipswich eoliths of England are the handiwork of Tertiary man.

Under any circumstances, a great advance has been made in recent years in further proving the general course of the evolution of man. The characteristics of this evolutionary progress toward present-day humanness are, in physical changes alone, as summed up by Lull, an increase in stature and erectness of body, an increase in cranial capacity and perfection of the brain, especially in that portion of it which is concerned with the higher intellectual faculties and with speech, change in skull conformation, a heightening of the forehead and lessening of the brow ridges, a reduction of jaw power and dental arch, with resulting chin prominence, and changes in the teeth, such as a reduction of the canines and loss of the diastemata.

As we survey the imposing array of human fossils now on exhibition before the wondering eyes of modern man running from ape-man Pithecanthropus through Heidelberg and Piltdown dawn man, on through Neanderthal and Cro-Magnon man up to man of to-day, we can plainly see man's physical evolution, even as we see that of the horse in the series from little five-toed Eohippus of early Tertiary times, through later and larger four-toed Orohippus and still later and larger three-toed Mesohippus to one-toed Equus of to-day.

Another kind of evidence for man's evolution is afforded by an examination of the various races or types of man existing to-day. Not all present men are alike. They differ, not merely individually but as groups. There are major varieties or types of present-day man. These varieties differ not only in their culture or kind of civilization, which is a variation that can be partly explained, at least, as a more or less superficial difference due to various environmental factors impinging on each successive generation; but they differ also in inherent and biologically heritable characters of structure and physiology.

It is the custom of anthropologists and biologists to classify all existing men as of one species. That is, they call the major different types, such as Caucasian, Negroid and Mongoloid, only different subspecies, and the major subtypes within each of these subspecies they call races. For example, the Nordics, Alpines and Mediterraneans are called races of the Caucasian subspecies. For all of these subspecies and races can intermate fertilely, and that is the biologist's principal physiological criterion of a species.

But if differences in such constant structural characters as stature, skull conformation, skin color, form and color of hair, etc., were to be assumed to indicate species differences, as similar differences constantly are assumed to indicate different species in classifying the animals and plants, then we should unhesitatingly rank a number of the existing different races of man as different human species. As a matter of fact, the biologists and anthropologists do classify several of the different fossil types of man as of different human species and even genera. This classification is based, of course, exclusively on the marked structural differences apparent among these extinct types. The physiological criterion of fertile intermating cannot be made use of.

But whether looked on as different species, or different varieties or races, the present living types of man are susceptible of classificatory separation on the basis of marked physical and, probably, mental differences. This separation can and does take the general form of constituting a series of human types representing different stages of human evolution. These stages correspond in some degree with stages recognizable in the series, as so far known, of prehistoric human kinds, running, that is, from lower to higher types of evolutionary development. Even so conservative a scholar as Kroeber, leaning strongly toward an environmental rather than an hereditary explanation of present human varieties, recognizes that on a basis of fairly sound inherent physical differences "the vast bulk of mankind does fall naturally into three great divisions, each of which again subdivides into three or four principal branches, in regard to whose distinctness there is no serious difference of opinion. The scattering remainder of races are allied sometimes to one primary stock, sometimes to another, but always with some special peculiarities."

There is little difficulty in recognizing a distinct evolutionary difference between the dwarf negritos of equatorial Africa and Malaysia or the prognathous and beetling-browed Australians on the one hand, and the Nordic, Alpine and Mediterranean-Caucasian races of Europe on the other. The whole problem of the existence and geographical distribution of different races of living man is exactly the same kind of problem that constantly faces the faunistic naturalist in his study of any group of related kinds of lower animals and plants. It is an evolutionary problem.

There should be added to this brief account of the evidences of human evolution at least a reference to the interesting blood tests devised by Dr. George H. F. Nuttall of Cambridge (England) and others, which indicate the chemical likeness of the blood of the anthropoid apes and that of man. These tests, called precipitin tests, are based on the discovery that if the fresh blood serum of any animal is injected into the veins of a rabbit there will be produced in the rabbit's blood an antibody. This is analogous to the antitoxin which is produced in the blood of a horse by the injection of diphtheria virus. Now, if into blood, taken from an animal of the same species as that from which serum was originally injected into the rabbit's body, there be introduced a few drops of the drawn-off blood serum of the treated rabbit a white precipitate will be produced. But if the rabbit serum is introduced into blood from another kind of animal, *unless a kind closely related to the animal species* from which the original injection of blood into the rabbit's body was made, there will be no precipitate.

If we use human blood for the injection into the rabbit's blood it will respond in this way when, later, a few drops of rabbit serum are added to human blood. There will be a similar response although less marked if blood from an anthropoid ape is used, or, but still less markedly, if blood from a monkey be used. But there will be no precipitin reaction if the blood of a horse or pig or other animal be used.

If, however, blood from a horse be used for the original injection into the rabbit's body, then the rabbit serum will produce a precipitin reaction in blood from another horse or from a donkey. The same is true if dog and wolf are used in the experiment.

In other words, this blood test reveals a chemical similarity in the blood of closely related animals, and a dissimilarity in the case of that of widely related animals. The fact that the human blood and the blood of the anthropoid apes both produce a nearly identical reaction is clear evidence of their close genetic, or "blood" relationship.

CHAPTER XIII

EVOLUTION OF MIND

The human mind is the distinctive attribute of man. The nature and range of the powers of man's mind are what most importantly differentiate the human family from all other living creatures. Man's mind is of much more importance to him than his erect posture, his chin, his hand, his lack of hairiness or any other of those several characters which more or less sharply distinguish him from his nearest animal cousins. How has man come to have this master possession which places him so indisputably above and beyond all other animals?

We can see something of the later progressive evolution of the human brain in the picture given us by the students of human embryology. We have seen how the embryologists have demonstrated that the developing human brain, especially that part of it forming the major portion of the cerebrum, passes through a series of successive stages roughly but unmistakably corresponding to the adult brain conditions in fishes, amphibians, reptiles and the lower mammals.

Also, we can see something of this evolution of the human brain in the character of the cranial cavity of the various human and near-human creatures which lived in earlier geologic days than the present. When we compare the endocranial casts made from the fossil skulls and skull parts of Pithecanthropus, the Piltdown man, the Rhodesian man, the Neanderthal man and the Cro-Magnon man with one another, and with that of man of to-day, we can detect a progressive expansion of those lateral and frontal territories of the brain which are especially associated with the increasing human powers of manual dexterity, discrimination, and mental concentration.

The anthropological studies, too, of the status of the mind in the different living subspecies of man —the Caucasian, the Mongoloid, and the Negroid —and in their races—the Caucasian Nordics, Alpines and Mediterraneans, the Mongoloid Asiatics, Malaysians, Eskimos and Americans, and the Negroid Australians, Negritos, Melanesians, and African Bushmen—indicate that apart from differences due to purely environmental and cultural conditions, there are some inherent differences in mind among living racial stocks. These differences are more or less gradatory in character and illustrate a progressive evolution from the relatively low mind type of the most primitive Negroids to the much higher type possessed by the present Occidental Caucasians.

But the progress of the brain and mind thus revealed is only a comparatively recent chapter in the whole story of the evolution of the human mind. It is only that chapter which treats of the progress of the human brain and mind since the appearance on earth of actual human or near-human beings. But the whole story goes back and down much farther than this. It goes back to the first living creatures appearing on earth; it goes down to the simplest ones now existing.

In taking this broad and inclusive look at mind, we must first of all rid ourselves of our usual too anthropocentric attitude toward it. We must not think of mind as an exclusive attribute of man, for there are hundreds of thousands of species of animals all possessing mind of one sort or another. Nor must we think, even, of that major characteristic of the human mind, intelligence, as something totally unshared by the lower animals. For not only the miscellaneous observations on the behavior of wild and domesticated animals in field and barnyard and kennel made by naturalists and, indeed, by all of us, but the results of the carefully planned and controlled experiments of the genetic psychologists and trained students of animal behavior, reveal varying positive degrees of intelligence in animals, especially in the higher mammals, and also in birds, reptiles, amphibians and even fishes.

But mind in the lower animals, and in man himself, includes much besides intelligence. There are other organs of the body besides the brain whose functions contribute to the existence of mind. Indeed, if we look at mind in the broadest and fairest way we shall recognize it as existent in animals which have no brain at all, not even a special nervous system. Looking at mind as the total function of control of animal behavior, and at the *loci* of mind as being in any structures of the animal body that help to determine this function, we shall come to a rather startling conclusion. This is, that mind and behavior, in the simplest animals, are little more than phenomena which can be explained, or, at least, described, in terms of mere physics and chemistry, and are inherent in the very basic substance of which the bodies of these animals are composed.

There is a whole host of living creatures, mostly minute one-celled, some of them called animals and others plants, according to their physiological characteristics, whose bodies contain no differentiated tissues or organs which may be called nerves or brains, and whose behavior seems wholly determined by two sets of physicochemical conditions. These are, first, those of their own fundamental physicochemical make-up, and, second, those of the physicochemical character of their environment. These simple living creatures have an exceedingly limited range of behavior, and this behavior consists chiefly, if not solely, of inevitable mechanical responses to varying environmental influences. These responses are called tropisms, or reflexes, and after a sufficient number of experiments they can be learned and foretold. We find these simple creatures moving inevitably toward or away from light (positive or negative phototropism); toward or away from various chemicals (positive or negative chemotropism); in, or opposite to the direction of the pull of gravitation (positive or negative geotropism); in contact with, or avoiding contact with, solid substance (positive or negative stereotropism); and so on; all strictly mechanistic behavior. Or, to substitute for the word behavior the name of that which presumably governs behavior, that is, mind (in our broad use of the word), we can say that among the lowest animals the reflex or mechanistic mind seems to be the only, or, at least, the principal kind of mind.

When we move a step or two higher in the animal scale, and find ourselves among the simpler many-celled animals, and especially when we reach the higher invertebrates, notably the insects, we still see tropisms or reflexes responsible for a considerable part of behavior. But we also find another, although closely related, type of behavior control much in evidence. This is instinct, and animals whose behavior is largely determined by instinct may be said to have instinct mind.

This kind of mind may determine a behavior of great complexity and of most definite and specific advantage to its possessors in the struggle for existence. Those many extraordinary adaptations in behavior displayed by the insects and many other invertebrates which constantly excite our wonder and admiration, are sufficient illustration of the great possibilities of instinct mind. For all these insects and other invertebrates have minds chiefly of the nature of instinct mind. There is in all of them an element, larger among the lower ones, less large among the higher ones, of the purely reflex and tropismic mind, and there may be among the highest a small element of the intelligence mind. But the element of instinct mind is by far the most important feature in the mental make-up of all those hundreds of thousands of invertebrates which constitute the overwhelming majority of living animal kinds. Proud as we are of our own mind, in which the element of intelligence plays so large and important a part, and familiar as we are with seeing this element play a smaller or greater rôle in the minds of the higher vertebrates, we should not forget the fact that an immensely larger number of animals have their behavior controlled by instinct than by intelligence. And these instinct-minded animals live successful lives.

When one contemplates the variety, precision and successful achievement of honeybee behavior or ant behavior, or of the behavior of the solitary wasps, made familiar to us by Fabre's entertaining accounts, we hesitate to accent the fact that all of this is the achievement of the instinct mind—of a mind which does not learn, which permits of almost no variation in its determination of behavior, and which is entirely inherited and almost identical in degree of development in each of all the myriad individuals of any given species. Yet reflexes and instinct account for all their marvelous behavior.

Yet at the same time we are struck, and almost shocked, by the limitations of the instinct mind. Its possessor does not need to be taught or to learn by experience the elaborate and successful behavior which is an essential part of its life activities. But, on the other hand, it cannot learn. It cannot add to its mental possession anything not given it by heredity. With any serious modification in environment the possessor of instinct mind alone is lost. It may show remarkable inherited adaptation but it shows no individual adaptation, or extremely little. The solitary wasp mother must find, depending on her species, just this or that kind of insect or spider victims with which to stock her nest burrow for the food of her children. She must dig this burrow in just such and such a way, in just such and such a place. She must sting her victims in precisely such a way as to paralyze but not kill them. She must drag them into the nest burrow in precisely one particular way. If anything happens to disarrange the elaborate series of successive performances, she must begin all over again, or give up entirely.

Thus, though the instinct mind enables its possessor to do remarkable things, it has remarkable limitations. It has had an extraordinary development in animal evolution, but this development has not led to the highest form or type of mind. Instinct has not developed into intelligence or reason. It has run a course of its own, a course that has, indeed, carried it quite away from intelligence, but has led it very far along its own line. The behavior of a honeybee is more complex and of much more specialized adaptative character than the behavior of the animals with low grades of intelligence, but the behavior of the animals with higher grades of intelligence has far greater possibilities than that of the honeybee.

The highest type of intelligence mind is that possessed by man. Indeed, so much more capable and so much higher is the mind of man than that of any other animals possessed of intelligence, that many persons, thinking especially of its capacity for memory, inference and constructive imagination, maintain that it has elements in it qualitatively different from those entering into the mental make-up of other animals. The evolutionist, however, does not feel forced to admit this. He recognizes a great quantitative difference between the human mind and that of any other animals, even the highest of the mammals. But he believes this difference to be essentially only quantitative, not qualitative. However, he is open to proof to the contrary.

The evolutionist-psychologist who considers mind as not merely the functioning of the brain but as all that goes to determine the many various performances in or of a human individual, finds, in his analysis of the human mind, a certain proportion of reflexes, a certain proportion of instinct, a certain proportion of unconscious brain activity, and a certain proportion of conscious intelligence. In the knee jerk he sees a reflex: in the child's suckling he sees an adaptive, life-saving instinct: in dreams and many performances not the result of conscious intent, he sees the brain working unconsciously, and in activities consciously chosen and carried out he sees the element of intelligence and reason. A great American medical scholar has recently declared that man's proud possession of the intelligence mind does not lift him so high above the lower animals as he is wont to think. Even when he is awake, this scholar declares, man is only a quarter conscious of what his body is doing. Three quarters of the energy created by the food man eats and the air he breathes is spent without his knowing it.

Also, there is no doubt that man is not alone, or peculiar, in possessing an element of intelligence in his mind. Some students of the behavior of the animals are so irritated by the popular and conceited assumption that man alone is an intelligent creature that they are led to such sharp expressions as the one recently published by Dr. Hornaday, the veteran naturalist and present director of the New York Zoölogical Gardens, in his book, *The Mind and Manners of Wild Animals.* Here he declares that "some animals have more intelligence than some men, and some have far better morals!"

Without necessarily accepting this dictum, we can all accept Dr. Hornaday's proofs, on the basis of a host of miscellaneous observations, of the existence of an intelligence element in the minds of many mammals and even lower vertebrates. His book is a fascinating collection of authentic accounts of intelligent and reasoned behavior on the part of various wild animals in field, forest and zoölogical gardens. Indeed, there are few of us but can tell our own stories of intelligent behavior on the part of pet dog, cat, horse, even chicken or canary. And the carefully planned and often repeated laboratory experiments of the professional students of animal behavior reveal indisputable instances of intelligent reasoned behavior on the part of representatives of all the great vertebrate classes, even including the fishes.

But man certainly stands preëminent among living creatures in his high development of mind. And this height is reached by his large possession of intelligence, not by any unusual development of instinct. The seat of this intelligence is the brain, especially the forebrain, or cerebrum, and man's brain is, even in the most primitive of living human kinds and the most ancient of true human species, larger than the brain of any other animal except the elephants and larger whales. The average size of the brain of present-day man is nearly three times that of the gorilla, which is the anthropoid ape most comparable with man in size. Almost midway in size between these two was the brain of Pithecanthropus, the ape man of Java. This creature had a very limited forebrain and was probably governed in its reactions to environment, and in its general behavior, more by reflexes and instinct than by intelligence.

True man has had a brain of the size of that possessed by present-day humankind ever since the days of Cro-Magnon man who lived in Europe twenty-five or thirty thousand years ago. Cro-Magnon man was probably the first race of the present-day human species (*Homo sapiens*). Before him, man of different geologic periods was, as far as known fossils show, of kinds sufficiently different from present-day man to be fairly ranked as different species (as *Homo neanderthalensis, Homo heidelbergensis, etc.*). In these early species of man, living from one to three or four hundred thousand years ago, the brain, especially the forebrain, was distinctly smaller and of less frontal development than in *Homo sapiens,* the present-day human species.

There is a difference in brain size, too, among living human races. Such primitive races as the Bushmen, Negritos, Veddas, Australians, and Tasmanians (these latter having become extinct within historic times) have a brain running about ten per cent less in size than the average brain of European Caucasians. However, most of these primitive living races are of smaller body stature than the Caucasians, and cranial capacity is somewhat related to bodily size. Also, there is considerable overlapping, for the larger-brained individuals of primitive races reach the average brain size of Caucasians, and smaller-brained Caucasian individuals have a brain no larger than that of some Negritos. But on the whole it can fairly be said that there are distinct and characteristic differences in brain size among different living races of man.

These differences indicate an evolution of the human brain, hence of the human mind, within the human genus, in the period of the existence of this genus on earth. The question, therefore, naturally arises, is this evolution still going on and is it to go on through future time?

Anything like a positive answer to this question is very difficult, perhaps impossible, to make. If the human brain has not increased perceptibly in size since the time of Cro-Magnon man, twenty-five thousand years ago—and it has not—and if inherent human mental capacity has not increased perceptibly since the days of the Egyptians of six thousand years ago, or of the Greeks of Homer's time—and this is generally admitted—it is easy to see that the anthropologist cannot say positively that the evolution of the human mind is still going on. And if he cannot say this, equally he cannot say that it will go on in future time.

But, on the other hand, that anthropologist or psychologist who would presume to declare, taking into account the brief period, from a geologic and evolutionary point of view, during which no perceptible biological evolution of the human brain and mind has been apparent, that no such evolution was in course, and that the human mind had reached its limit of development, would be a brave—or foolish—person. President Angell of Yale University, a psychologist of high standing, has well stated the position of the conservative scholar in a recent essay on the evolution of intelligence:

"Is the evolutionary process at an end, so far as concerns the human brain and human intelligence? In the nature of the case no dogmatic reply can be offered with confidence, and one must fall back upon the probabilities of the case. I cannot altogether sympathize with the somewhat definite negative opinion occasionally advanced, for such negation has its chief justification in the vast extent of time throughout which little or no demonstrable advance has occurred in the organization of the human brain and therefore presumably in human intelligence. One cannot challenge the fact that for many thousands of years there has been little or no such change; but, on the other hand, the period of time for which we have such evidence, twenty or thirty thousand years, is so trifling compared to the total life of the race and the total duration of life itself on this planet, that a prediction based on such a relatively insignificant segment of man's history seems highly precarious. Assuming some extra-mundane observer of the primeval slime out of which organic life has come, it would certainly have seemed to such an one grotesque to predict such changes as have actually come to pass, and particularly as regards intelligence. Similarly it is entirely impossible to surmise at what point progress beyond present human capacities may occur, but to conclude with any certainty that such further progress will not occur, much more that it cannot occur, seems hardly warranted."

The evidences of evolution in the human mind, since the appearance, in Early Glacial time, of true human beings, are not limited to inferences which may be drawn, however fairly and certainly, from the increasing size of the brain during this period and from the varying size of the brain in different living human races. The anthropologists who study prehistoric man as well as those who study present-day man have a great mass of data before them. This they have made partially accessible to the general public, and the public can now trace the gradatory or evolutionary steps in the development of human capacity to make and use weapons, tools, and ornaments, to construct habitations and means of transportation, to carve and draw and paint, to repair wounds and fight disease, to develop social relations and societal organization, to develop religion; in a word, to become civilized.

Along with the actual fossil remains of Glacial and Post-Glacial man, hundreds of thousands of actual examples of man's handicraft have been found and studied and classified. These have enabled the modern student to recognize and define a long series of cultural stages in human evolution.

For a long time, certainly no less than one or two hundred thousand years, perhaps longer, man had no implements but stone ones, and these almost all composed of pieces of flint variously shaped by chipping and flaking, but showing in the process of shaping and finishing different degrees of perfection. For a long period these stone weapons and tools were made by simply knocking off coarse flakes from a piece of flint, the core thus rudely shaped serving as the implement. These cores were all about alike. Then followed a period in which more varied core shapes were made. Then came the step of making some of the chipped-off flakes useful by sharpening them by a retouching by pressure on one side. Then this retouching became more skillful and the flake implements were much improved; later they were retouched on both sides. Finally prismatic flakes were formed by blows transmitted through a point.

By the time man of the Old Stone, or Paleolithic, Age had reached the stage of making and using retouched flakes of flint, he had also begun, in a most simple way, to make and use tools made from the bones of the wild animals he killed for food. Then came the use of horn. Bone heads for javelins and spears, bone awls or pins, bone polishers, and later bone hammers and chisels or wedges were made. Reindeer antlers provided material for various horn implements such as harpoons and throwers.

Man of the Old Stone Age, at least after the first one or two hundred thousand years of his existence, undoubtedly used wood and skins and crude shell or other ornaments. He had fire, but there is no evidence extant that he made dwelling houses or tents. He lived under rock shelters and in caves. He made carvings out of bone and horn and mammoth ivory, and later, at least, made drawings on the rock surfaces of cave walls. He colored some of these drawings by using ocher of various tints. He had, indeed, a veritable art. He had certain burial practices, which suggest a simple religion.

The end of the Paleolithic Age, which was probably no less than 300,000 years after man had begun to exist, sees him with simple tools of considerable variety, sees him using fire, cooking food, wearing clothes, living in definite shelters, capable of a simple but true art, and probably possessing some kind of religion. Starting as "animals among animals," he had come this far—in 300,000 years!

Then came man of the New Stone, or Neolithic, Age, with his smooth, polished stone implements and a much greater variety of tools. With him came the bow and arrow, pottery, living in houses in communities, the domestication of plants and animals. But this was the time of Cro-Magnon man with a brain as large as ours to-day. This was only 30,000 years ago. After him came man of the various Metal ages, and then man of historic time. In those 30,000 years of Neolithic and Metal and historic ages has come all that man has to-day which he did not have at the end of the Old Stone Age, that is, 300,000 years after he first appeared on earth. What an acceleration of development! Why did human civilization move so slowly in those old days, and so rapidly in the new ones? There are two reasons. One is, that the biological evolution of human brain and mind from their condition in earliest prehistoric man to that in Cro-Magnon man took, as all biological evolution takes, much time. The second is, that when there was finally reached a certain stage in this evolution, a new kind of human evolution, which we may call societal to distinguish it from the strictly biological evolution, depending on social inheritance as distinct again from true biological inheritance, became possible. And this social evolution is capable of extremely rapid development and did develop extremely rapidly. The next chapter will be devoted to a special discussion of this matter.

Before, however, we leave the subject of the biological evolution of the human mind, and its illustrations and consequences, we should note again that the anthropologists find among living human races different stages of human civilization associated with and undoubtedly partly, at least, dependent on existing racial differences in the biological evolution of brain and mind. These stages show, as already pointed out in the last chapter, much parallelism with the various successive stages in time of prehistoric and historic man. There are human races living to-day which exist in a condition similar to that of the later periods of man of the Stone Age. There are still others living under circumstances like those of the metal ages which immediately preceded historic time. We thus have in the varying living human races a picture of the evolution of humankind confirming that which we gain from a study of the successive prehistoric races of man.

CHAPTER XIV

SOCIAL INHERITANCE AND SOCIETAL EVOLUTION

The word "inheritance" has come to have a double meaning in connection with human affairs, and hence its use is clouded by some misunderstanding. We speak of inheritance in connection with the passing on of money and goods from parents to children, and with the passing on from group to group and from generation to generation, by teaching, precept and example, of acquired and accumulated knowledge and customs and beliefs. This is social inheritance. Through it man is capable of transmitting knowledge and ideas, by various means, to such an extent that, as Julian Huxley has put it, "the experience of Moses, Archimedes and Charlemagne, of Jesus, Newton, and James Watt is modifying our behavior of to-day." But we speak also of a child's inheritance from parents and ancestors of eye and hair color, of bodily size and facial contour, of resistance and nonresistance to disease, of general mental capacity and of particular mental traits; in a word, of inherent structural, physiological and mental characteristics. This is biological inheritance, or heredity.

These two kinds of inheritance are fundamentally different and play different rôles in evolution, and these rôles vary in extent and importance in the evolution of different organisms. Among the plants and lower animals inheritance is almost exclusively biological. Among the higher animals, social inheritance appears and assumes a varying degree of importance. In some of the birds and mammals the parents seem to pass on to their young, by a certain amount of teaching, the beginnings of that knowledge necessary for carrying on certain life-saving behavior.

But, taken altogether, there is little social inheritance and societal evolution among the animals other than men. On the contrary, as important as biological inheritance is among human beings, social inheritance, from one point of view, is even more important. Or, to avoid the dilemma of attempting to compare the values of these two equally indispensable and mutually complementary factors which have made man what he now is, we may better say that however important biological inheritance has been, and is, and will continue to be in human evolution, we could never have attained without social inheritance, by this time, nor perhaps in any time, the high and dominant position in nature which we have attained.

This human evolution, dating it from the time when man was already human, or near-human, has been rapid. Of course "rapid" as thus used is a comparative term. As a matter of fact it has taken, as has been pointed out in an earlier chapter, probably a half million, certainly more than a hundred thousand, years for man to climb from the structural and cultural stage of earliest Glacial time to the stage of man of to-day. But this period is not a long one in geologic and evolutionary history. It is, indeed, a very short one. It may be roughly divided into two periods of very unequal length; a first, or Paleolithic period, when the evolution of man was almost wholly biological in character, and moved with the characteristically slow pace of biological evolution in general, and a second, or Neolithic-Metal Age-Historical period beginning only twenty or thirty thousand years ago, when the new factor of societal evolution based on social inheritance entered into human evolution and speeded it up enormously as regards its cultural and achieving phase.

Changes in man due to biological evolution have been slight, and apparently not at all progressive or advantageous, perhaps indeed even retrogressive, since the time of Cro-Magnon man twenty thousand years ago. Cro-Magnon man had a body in every way as well developed as ours, a brain as large, and probably a mental capacity as great, as ours. With the weakening of the natural selective processes which have come about as an incident of our growing altruism and our use of elaborate weapons, varied tools and machines, specialized houses, preventive and curative medicine and what-not other means for mass and individual self-protection and the amelioration of untoward natural conditions, the human body and its inherent physical capacities have almost certainly retrograded rather than advanced since the time of Cro-Magnon man. And there is no reason to believe that its inherent mental capacities—not its possibilities of mental achievement—have increased since that time.

Anthropologists are often asked, especially by those who would find arguments against man's evolutionary origin and development, whether they claim that man of to-day is natively superior to the early Greeks and the earlier Egyptians and Mesopotamians six or seven thousand years ago. And the question might well be broadened to include Cro-Magnon man of twenty thousand years ago. The answer would have to be the same. It is, "No."

But that does not mean that man has not had an evolutionary advance of startling character since that time. He has had this advance, but it is an advance in societal evolution, based on the rapid acquirement and accumulation of knowledge and its cumulative passing on from generation to generation by social inheritance.

This element of societal evolution, and the acceleration which it produces in human evolution, is apparent even in the prehistory of man. On examining the myriad articles of prehistoric human handicraft which have been found, and noting their relation to geologic time, it is easy to see that in the series of cultural stages in the life of prehistoric man, the earlier and cruder of these stages were of much longer duration than the later more rapidly succeeding and obviously higher ones. The short Neolithic time produced a much larger variety and a much greater refinement of weapons and tools and utensils and ornaments than were produced in the ten or twenty times longer period of Paleolithic time. And with the oncoming of the Metal Ages, each successively shorter, and of early Historic time, this acceleration of cultural development, due to the larger and larger influence of social inheritance and societal evolution, was more and more marked.

The importance of societal evolution in human development is also, of course, clearly revealed among living races of mankind by a comparison of the various cultural stages now represented among them and an analysis of the varying degree to which societal evolution is active in each of them.

Professor Breasted, the well-known American archæologist, was pursuing certain archæological investigations in the Valley of the Tigris during part of the Great War period. He found there some ancient mural decorations revealing many details of the condition of life among the inhabitants of this valley four thousand years ago. And he noticed that there was little difference between those details and those of the life of the native people living there to-day. Then, suddenly, a British expeditionary force swept into the region with all of the paraphernalia and methods devised by modern science for transport, personal comfort, and highly effective warfare. The contrast of a highly developed cultural stage and a crudely primitive one was striking. Yet there was little contrast in the inherent physical and mental capacities of these two groups of human beings. But in one the social inheritance and societal evolution factor was highly active and had produced its striking results, while in the other it had not yet played the rôle in human development to the extent possible to it.

The difference between the early Egyptians and Greeks, on the one hand, and modern man, on the other, is a difference in societal evolution. Modern man is not better endowed with body or brain than were the great men of Greece, but he is better endowed with accumulated knowledge and the material results of the applications of science. He can achieve much more than the Greeks could in those lines of human activity depending on accumulated scientific knowledge and perfected instruments of power and precision. Similarly, the marked differences in the extent to which societal evolution has advanced among living groups of peoples are recognized by our classification of a whole range of cultures, from those of "barbarians" to those of "civilized" peoples.

Raphael Zon has written a fascinating account of the age-old warfare of man and the forests. First, man was dominated by the forests, then he struggled on more and more even terms with them, and now he dominates them. At least, he does where he has developed a high degree of societal evolution. But there are still culturally primitive peoples who continue in the stage of domination by great forests.

A similar story could be written about man's relation to nature in a score and more of phases. His relation to the Tropics and the Arctics and to heat and cold in general; to the oceans and the deserts; to the bowels of the earth and the air and winds over it; to coal and ores and building stones; to the chemical elements, to magnetism and electricity; to the plants and animals and to the various races of his own species—each could be the subject of a fascinating story of the all-powerfulness of the social inheritance and societal evolution factor in his general evolutionary development.

And there is another story or group of stories, as yet only partly written, which reveals in some measure his interesting relations to the mysteries of his own body and mind. Man has always turned his eyes in upon himself and upon human nature in general as much as, or more than, he has turned his eyes toward the many phases of nature about him. His at first slowly growing and later ever more swiftly growing knowledge of his own bodily make-up and physiology; his struggles to understand the still deeper mysteries of his mind and his spirit—these play no less a part in his cultural development than his attempts to learn and master the secrets of that wide nature about him of which he is truly but a part, but of which he is unique in being a conscious and rationalizing part.

In any study of the beginnings of human civilization the relations of culture to speech and language call, perhaps, for first consideration. Is it possible for one to exist without the other? "Actually, of course," says Kroeber, in his recent important book, *Anthropology,* "no such case is known. Speculatively, different conclusions might be reached. It is difficult to imagine any generalized thinking taking place without words or symbols derived from words. Religious beliefs and certain phases of social organization also seem dependent on speech; caste ranking, marriage relations, kinship recognition, law and the like. On the other hand, it is conceivable that a considerable series of inventions might be made, and the applied arts might be developed in a fair measure by imitation, among a speechless people. Finally, there seems no reason why certain elements of culture, such as music, should not flourish as successfully in a society without as with language."

"On the whole, however," he continues, "it would seem that language and culture rest, in a way which is not yet fully understood, on the same set of faculties, and that these, for some reason that is still more obscure, developed in the ancestors of man, while remaining in abeyance in other species."

In the examination of certain of the fossils of early Paleolithic man, it has been noted that the conformation of the jaws and the smallness of the bony areas to which certain special muscles used in speaking are attached, suggest that these earlier human beings were restricted in their speaking possibilities, or at least made limited use of speech. On the other hand, those areas of the brain cortex in which the nervous activities connected with speech are most centralized in present man, are fairly well developed in these early men, as is shown by casts of the skull interiors, which conform closely to the brain surface. Fossil man, then, apparently had the language faculty, and probably spoke. But the history and causes of the development in incipient man of the group of traits that may be called the faculties for speech and civilization, remain, as Kroeber points out, one of the darkest areas in the field of knowledge.

In the study of the beginnings of human civilization there are and probably must remain serious gaps because of the lack of preserved materials to illuminate this study. While stone implements are abundant from the time of the very earliest human fossils, implements of wood or articles of clothing do not appear until much later. But this may be because of their lack of preservation rather than their lack of early existence. However, metal implements, which could have endured from early times, as well as stone and bone and horn implements, are not found of older date than the Metal Ages five or six thousand years ago. So it seems reasonable to assume that they did not exist in the older Stone Ages. Drawings on cave walls and carvings of horn and bone go back only to a certain period long subsequent to the time of the earliest human fossils and implements.

Altogether, despite gaps and the one-sidedness of information due to possible lack of preservation of certain kinds of early human handicraft, and the preservation of others, much has been learned of the beginnings of human civilization, while of course much more is known of its progress after the earliest days of human existence. Where archæology can take the place of paleontology in revealing the records of prehistoric man, and the ethnologic study of primitive still living human groups can add its parallel testimony to that of archæology, we have a fairly clear and continuous story of the later development of prehistoric human civilization. The migrations of early peoples, their religions and tribal and family relations and customs, their numerous legends, their gradually increasing domestication of animals and plants, and their developing and diversifying hunting, fishing, agricultural, industrial and housing advances, are all revealed with more or less fullness by the available records. Finally, where history can take the place of archæology, the accounts of human civilizing processes and of civilization itself are comparatively complete.

Now, in all this story of human development since the days when man was merely "animal among animals," it is societal evolution rather than biological evolution which appears as the determining factor. And yet—and this is of fundamental importance—there has been a constant relation between man's biological and his societal evolution which must never be overlooked, and which, as an inevitable and continuing relation, must be constantly regarded as we seek for light on the possibilities and probabilities of future human evolution. For, on the one hand, societal evolution could never have played the part it has played in human development unless and until man's biological evolution had carried him to such a stage of mental and peculiar physical development as to make possible conscious thought and the accumulation and transference of knowledge by speech and writing; for these are the basis of social inheritance and societal evolution. And, on the other hand, as soon as societal evolution came well into existence, the further biological evolution of man could be and has been more or less controlled, and its direction, consciously or unconsciously, determined by his societal evolution.

CHAPTER XV

THE HUMAN FUTURE

We are living in a period of feverish "time-binding" activity. We are bringing together, as never before, the yesterdays with to-day. The archæologists are opening, before the expanding eyes of the world, the tombs of Egyptian Pharaohs which were sealed thirty centuries ago. The anthropologists are uncovering less conspicuous, but more significant, relics of prehistoric types of man who lived all the way from tens to hundreds of thousands of years ago. We are truly learning the human past.

But what of the human future? Can we project our vision into the centuries to come and see man then? Have our intensive studies of man of yesterday and to-day given us any knowledge that we can use in helping us to picture man of to-morrow; to say whither man now is tending?

Man has an insistent urge to speculate about his future, most keenly about his future as individual, but also, with lively interest, about his future as race or species. We guess; we try to find clues; we welcome, and sometimes accept all too readily, declarations from any sources that have some seeming of authority. But in all this speculating, one type of man, the scientific type, tries to guard his speculations about the human future by holding to those same methods of inquiry which he has used with encouraging success in seeking answers to other great problems of nature. For the scientific man believes that man, for all of his high estate, is in and a part of nature, not above or out of it, and that human make-up and life and fate are to be studied as are other parts and phenomena of nature. He attempts, therefore, to get some glimpse of where man is tending in his evolutionary movement by studying the paths and the causes by which man has reached, from an earlier and different status, his status of to-day.

Something of an outline of these paths and causes has been given in the earlier chapters of this book. We have had a fleeting picture of man slowly, very slowly at first, rising out of the welter of animal life from beastliness to humanness. "Animal among animals" in those earliest days of his first emergence in human, or near-human guise, he depended on brute strength in his struggle for existence, but with the advantage of already sharpened wits. Then, by virtue of these ever increasing wits, he added to his defensive and aggressive resources by devising simple weapons and tools made of the flint stones all about him and of the bones and horns of the great mammals which were his competing associates. Then, as his brain grew in size and his mentality in capacity, he came to depend ever more and more on this great advantage in his struggle to live and spread and adapt himself to varying natural conditions. He rapidly devised and used a myriad of new articles of handicraft and new means of dominating and making use of natural forces and resources. And he developed that important new element, making for a rapid acceleration of evolutionary advancement, to which we have referred—societal evolution in contrast with that strictly biological evolution to which the plants and other animals are almost exclusively restricted for advance. Finally, he reached the status in which we know him to-day, with all his wonderful achievements and visions of others still more wonderful, his high development of the societal evolution factor and the recognition of his growing power, through this development, to play a conscious rôle in helping to determine his future fate. This is the outline of man's ascent from beastkind to first humankind and then to humankind of to-day. And now, seeing what has so far come to pass, conscious of our present status in nature, and certain that change, for better or worse, is inevitable, we utter that insistent inquiry: What of the human future?

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In attempting even the beginnings of a consideration of this inquiry, the distinction between those two major factors in human evolution which have been called biological evolution and societal evolution must be kept clearly in mind. But at the same time we must keep in mind the fact that although these major elements can be treated for the purposes of analytical discussion as more or less separable factors, they are, in reality, closely intermingled and mutually interacting.

The biological evolution of man, as of the plants and other animals, has been, is being to-day, and will be in the future, determined by the complex interaction of such familiar fundamental evolutionary factors as variation, heredity, selection, and influence of environment. But man is able, consciously, to modify the natural working of some of these factors not only with regard to himself, but also with regard to various plant and animal kinds which he has domesticated. He has unconsciously modified the conditions affecting the life of many wild plants and animals by acting as a powerful environmental agent. As such agent he has determined what shall be the environment, who shall be parents, what lines of variation and heredity shall persist and what be extinguished.

All this influence exerted by man, both consciously and unconsciously, on the evolution of various plants and animals, and on his own biological evolution, is one of the consequences of the varying form which his societal evolution has taken at various times in various places. It would not be difficult to estimate, with some reasonable approach to accuracy, the extent and character of the results of this man-exerted influence as it has affected the fate of many plants and animal kinds. Consider the extinction of the American bison and passenger pigeon, the increase of the rabbit in Australia and the mongoose in Jamaica, the geographical restriction of the protozoan parasites of malaria and yellow fever, the modifications through artificial selection and forced hybridization of the host of domesticated plants and animals. However, it would be very difficult, not to say impossible, to trace through the haze of prehistoric time and the growing complexity of human life, the character and extent of the results on man's biological evolution exerted by his early folkways, with their marriage restrictions, infanticide, sacrificial rites of magic and religion, food tabus, priestly medical practice and malpractice, and the many other family and tribal customs which exercised, directly or indirectly, a certain degree of artificial selection within various human groups.

But we can see in our life of to-day and in earlier historic time the reality of similar selective influences and, in some degree, the reality of their results.

Especially can we see very plainly a number of influences that cannot but have, and must already have had, a seriously deleterious effect on the biological evolution of humankind. Think of the draining of the "blood of the best" by drastic war; the loss to the Teutonic stock by the Thirty Years' War, to the French stock by the Napoleonic Wars, to the American stock by the Civil War and again to the French and German stocks by the Great War. Realize what the wearing out of women and children in the treadmills of modern industry must mean to the race. And, what, too, is resulting from the selective birthrates in civilized nations where inferior stocks are increasing at the expense of superior stocks; and the undiscriminating altruism that keeps alive and ever breeding the hopelessly defective and unfit Jukes and Nams and Kallikaks. All these and other readily discernible unfortunate influences proceeding out of the present form of our societal evolution, have had or are having their inevitable effects on our biological evolution, effects that we must recognize as malign in their relation to the human future.

The figures just published by Sir George Newman, chief medical officer of the Board of Education in England, in his annual report for 1922, show that more than forty per cent of the children in the elementary schools of England and Wales are defective in some degree. Professor Karl Pearson, the eminent vital statistician of the University of London, declares that one fourth of England's population is producing one half of England's next generation and that this fourth is that part of England's people most poorly endowed by both biological and social inheritance.

Thoughtful students of human evolution have been more and more impressed with the growing extent of these hurtful influences and their effects on the human future. In two recent books by Professor S. J. Holmes of the University of California, called *The Trend of the Race* and *Studies in Evolution and Eugenics,* this feeling is expressed in strong, even poignant, terms. Professor Holmes makes a very gloomy forecast for the future of the human family, unless a change is produced in the conditions affecting its evolutionary course. Similar views are advanced by Professor E. M. East of Harvard University in his even more recent book *Mankind at the Crossroads.*

We must give a serious attention to the situation. It is not sufficient, it is definitely dangerous, to brush aside these pessimistic utterances with an impatient resentment at feeling ourselves and our evolutionary fate examined cool-bloodedly by biologists from the same point of view as they examine the fate of animal and plant kinds. It is dangerous to assume that a fate determined by natural factors and the familiar evolutionary processes may be accepted as inevitable in the case of plants and animals, but that we, all-powerful creatures of a superior kind, capable of self-understanding and self-determination, are exempt from these biological controls which determine the individual and racial fate of the lower creatures.

That is to be fatally blind. All the history of the human race and of human groups tells us otherwise. We have originated and risen as have other animal species. And we are not exempt from the natural laws of life and evolution. Other animal groups and species have appeared and risen and persisted or fallen. We have appeared and risen and so far persisted—but we may fall. Indeed, when we examine ourselves as subdivided into groups or nations, each with its own history of development and fate, we see that some of us have fallen. And in most of these cases of the fall of groups, analysis will reveal biological factors as potent determinants in these catastrophes.

Fortunately, in our evolutionary rise there has been included such a development of mind that we alone among living creatures can know and understand something, at least, of the natural conditions and laws which control organic evolution. And we are able to cumulate this knowledge by social inheritance, and thus to develop in high degree certain possibilities in the way of biologic control.

In that respect alone are we different, in our relation to our evolution, from the plants and other animals. By this we are indeed given a certain control of our evolutionary fate. But this control is one not in despite of natural laws. It is a control by virtue of the fact that we can understand these laws and make use of our understanding to adapt ourselves to them, to take advantage of them and use them in a conscious attempt to give ourselves the evolutionary fate which we desire.

Thoughtful and informed men understand this, and on this understanding, and on the possibility of making everybody, or at least a governing majority, similarly understand this, depends our hope and our possibility of proving ill-founded the gloomy forebodings of such students of human biology and sociology as Holmes and East and the numerous other prophets of the decline of the race.

There are encouraging signs of a widening interest and action in this matter. The modern eugenist disciples of Plato, with Galton at their head until his death, are now ever-increasingly numerous and active in all civilized countries. There is a growing tendency to temper altruism by intelligence. We find a great advance in guarding the public health, and a strong opposition to war as a powerful agent making for a dangerous artificial selection, a "reversed selection," as it has been called. We see an American effort to safeguard its stock from the effects of ill-advised race mixture resulting from indiscriminate immigration; the growing attempts to ameliorate the disastrous effects on women and children of selfish industrial methods; the active inquiry into the merits and demerits of birth control; the earnest and partly successful efforts to understand better the nature and distribution of intelligence; and, finally, the constant increase of general education in biological facts and principles. All these, and numerous other encouraging present-day societal activities, which have a more or less direct influence on our biological evolution, are to be put on the right side of the ledger account of the present conditions in human life to offset those sad entries on the other side which provide the basis for the gloomy prognostications so much in evidence to-day.

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There are thus three all-important things to be kept in mind by those who already know them, and to be introduced into the minds of those who do not. First, that human evolution, hence the human future, is determined by two groups of causal factors, one group comprising those producing biological evolution and the other those producing societal evolution. Second, that through societal evolution the course of biological evolution can be largely directed. And, third, that the determination of our societal evolution depends in a great measure on our own decisions and efforts. We may, by education, propaganda, and legislation, develop this societal evolution in such a way as to make it directly helpful or hurtful in its relation to our future through its immediate effects as an environmental agent, and indirectly helpful or hurtful through its influence on our biological, or fundamentally racial, evolution.

These things are certain, and should be as widely and clearly understood as possible. Two other things about which there is less certainty should also be taken into consideration and intensively studied. One is the question as to whether or not there are elements in human life which tend to mold our societal evolution despite our own efforts to determine it. The disconcerting way in which we continue to indulge in destructive war, despite the knowledge of informed men of its societal and biological danger and the desire of the great majority of civilized human beings to avoid it, and the impotence with which we seem to face the pressing needs of post-war rehabilitation make us fear that we are in the grip of obscure but powerful forces which have their way with us despite our wishes. The other uncertain matter is the still open question as to whether or not effects produced on individuals by environmental influences can be introduced in some degree into our heredity: in other words, whether it is really true, as most biologists hold, that no kinds of acquired characters can be inherited. These two matters need concentrated and prolonged scientific study. The results of such study may modify the attitude that we must take toward human evolution and hence the human future.

But in the present state of our knowledge of the factors which enter into the determination of the fate of humankind we must leave these uncertain matters by the side, and fasten our attention on things that are certain. In the light which these give us, what shall we do to insure, as far as our conscious efforts can insure, and according to our understanding of human values, the human future we should like to have? How shall we make our children's land, and the land of our children's children a better land than ours?

Let us selfishly, if it seems so, confine our attention, for the moment, to America, to our own people. Let us think of the human future in terms of the American future. While many of the evolutionary problems of different peoples are common to all of them, some are particular to each people. For example, the problem of immigration, with its social and its biological, or racial, effects, is peculiarly an

American problem. So is the negro problem, which also has both social and biological phases. The problem of the decrease of good stocks through a selective birthrate is a problem common to all civilized peoples. So is the problem of the relation of a growing population to the food supply. There is, indeed, a host of problems posed to us by any examination of our life of to-day, which we must squarely face if we would look forward to our future with any attempt to help determine it. For this future will almost certainly not be determined for us by sudden destructive catastrophe nor by sudden benevolent act of Providence, happening without some foreknowledge on our part or unrelated to our present conditions and mode of life. Just as these conditions and mode have gradually and obviously grown out of our past conditions of life and manner of behavior, so the future will grow out of to-day. The future will be the effect of present causes; it is being shaped now.

These causes lie in our present-day societal organization and behavior and our present biological status. They will produce the future both through societal and through biological evolution. Now, we know enough to be sure that, as regards our societal organization, we want such changes as will enable our people to be more widely and more soundly educated, more competently protected from disease and accident, more comfortably housed and wisely fed, more secure from harrowing class struggle, more encouraged and stimulated to live according to the Golden Rule. And we also know enough to be sure that we want our societal evolution to be of a kind which will influence our biological evolution to move along eugenic, not dysgenic, lines; to develop an American stock of inherently sounder bodies and higher intelligence. We do not want the American blood to be drained of its best elements by destructive war, or to be diluted and discolored by indiscriminate mingling with poorer blood. We do not want the inferior elements in our racial stock to increase while the superior elements decrease. We do not want our inherently mentally defective and our hereditarily infirm to multiply until our asylums outnumber our universities and colleges. We do want the opposite of all this. We want everything in our societal organization and behavior which directly or indirectly affects our biological evolution—and most of it does—to affect this evolution in such a way as to make it move forward and upward, not backward and downward.

We cannot change this biological evolution into radically new lines; we can only go forward or backward along a path already well determined. The human species has attained such a specialization of structure, physiology and psychology that the stage of generalization, from which many different paths lead out, any one of which may be followed, has long ago been passed. Our evolution has been more and more canalized. We can go farther, or we can stop, or we can go backward. But we cannot branch out laterally. We cannot undertake new lines of development.

This canalization of evolutionary movement by the attainment of a high degree of specialization is a familiar matter to the biologist and paleontologist. He knows many examples in the biological history of plant and animal kinds, of the ever increasing success of specialized species in the face of a particular environment, and later their slow extinction because their specialization has not been of a kind to be successful in the face of a changing environment. He recalls the rise and fall of the mighty reptilian monsters of the inland American seas of Triassic, Jurassic and Cretaceous times. As their environment slowly changed these highly specialized monsters faded out. They were beyond readapting themselves to the new conditions.

But the fate of extinction through overspecialization is not indicated for man. For one of the happy features in man's specialization is that of a great capacity for adaptation through his possession of a mind of intelligence and reason and, by virtue of it, a capacity for dominating nature and using natural resources to his advantage. He can overcome cold and heat, humidity and dryness, although naturally very susceptible to them; he can move across the oceans or through the air although he has no fins or wings; he can conquer forests and swamps, deserts and mountains; distance and darkness; he converts energy of one kind into another and makes new combinations of chemical elements for his use. In a word, he adapts himself to nature, not by changes of structure but by exercise of wits, and he modifies nature to suit himself. This particular character of his high specialization can save him from the fate that so often attends over-specialization among plants and animals.

But, nevertheless, he cannot diverge widely from the canalized path of evolution which the character of his biological specialization has determined for him. So he must bring all his great capacity for understanding and for acting to bear on the problem of making this already determined evolutionary path lead him to the happy and beneficent future which he so much desires and in the achieving of which he has so important a personal rôle to play. In a word, the problem of the human future, both societal and biological, is a problem of which man holds the solution very largely in his own hands. It depends on his own intelligent conscious endeavor to solve this problem happily. There are different possible human futures. The one which man wants and works for is the one which men can have.

We can say the same of the American future. It is only a part, to be sure, of the general human future, but it is a part the particular features of which can be determined by the American people. If they determine this wisely they will influence for the good not only their own but the general human future. Circumstances have combined to give America a peculiar place among the present peoples of the earth. They have given her an unusual power to work for the good of the race. This unusual power gives her an unusual responsibility. To a peculiar and perhaps hardly sufficiently recognized degree, the human future depends on the influence which America will, for good or ill, inevitably exert during the next few years. Let her take science as a handmaiden and make her serve in the cause of assuring human capacity and happiness. Let her direct the evolution of her own people in the way she would have it go; for the means to do this are in her own hands. If she does this she will not only do greatly for herself, but she will go far toward assuring the best evolution of all humankind.

INDEX

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