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## *COLUMBIA UNIVERSITY LECTURES*

**THE DOCTRINE OF EVOLUTION**

**ITS BASIS AND ITS SCOPE**

**BY**

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# PREFACE

The present volume consists of a series of eight addresses delivered as the Hewitt Lectures of Columbia University at Cooper Union in New York City during the months of February and March, 1907. The purpose of these lectures was to describe in concise outline the Doctrine of Evolution, its basis in the facts of natural history, and its wide and universal scope. They fall naturally into two groups. Those of the first part deal with matters of definition, with the essential characteristics of living things, and, at greater length, with the evidences of organic evolution. The lectures of the second group take up the various aspects of human evolution as a special instance of the general organic process. In this latter part of the series, the subject of physical evolution is first considered, and this is followed by an analysis of human mental evolution; the chapter on social evolution extends the fundamental principles to a field which is not usually considered by biologists, and its purpose is to demonstrate the efficiency of the genetic method in this department as in all others; finally, the principles are extended to what is called "the higher human life," the realm, namely, of ethical, religious, and theological ideas and ideals.

Naturally, so broad a survey of knowledge could not include any extensive array of specific details in any one of its divisions; it was possible only to set forth some of the more striking and significant facts which would demonstrate the nature and meaning of that department from which they were selected. The illustrations were usually made concrete through the use of photographs, which must naturally be lacking in the present volume. In preparing the addresses for publication, the verbal form of each evening's discussion has been somewhat changed, but there has been no substantial alteration of the subjects actually discussed.

The choice of materials and the mode of their presentations were determined by the general purpose of the whole course. The audiences were made up almost exclusively of mature persons of cultivated minds, but who were on the whole quite unfamiliar with the technical facts of natural history. It was necessary to disregard most of the problematical elements of the doctrine so as to bring out only the basic and thoroughly substantiated principles of evolution. The course was, in a word, a simple message to the unscientific; and while it may seem at first that the discussions of the latter chapters lead to somewhat insecure positions, it should be remembered that their purpose was to bring forward the proof that even the so-called higher elements of human life are subject to classification and analysis, like the facts of the lower organic world.

It may seem that the biologist is straying beyond his subject when he undertakes to extend the principles of organic evolution to those possessions of mankind that seem to be unique. The task was undertaken in the Hewitt Lectures because the writer holds the deeply grounded conviction that evolution has been continuous throughout, and that the study of lower organic forms where laws reveal themselves in more fundamental simplicity must lead the investigator to employ and apply those laws in the study of the highest natural phenomena that can be found. Another motive was equally strong. Too frequently men of science are accused of restricting the application of their results to their own particular fields of inquiry. As individuals they use their knowledge for the development of world conceptions, which they are usually reluctant to display before the world. It is because I believe that the accusation is often only too well merited that I have endeavored to show as well as circumstances permit how universal is the scope of the doctrine based upon the facts of biology, and how supreme are its practical and dynamic values.

It remains only to state that the present volume contains nothing new, either in fact or in principle; the particular form and mode of presenting the evolutionary history of nature may be considered as the author's personal contribution to the subject. Nothing has been stated that has not the sanction of high authority as well as of the writer's own conviction; but it will be clear that the believers in the truth of the analysis as made in the later chapters may become progressively fewer, as the various aspects of human life and of human nature are severally treated. Nevertheless, I believe that this volume presents a consistent reasonable view that will not be essentially different from the conceptions of all men of science who believe in evolution.

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# I

**EVOLUTION. THE LIVING ORGANISM AND ITS NATURAL HISTORY**

The Doctrine of Evolution is a body of principles and facts concerning the present condition and past history of the living and lifeless things that make up the universe. It teaches that natural processes have gone on in the earlier ages of the world as they do to-day, and that natural forces have ordered the production of all things about which we know.

It is difficult to find the right words with which to begin the discussion of so vast a subject. As a general statement the doctrine is perhaps the simplest formula of natural science, although the facts and processes which it summarizes are the most complex that the human intellect can contemplate. Nothing in natural history seems to be surer than evolution, and yet the final solution of evolutionary problems defies the most subtle skill of the trained analyst of nature's order. No single human mind can contain all the facts of a single small department of natural science, nor can one mind comprehend fully the relations of all the various departments of knowledge, but nevertheless evolution seems to describe the history of all facts and their relations throughout the entire field of knowledge. Were it possible for a man to live a hundred years, he could only begin the exploration of the vast domains of science, and were his life prolonged indefinitely, his task would remain forever unaccomplished, for progress in any direction would bring him inevitably to newer and still unexplored regions of thought.

Therefore it would seem that we are attempting an impossible task when we undertake in the brief time before us the study of this universal principle and its fundamental concepts and applications. But are the difficulties insuperable? Truly our efforts would be foredoomed to failure were it not that the materials of knowledge are grouped in classes and departments which may be illustrated by a few representative data. And it is also true that every one has thought more or less widely and deeply about human nature, about the living world to which we belong, and about the circumstances that control our own lives and those of our fellow creatures. Many times we withdraw from the world of strenuous endeavor to think about the "meaning of things," and upon the "why" and "wherefore" of existence itself. Every one possesses already a fund of information that can be directly utilized during the coming discussions; for if evolution is true as a universal principle, then it is as natural and everyday a matter as nature and existence themselves, and its materials must include the facts of daily life and observation.

Although the doctrine of evolution was stated in very nearly its present form more than a century ago, much misunderstanding still exists as to its exact meaning and nature and value; and it is one of the primary objects of these discussions to do away with certain current errors of judgment about it. It is often supposed to be a remote and recondite subject, intelligible only to the technical expert in knowledge, and apart from the everyday world of life. It is more often conceived as a metaphysical and philosophical system, something antagonistic to the deep-rooted religious instincts and the theological beliefs of mankind. Truly all the facts of knowledge are the materials of science, but science is not metaphysics or philosophy or belief, even though the student who employs scientific method is inevitably brought to consider problems belonging to these diverse fields of thought. A study of nervous mechanism and organic structure leads to the philosophical problem of the freedom of the will; questions as to the evolution of mind and the way mind and matter are related force the investigator to consider the problem of immortality. But these and similar subjects in the field of extra-science are beyond its sphere for the very good reason that scientific method, which we are to define shortly, cannot be employed for their solution. Evolution is a science; it is a description of nature's order, and its materials are facts only. In method and content it is the very science of sciences, describing all and holding true throughout each one.

The overwhelming importance of knowing about natural laws and universal principles is not often realized. What have we to do with evolution and science? Are we not too busy with the ordering of our immediate affairs to concern ourselves with such remote matters? So it may appear to many, who think that the study of life and its origin, and of the vital facts about plants and animals may be interesting and may possess a certain intellectual value, but nothing more. The investigation of man and of men and of human life is regarded by the majority as a mere cultural exercise which has no further result than the recording of present facts and past histories; but it is far otherwise. Science and evolution must deal with mere details about the world at large, and with human ideals and with life and conduct; and while their purpose is to describe how nature works now and how it has progressed in the past, their fullest value is realized in the sure guidance they provide for our lives. This cannot be clear until we reach the later portions of our subject, but even at the outset we must recognize that knowledge of the great rules of nature's game, in which we must play our parts, is the most valuable intellectual possession we can obtain. If man and his place in nature, his mind and social obligations, become intelligible, if right and wrong, good and evil, and duty come to have more definite and assignable values through an understanding of the results of science, then life may be fuller and richer, better and more effective, in direct proportion to this understanding of the harmony of the universe.

And so we must approach the study of the several divisions of our subject in this frame of mind. We must meet many difficulties, of which the chief one is perhaps our own human nature. For we as men are involved, and it is hard indeed to take an impersonal point of view,—to put aside all thoughts of the consequences to us of evolution, if it is true. Yet emotion and purely human interest are disturbing elements in intellectual development which hamper the efforts of reason to form assured conceptions. We must disregard for the time those insistent questions as to higher human nature, even though we must inevitably consider them at the last. Indeed, all the human problems must be put aside until we have prepared the way for their study by learning what evolution means, what a living organism is, and how sure is the evidence of organic transformation. When we know what nature is like and what natural processes are, then we may take up the questions of supreme and deep concern about our own human lives.

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Human curiosity has ever demanded answers to questions about the world and its make-up. The primitive savage was concerned primarily with the everyday work of seeking food and building huts and carrying on warfare, and yet even he found time to classify the objects of his world and to construct some theory about the powers that made them. His attainments may seem crude and childish to-day, but they were the beginnings of classified knowledge, which advanced or stood still as men found more or less time for observation and thought. Freed from the strife of primeval and medieval life, more and more observers and thinkers have enlarged the boundaries and developed the territory of the known. The history of human thought itself demonstrates an evolution which began with the savages' vague interpretation of the "what" and the "why" of the universe, and culminates in the science of to-day.

What, now, is a science? To many people the word denotes something cold and unfeeling and rigid, or something that is somehow apart from daily life and antagonistic to freedom of thought. But this is far from being true. Karl Pearson defines science as *organized knowledge*, and Huxley calls it *organized common sense*. These definitions mean the same thing. They mean that in order to know anything that deserves confidence, in order to obtain a real result, it is necessary in the first place to establish the reality of facts and to discriminate between the true, the not so sure, the merely possible, and the false. Having accurate and verified data, scientific method then proceeds to classify them, and this is the *organizing* of knowledge. The final process involves a summary of the facts and their relations by some simple expression or formula. A good illustration of a scientific principle is the natural law of gravitation. It states simply that two bodies of matter attract one another directly in proportion to their mass, and inversely in proportion to the square of the distance between them. In this concise rule are described the relations which have been actually determined for masses of varying sizes and at different distances apart,—for snowflakes falling to the earth, for the avalanche on the mountain slope, and for the planets of the solar system, moving in celestial coördination.

Such a principle as the law of gravitation, like evolution, is true if the basic facts are true, if they are reasonably related, and if the conclusion is drawn reasonably from them. It is true for all persons who possess normal minds, and this is why Huxley speaks of science as "common sense,"—that is, something which is a reasonable and sensible part of the mental make-up of thinking persons that they can hold in common. The form and method of science are fully set forth by these definitions, and the purpose also is clearly revealed. For the results of investigation are not merely formulæ which summarize experience as so much "conceptual shorthand," as Karl Pearson puts it, but they must serve also to describe what will probably be the orderly workings of nature as future experience unfolds. Human endeavor based upon a knowledge of scientific principles must be far more reliable than where it is guided by mere intuition or unreasoned belief, which may or may not harmonize with the everyday world laws. Just as the law of gravitation based upon past experience provides the bridge builder and the architect with a statement of conditions to be met, so we shall find that the principles of evolution demonstrate the best means of meeting the circumstances of life.

Evolution has developed, like all sciences, as the method we have described has been employed. Alchemy became chemistry when the so-called facts of the medievalist were scrutinized and the false were discarded. Astrology was reorganized into astronomy when real facts about the planets and stars were separated from the belief that human lives were influenced by the heavenly bodies. Likewise the science of life has undergone far-reaching changes in coming down to its present form. All the principles of these sciences are complete only in so far as they sum up in the best way the whole range of facts that they describe. They cannot be final until all that can be known is known,—until the end of all knowledge and of time. It is because he feels so sure of what has been gained that the man of science seems to the unscientific to claim finality for his results. He himself is the first to point out that dogmatism is unjustified when its assertions are not so thoroughly grounded in reasonable fact as to render their contrary unthinkable. He seeks only for truth, realizing that new discoveries must oblige him to amend his statement of the laws of nature with every decade. But the great bulk of knowledge concerning life and living forms is so sure that science asserts, with a decision often mistaken for dogmatism, that evolution is a real natural process.

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The conception of evolution in its turn now demands a definite description. How are we to regard the material things of the earth? Are they permanent and unchanged since the beginning of time, unchanging and unchangeable at the present? We do not need Herbert Spencer's elaborate demonstration that this is unthinkable, for we all know from daily experience that things do change and that nothing is immutable. Did things have a finite beginning, and have they been "made" by some *supernatural* force or forces, personified or impersonal, different from those agencies which we may see in operation at the present time? So says the doctrine of special creation. Finally, we may ask if things have changed as they now change under the influence of what we call the natural laws of the present, and which if they operated in the past would bring the world and all that is therein to be just what we find now. This is the teaching of the doctrine of evolution. It is a simple brief statement of natural order. And because it has followed the method of common sense, science asserts that changes have taken place, that they are now taking place, and furthermore that it is unnecessary to appeal to other than everyday processes for an explanation of the present order of things.

Wherever we look we see evidence of nature's change; every rain that falls washes the earth from the hills and mountains into the valleys and into the streams to be transported somewhere else; every wind that blows produces its small or greater effect upon the face of the earth; the beating of the ocean's waves upon the shore, the sweep of the great tides,—these, too, have their transforming power. The geologists tell us that such natural forces have remodeled and recast the various areas of the earth and that they account for the present structure of its surface. These men of science and the astronomers and the physicists tell us that in some early age the world was not a solid globe, with continents and oceans on its surface, as now; that it was so very hot as to be semi-fluid or semi-solid in consistency. They tell us that before this time it was still more fluid, and even a mass of fiery vapors. The earth's molten bulk was part of a mass which was still more vast, and which included portions which have since condensed to form the other bodies of the solar system,—Mars and Jupiter and Venus and the rest,—while the sun remains as the still fiery central core of the former nebulous materials, which have undergone a natural history of change to become the solar system. The whole sweep of events included in this long history is called cosmic evolution; it is the greater and more inclusive process comprising all the transformations which can be observed now and which have occurred in the past.

At a certain time in the earth's history, after the hard outer crust had been formed, it became possible for living materials to arise and for simple primitive creatures to exist. Thus began the process of organic evolution—*the natural history of living things*—with which we are concerned in this and later addresses. Organic evolution is thus a part of the greater cosmic process. As such it does not deal with the origin of life, but it begins with life, and concerns itself with the evolution of living things. And while the investigator is inevitably brought to consider the fundamental question as to the way the first life began, as a student of organic forms he takes life for granted and studies only the relationships and characteristics of animals and plants, and their origins.

But even as a preliminary definition, the statement that organic evolution means *natural change* does not satisfy us. We need a fuller statement of what it is and what it involves, and I think that it would be best to begin, not with the human being in which we are so directly interested, nor even with one of the lower creatures, but with something, as an analogy, which will make it possible for us to understand immediately what is meant by the evolution of a man, or of a horse, or of an oak tree. The first steam locomotive that we know about, like that of Stephenson, was a crude mechanism with a primitive boiler and steam-chest and drive-wheels, and as a whole it had but a low degree of efficiency measured by our modern standard; but as time went on inventive genius changed one little part after another until greater and greater efficiency was obtained, and at the present time we find many varied products of locomotive evolution. The great freight locomotive of the transcontinental lines, the swift engine of the express trains, the little coughing switch engine of the railroad yards, and the now extinct type that used to run so recently on the elevated railroads, are all in a true sense the descendants of a common ancestor, namely the locomotive of Stephenson. Each one has evolved by transformations of its various parts, and in its evolution it has become adapted or fitted to peculiar circumstances. We do not expect the freight locomotive with its eight or ten powerful drive-wheels to carry the light loads of suburban traffic, nor do we expect to see a little switch engine attempt to draw "the Twentieth Century Limited" to Chicago. In the evolution, then, of modern locomotives, differences have come about, even though the common ancestor is one single type; and these differences have an adaptive value to certain specific conditions. A second illustration will be useful. Fulton's steamboat of just a century ago was in a certain true sense the ancestor of the "Lusitania," with its deep keel and screw propellers, of the side-wheel steamship for river and harbor traffic like the "Priscilla," of the stern-wheel flat-bottom boats of the Mississippi, and of the battleship, and the tug boat. As in the first instance, we know that each modern type has developed through the accumulation of changes, which changes are likewise adjustments to different conditions. The diversity of modern types of steamships may be attributed therefore to adaptation.

The several kinds are no more interchangeable than are the different forms of locomotives that we have mentioned. The flat-bottom boat of the Mississippi would not venture to cross the Atlantic Ocean in winter, nor would the "Lusitania" attempt to plow a way up the shallow mud-banked Mississippi. These products of mechanical development are not efficient unless they run under the circumstances which have controlled their construction, unless they are fitted or adapted to the conditions under which they must operate.

Evolution, then, means *descent with adaptive modification*. We must examine the various kinds of living creatures everywhere to see if they, like the machines, exhibit in their make-up similar elements which indicate their common ancestry in an earlier age, and if we can interpret their differences as the results of modifications which fit them to occupy different place in nature.

Two objections to the employment of these analogies will present themselves at once. The definition may be all very well as far as the machines are concerned, but, it may be asked, should a living thing like a horse or a dog be compared with the steamship or the locomotive? Can we look upon the living thing as a mechanism in the proper sense of the word? A second objection will be that human invention and ingenuity have controlled the evolution of the steamship and engine by the perfection of newer and more efficient parts. It is certainly true that organic evolution cannot be controlled in the same way by men, and that science has not yet found out what all the factors are. And yet we are going to learn in a later discussion that nature's method of transforming organisms in the course of evolution is strikingly similar to the human process of trial and error which has brought the diverse modern mechanisms to their present conditions of efficiency. This matter, however, must remain for the time just as it stands. The first objection, namely, that an organism ought not to be viewed as a machine, is one that we must meet immediately, because it is necessary at the very outset to gain a clear idea of the essentially mechanical nature of living things and of their relations to the conditions under which they live. It is only when we have such a clear understanding that we can profitably pursue the further inquiries into the evidence of evolution. Our first real task, therefore, is an inquiry into certain fundamental questions about life and living things, upon which we shall build as we proceed.

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All living things possess three general properties which seem to be unique; these are a peculiar chemical constitution, the power of repairing themselves as their tissues wear out, and the ability to grow and multiply. The third property is so familiar that we fail to see how sharply it distinguishes the creatures of the organic world. To realize this we have only to imagine how strange it would seem if locomotives and steamships detached small portions of themselves which could grow into the full forms of the parent mechanisms. Equally distinctive is the marvelous natural power which enables an animal to re-build its tissues as they are continually used up in the processes of living; for no man-made, self-sustaining mechanism has ever been perfected. The property of chemical composition is believed by science to be the basis of the second and the third; but this matter of chemical constitution must take its proper place in the series of structural characters, which we shall discuss further on as we develop the conception of organic mechanism.

Whatever definition we may employ for a machine or an engine, we cannot exclude the living organism from its scope. As a "device for transforming and utilizing energy" the living organism differs not at all from any "dead" machine, however complex or simple. The greatest lesson of physiological science is that the operations of the different parts of the living thing, as well as of the whole organism itself, are mechanical; that is, they are the same under similar circumstances. The living creature secures fresh supplies of matter and energy from the environment outside of itself; these provide the fuel and power for the performance of the various tasks demanded of an efficient living thing, and they are the sources upon which the organism draws when it rebuilds its wasted tissues and replenishes its energies. The vital tasks of all organisms must be considered in due course, but at first it is necessary to justify our analogies by analyzing the structural characteristics of animals and plants, just as we might study locomotives in a mechanical museum before we should see how they work upon the rails.

Among the familiar facts which science reveals in a new light are the peculiarly definite qualities of living things as regards size and form. There is no general agreement in these matters among the things of the inorganic world. Water is water, whether it is a drop or the Pacific Ocean; stone is stone, whether it is a pebble, a granite block, or a solid peak of the Rocky Mountains. It is true that there is a considerable range in size between the microscopic bacterium at one extreme and the elephant or whale at the other, but this is far less extensive than in the case of lifeless things like water and stone. In physical respects, water may be a fluid, or a gas in the form of steam, or a solid, as a crystal of snow or a block of ice. But the essential materials of living things agree throughout the entire range of plant and animal forms in having a jellylike consistency.

But by far the most striking and important characteristic of living things is their definite and restricted chemical composition. Out of the eighty and more chemical elements known to science, the essential substance of living creatures is formed by only six to twelve. These are the simple and obvious characteristics of living things which are denoted by the word "organic." Everyone has a general idea of what this expression signifies, but it is important to realize that it means, in exact scientific terms,—*constituted in definite and peculiar ways*.

The living thing, then, possesses a definite constitution, which is a mechanical characteristic, while furthermore it is related to its surroundings in a hard and fast way. Just as locomotives are different in structure so that they may operate successfully under different conditions, so the definite characteristics of living things are exactly what they should be in order that organisms may be adjusted or fitted into the places in nature which they occupy. This universal relation to the environment is called *adaptation*. It is only too obvious when our attention is directed to it, but it is something which may have escaped our notice because it is so natural and universal. The trunk of a tree bears the limbs and branches and leaves above the ground, while the roots run out into the surrounding soil from the foot of the trunk; they do not grow up into the air. An animal walks upon its legs, the wings of a bird are just where they should be in order that they may be useful as organs of flight. And these mechanical adjustments in the case of living creatures occur for the same reason as in mechanisms like the steamship, which has the propeller at its hinder end and not elsewhere, and which bears its masts erect instead of in any other way.

The next step in the analysis of organisms reveals the same wonderful though familiar characteristics. The living organism is composed of parts which are called *organs*, and these differ from one another in structural and functional respects. Each of them performs a special task which the others do not, and each differentiated organ does its part to make the whole creature an efficient mechanism. The leg of the frog is an organ of locomotion, the heart is a device for pumping blood, the stomach accomplishes digestion, while the brain and nerves keep the parts working in harmony and also provide for the proper relation of the whole creature to its environment. So rigidly are these organs specialized in structure and in function that they cannot replace one another, any more than the drive wheels of the locomotive could replace the smokestack, or the boiler be interchanged with either of these. All of the organs are thus fitted or adjusted to a particular place in the body where they may most efficiently perform their duties. Each organ therefore occupies a particular place in an organic environment, so to speak. Thus the principle of adaptation holds true for the organs which constitute an organism, as well as for organisms themselves in their relations to their surroundings.

The various organs of living things are grouped so as to form the several organic systems. There are eight of these, and each performs a group of related tasks which are necessary for complete life. The alimentary system concerns itself with three things: it gets food into the body, or ingests; it transforms the insoluble foods by the intricate chemical processes of digestion; and it absorbs or takes into itself the transformed food substances, which are then passed on to the other parts of the body. It is hardly necessary to point out that the ingestive structures for taking food and preparing it mechanically lie at and near the mouth, while the digesting parts, like the stomach, come next, because chemical transformation is the next thing to be done; while finally the absorbing portions of the tract, or the intestines, come last. The second group of organs, like gills and lungs, supplies the oxygen, which is as necessary for life as food itself; this respiratory system also provides for the passage from the body of certain of the waste gases, like carbonic acid gas and water vapor. The excretory system of kidneys and similar structures collects the ash-waste produced by the burning tissues, and discharges this from the whole mechanism, like the ash hoist of a steamship. The circulatory system, made up of smaller and larger vessels, with or without a heart, transports and propels the blood through the body, carrying the absorbed foods, the supplies of oxygen, and the waste substances of various kinds. All of these four systems are concerned with "commissary" problems, so to speak, which every individual must solve for and by itself.

Another group of systems is concerned with wider relations of the individual and its activities. For example, the motor system accomplishes the movements of the various organs within the body, and it also enables the organism to move about; thus it provides for motion and locomotion. Systems of support, comprising bones or shells, occur in many animals where the other organs are soft or weak. Perhaps the most interesting of the individual systems of relation is the nervous system. The strands of its nerve fibers and its groups of cells keep the various organs of the body properly coördinated, whereas in the second place, through the sensitive structures at the surface of the body, they receive the impressions from the outside world and so enable the organism to relate itself properly to its environment. The last organic system differs from the other seven in that the performance of its task is of far less importance to the individual than it is to the race as a whole. It is the reproductive system, with a function that must be always biologically supreme. We can very readily see why this must be so; it is because nature has no place for a species which permits the performance of any individual function to gain ascendency over the necessary task of perpetuating the kind. Nature does not tolerate race suicide.

All organisms must perform these eight functions in one way or another. The bacterium, the simplest animal, the lowest plant, the higher plants and animals,—all of these have a biological problem to solve which comprises eight terms or parts, no more and no less. This is surely an astonishing agreement when we consider the varied forms of living creatures. And perhaps when we see that this is true we may understand why adaptation is a characteristic of all organisms, for they all have similar biological problems to solve, and their lives must necessarily be adjusted in somewhat similar ways to their surroundings.

Carrying the analysis of organic structure one step further, it is found that the various organisms are themselves complex, being composed of *tissues*. A frog's leg as an organ of locomotion is composed of the protecting skin on the outside, the muscles, blood vessels, and nerves below, and in the center the bony supports of the whole limb. Like the organs, these tissues are differentiated, structurally and functionally, and they also are so placed and related as to exhibit the kind of mechanical adjustment which we call adaptation. The tissues, then, in their relations to the organs are like the organs in their relations to the whole creature, i.e. adapted to specific situations where they may most satisfactorily perform their tasks.

Finally, in the last analysis, all organisms and organs and tissues can be resolved into elements which are called *cells*. They are not little hollow cases, it is true, although for historical reasons we employ a word that implies such a condition. They are unitary masses of living matter with a peculiar central body or nucleus, and every tissue of every living thing is composed of them.

The cells of bone differ from those of cartilage mainly in the different consistency of the substances secreted by the cells to lie between them; skin cells are soft-walled masses lying close together; even blood is a tissue, although it is fluid and its cells are the corpuscles which float freely in a liquid serum. Thus an organism proves to be a complex mechanism composed of cells as structural units, just as a building is ultimately a collection of bricks and girders and bolts, related to one another in definite ways.

Our analysis reveals the living creature in an entirely new light, not only as a machinelike structure whose parts are marvelously formed and coordinated in material respects, but also as one whose activities or workings are ultimately cellular in origin. Structure and function are inseparable, and if an animal or a plant is an aggregate of cells, then its whole varied life must be the sum total of the lives of its constituent cells. Should these units be subtracted from an animal, one by one, there would be no material organism left when the last cells had been disassociated, and there would be no organic activity remaining when the last individual cell-life was destroyed. All the various things we do in the performance of our daily tasks are done by the combined action of our muscle and nerve and other tissue cells; our life is all of their lives, and nothing more. The cell, then, is the physiological or functional unit, as truly as it is the material element of the organic world. Being combined with countless others, specialized in various ways, relations are established which are like those exhibited by the human beings constituting a nation. In this case the life of the community consists of the activities of the diverse human units that make it up. The farmer, the manufacturer, the soldier, clerk, and artisan do not all work in the same way; they undertake one or another of the economic tasks which they may be best fitted by circumstances to perform. Their differentiation and division of labor are identical with the diversity in structure and in function as well, exhibited by the cells of a living creature. We might speak of the several states as so many organs of our own nation; the commercial or farming or manufacturing communities of a state would be like the tissues forming an organ, made up ultimately of human units, which, like cells, are engaged in similar activities. As the individual human lives and the activities of differentiated economic groups constitute the life of a nation and national existence, so cell-lives make the living of an organism, and the expressions "division of labor" and "differentiation" come to have a biological meaning and application.

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The cell, then, is in all respects the very unit of the organic world. Not only is it the ultimate structural element of all the more familiar animals and plants that we know, as the foregoing analysis demonstrates, but, in the second place, the microscope reveals simple little organisms, like *Amoeba*, the yeast plant and bacteria, which consist throughout their lives of just one cell and nothing more. Still more wonderful is the fact that the larger complex organisms actually begin existence as single cells. In three ways, therefore,—the analytic, the comparative, and the developmental,—the cell proves to be the "organic individual of the first order." As the ultimate biological unit, its essential nature must possess a profound interest, for in its substance resides the secret of life.

This wonderful physical basis of life is called *protoplasm*. It contains three kinds of chemical compounds known as the proteins, carbohydrates, and hydrocarbons. Proteins are invariably present in living cells, and are made up of carbon, hydrogen, nitrogen, sulphur, and usually a little phosphorus. The elements are also combined in a very complex chemical way. For example, the substance called hæmoglobin is the protein which exists in the red blood cells and which causes those cells to appear light red or yellow when seen singly. Its chemical formula states the precise number of atoms which enter into the constitution of a single molecule as: $C_{600}H_{960}N_{154}FeO_{179}$. This is truly a marvelously complex substance when compared with the materials of the inorganic world, like water, for example, which has the formula $H_{2}O$. And just as the peculiar properties of $H_{2}O$ are given to it by the properties of the hydrogen and the oxygen which combine to form it, just so, the scientist believes, the marvelous properties of protein are due to the assemblage of the properties of the carbon and hydrogen and other elements which enter into its composition.

It would be interesting to see how each one of these elements contributes some particular characteristic to the whole compound. The carbon atom, for example, is prone to combine with other atoms in definite varied ways, and the high degree of complexity which the protein molecule possesses may depend in greater part upon the combining power of its carbon elements. The nitrogen atom makes the protein an extremely volatile compound, so that the latter burns readily in the tissue cells; and the hydrogen and oxygen bring their specific characteristics to the total molecule. And furthermore, it is evident that the great complexity of this constituent, protein, gives to protoplasm its power of doing work, or, in a word, its power of living. In constructing it, much energy has been absorbed and stored up as potential energy, and so, like the stored-up energy in a watch spring or in gunpowder, this may be converted, under proper conditions, into the kinetic energy and the work of actual operation. On account of its peculiar and complex nature, it possesses great capacity for burning or oxidization, thus serving as a source of vital power. It burns in the living tissue just as coal oxidizes in the boiler of an engine; its atoms fly apart and unite with oxygen so as to satisfy their chemical affinities for this substance. If we could only see what happens to the protein molecule when it undergoes oxidization, we would witness a violent explosion, like that of a mass of gunpowder. And the astonishing fact is that this process is actually the same for the living molecule, for exploding gunpowder, and for the fuel which burns in the locomotive boiler. Does this mean that the essential process of what we call life is a chemical one? So it would seem on the basis of this fact alone, but a conclusion must be deferred until we reach a later point.

The second kind of substance which we find in protoplasm is the carbohydrate. A typical member of this group is common sugar, $C_{6}H_{12}O_{6}$; another sugar has the formula $C_{12}H_{22}O_{11}$. Starch is again a typical carbohydrate, and its formula is $C_{6}H_{10}O_{5}$, or some multiple of this. One sees at a glance that these substances agree in having twice as many hydrogen atoms as there are oxygen atoms, the same proportion that the hydrogen bears to the oxygen in the compound water,—a characteristic which makes it easy to remember the general constitution of carbohydrate as compared with the protein. The substances of this second class are obviously much less complex, both as regards the different kinds of atoms and in respect to the numbers of each kind that enter into the formation of a single molecule. Therefore the carbohydrates do not possess so much power or energy as the protein molecule; in short, they are not such good fuels for the living mechanism.

Finally, we find almost always in protoplasm other substances composed of carbon and hydrogen and oxygen which are called hydrocarbons, distinguished from carbohydrates by the fact that the number of oxygen atoms is less than half the number of hydrogen atoms. These substances are the fats and oils of various kinds, less powerful sources of energy than the proteins, but they contain more potential energy than the carbohydrates because they are more oxidizable.

Besides the characteristic substances of these three classes, protoplasm contains certain other chemical compounds, like the various salts of sodium, chlorine, magnesium and potassium, and a few others, which bring the list of chemical elements to the number twelve. We have already noted how strikingly small and restricted is the list of elements composing living matter as compared with the long array of eighty-odd different kinds of chemical atoms existing in the world as a whole.

But an astonishing result is reached through the brief analysis we have just made. It is this: we do not find *peculiar* kinds of atoms which occur exclusively in living matter; the materials are exactly the same as those of the outer world. In short, the elements of both the organic and inorganic divisions of the universe prove to be the same. Carbon is carbon, whether it is part of the substance of a living brain cell, or black inert coal, or the glistening diamond, or an incandescent part of the fiery sun. Hydrogen is the same, whether it be a constituent of the ocean, of the air, or of the living muscle fiber. And so it is with all of the other elements of the living mechanism. This starts us upon a line of thought which leads to a significant conclusion, namely, that a living thing which seems so distinct and permanent is after all only a temporary aggregate of elements which come to it from the not-living world; existing for a time in peculiar combinations which render life possible, they pass incessantly away from the living thing and return to the inorganic world. Every breath we draw sends out particles which were at one time living portions of ourselves; every movement we make involves the destruction of living muscle cells, whose protoplasm breaks down into the ash and gas and fluid wastes which eventually return to the world of dead things. A tree loses its living leaves with each recurring season, and the antlers of the stag are lost annually, to be replaced anew. Indeed the major part of some organisms is itself actually dead. The bones and hair and nails of such an animal as a cat are almost entirely lifeless, even though they are integral and necessary portions of the organism as a whole. They are constructed by living protoplasm which has died in their making. Thus without going beyond the boundaries of the individual body, these substances have passed from the sphere of life, and are dead. The apparent gap on the other side between the lifeless and living world is equally imaginary, for our living substance is continually replenished and rebuilt from the elements of our dead foods. So, as Huxley says, a living organism is like a flame or a whirlpool, which is an ever changing though seemingly constant individuality. We look at a gas flame, and we see in the flame itself those particles of gas which have come through the pipe to be agitated violently in the higher temperature of the flame as they are oxidized or burnt. These particles immediately pass off as carbonic acid gas and water vapor which are no longer parts of the flame. A fountain is continually replenished by the water which is not-fountain, but which becomes for the time a part of the graceful jet, falling out and away as it leaves the fountain itself. Just so a living organism is an ever changing, ever renewed, and ever destroyed mass of little particles—the atoms of the inorganic world which combine and come to life for a time, but which return inevitably to the world of lifeless things. This is one of the most fundamental facts of biology. The independence of a living thing like a human being or a crustacean is a product of the imagination. How can we be independent of the environment when we are interlocked in so many ways with inorganic nature? Our very substance with its energies has been wrested from the environment; and as we, like all other living things, must replenish our tissues as we wear out in the very act of living, we cannot cease to maintain the closest possible relations with the environment without surrendering our existence in the battle of life.

From the foregoing discussion, it will be evident, I am sure, that there is ample justification for the biological dictum that a living individual is a mechanism. Not only is the organism composed always of cell units grouped mechanically in tissues and organs and organic systems; not only are the operations which make up its life constant and regular under similar conditions; not only is the whole creature mechanically connected with the inorganic world; but above all the whole activity of a biological individual is concerned necessarily and again mechanically with the acquisition of materials endowed with energy, which materials and energy are mechanically transformed into living matter and its life. Even though an organism is so much more complex than a locomotive, and so plastic, nevertheless, in so far as both are mechanisms, the conception of the evolution of the former may be much more readily understood through a knowledge of the historical transformation of the latter.

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What, now, is life? To most people "life seems to be something which enters into a combination of carbon and hydrogen and the other elements, and makes this complex substance, the protoplasm, perform its various activities." Nearly every one finds it difficult to regard life and vitality as anything but actuating principles that exist apart from the materials into which they enter, and which they seem to make alive. According to this general conception, "life is something like an engineer who climbs into the cab of the locomotive and pulls the levers which make it go," as health might supposedly be regarded as something that does not inhere in well-being, but gets into the body to alter it. But is this conception really justified by the facts of animal structure and physiology? Let us recall the steps of our analysis. The living organism is a collection of differentiated parts, the organs; the life of an organism is a series of activities of the several organic systems and organs. If we could take away one organ after another, there would be nothing left after the last part had been subtracted. In a similar manner, the activities of organs prove to be the combined activities of the tissue-cells, and again the truth of this statement will be clear when we imagine the result of taking away one cell after another from organisms like the frog or tree. When the last cell had been withdrawn, there would be nothing left of the frog's structure, and there would be no element of the frog's life. It is true that the particular way the tissue-cells are combined is of primary importance, but it is none the less true that the life of a cell is the kind of element out of which the life of even the most complex organism is built. And we have seen that the essential substance of a cell is a complex chemical compound we call protoplasm, whose elements are identical with chemical substances outside the living world. Is there any ground for supposing that the properties of protoplasm are due to any other causes than those which may be found in the chemical and physical constitution of protoplasm? In brief, is life physics and chemistry? Nowadays the majority of biologists believe that it is. Just as the properties of water are contributed by the elements hydrogen and oxygen which unite to form it, just so the marvelous properties of protoplasm are regarded as the inevitable derivatives of the combined properties of the various chemical elements which constitute protoplasm. Biologists have known for more than a century, since the work of Lavoisier and Laplace in 1780, that the fundamental process of the living mechanism is oxidation, and that this process is the same, as they said, for the burning candle and the guinea pig. Beginning with Woehler, in 1828, scores of students of physiological chemistry have duplicated the chemical processes of living matter, which were regarded as so peculiar to the living organism that they seemed to be due to the operation of a non-mechanical and vital cause. The investigator mentioned was the first to construct artificially from inorganic substances the nitrogen-containing ash product of the living organism called urea. Now hundreds of so-called organic compounds have been made synthetically and their number is added to week after week. Therefore, the biologist who finds that a physical and chemical analysis of some vital processes is possible, and that the analysis is being extended with astonishing rapidity, finds himself unable to regard protoplasmic activity as anything different in kind or category from the processes of physics and chemistry which go on in the world of dead things.

It is true that even at the present time some biologists are reluctant to accept the thoroughgoing mechanical interpretation of organic phenomena, partly because these are so complex that their ultimate constituents cannot be discerned, but more often on account of the apparently purposeful nature of biological processes. Some, indeed, have gone so far as to postulate something like consciousness which controls and directs the formation of protoplasm, and the exercise of its distinctive properties in the way of growth, reproduction, and embryonic development into the adapted adult. But the fact remains that wherever analysis has been possible the constituent elements of an organic process prove to be physical and chemical. Protoplasm differs from inorganic materials only in its complexity and in the properties which seem to owe their existence to this complexity. As Huxley points out, it is no more justifiable to postulate the existence of a vitalistic principle in protoplasm than it would be to set up an "aquosity" to account for the properties of water, or a "saltness" for the qualities of a certain combination of sodium and chlorine. We may not know how the elements produce the properties of the compound, but we do know that such properties are the invariable products of their respective constituents in combination. As far as the evidence goes, it tells strongly and invariably in favor of the mechanistic interpretation.

Under the present limitations, it is impossible to give this subject the further discussion it deserves. It is not our purpose to review the origin of life in times past, and the origin of living matter from inorganic constituents, though the subject is one of the most important in the field of cosmic evolution. We must begin with the living organism; and how the first one arose must be of less importance to us than the knowledge of its mechanical constitution and of its mechanical operation. Of far greater value is the realization that a living creature is not an independent thing, but that, on the contrary, it must hold the closest possible relations with the world of materials and energies constituting its environment. We must again insist upon the importance of that mechanical adjustment to the conditions of life which is the universal characteristic of plants and animals. It is the history of these creatures and the origin of their adapted conditions that we are called upon to study. We must scrutinize the nature of to-day to see if we can find evidence that evolution is true, and if we can discern the forces which, acting upon the living mechanism as man has dealt with machines, might bring the various species of the present day to their modern forms.

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We have now learned that evolution means a common ancestry of living forms that have come to differ in the course of time; our common reason has shown us also that organisms are in a true sense complicated chemical mechanisms adapted to meet the conditions under which they must operate. We come now to the evidences offered by the organic world that evolution is true and that natural forces control its workings. Clearly the examination of the matter of *fact* is independent of the question of *method*. For just as the chemist may experiment with various substances to see if they will dissolve in water and not in alcohol before it is necessary or desirable for him to take up the further studies of the laws of solution, so reasonable grounds must be found for regarding evolution as true before passing to its method of accomplishment. And in the following discussions, the animals will be used almost exclusively, not because the study of plants fails to discover the same relations and principles, but because the better known animal series is more varied and extensive, and above all for the reason that the human organism arrays itself as the highest term of the animal series.

In the complete scheme adopted by most naturalists, five categories include the evidences bearing upon the fact of evolution. These are *Classification*; Comparative Anatomy, or *Morphology*; Comparative Development, or _Embryology; *Palæontology*, which comprises the facts provided by fossil relics of animals and plants of earlier geological ages; and *Geographical Distribution*. Each of these divisions includes a descriptive and analytical series of facts, whose characteristics are "explained" or summarized in the form of the general principles of the respective divisions. Such principles, taken singly and collectively, constitute the evidences of evolution.

The particular nature of any one of these categories, evolved in the development of science practically in the order stated, depends upon the special quality of an animal which it selects for comparison and organization in connection with other similar facts, and also in its own mode of viewing its facts. One and the same organism may present materials for two, three, or even all five of these divisions, for they are by no means mutually exclusive. For example, a common cat possesses certain definite characteristics which give it a particular place when animals more or less like it are grouped or classified according to their degrees of resemblance and difference, in small *genera* of very similar forms, in larger *tribes* or *orders* of similar genera, and in more and more inclusive groups of these lesser divisions, such as the *classes* and *phyla*, or main branches of the animal tree. The common cat and its relatives are even earlier to be regarded as anatomical subjects, and their thorough analysis belongs to comparative anatomy,—a name which explains itself. The purpose of this department of natural history is to explore the entire range of animal forms and animal structures, and to determine the degree of resemblance and difference exhibited by the general characters of entire organisms and by the special qualities of their several systems of organs. It provides the data from which classification selects those which indicate mutual affinities with greatest precision and surety. But its materials are *all* the facts of animal structure, and because each and every known organism can be and must be studied, the investigator engaged in formulating the evidence of evolution has at his disposal all the data referring to the entire realm of animals. The data of embryology are likewise coextensive with the territory of the animal world, for we do not know of any form which does not change in the course of its life history. An adult cat is the product of a kitten which is itself the result of a long series of changes from earlier and simpler conditions. In so far as it deals with structures in the making, embryology is a study of anatomy, but as it is concerned primarily with all of the plastic remodeling which animals undergo during the production of their final forms, it is an independent study. Nevertheless we shall learn how intimate are the relations of these two divisions of zoölogy and how the evolutionary teachings of each body of fact support and supplement those of the other.

Palæontology searches everywhere among the deposits of earlier ages for links to be fitted into their proper sequence of time, from which it constructs the chain of diverse types leading down to the species of the present. A cat of to-day is therefore viewed in an entirely different connection, as the last term in a consecutive series of species. Forming alliances with geology, and even with physics and chemistry, this department of zoölogy endeavors to reconstruct the past from what it learns to-day about organisms and the conditions under which they live. Finally the observations that cats of various kinds do not occur everywhere in the world, but only in certain more or less restricted localities, belong to the subject of geographical distribution, and illustrate its nature.

Our task is to learn the teachings of these several divisions by recalling and putting together what we know already about the commonest animals, or noting what can be observed in a visit to a zoölogical garden and aquarium. On account of the present limitations of time, the subject of classification will be combined with comparative anatomy; embryology will be taken up together with these subjects; palæontology will be the main subject of the next discussion, which will include also a brief statement of the meaning of distribution. Then we will be prepared to study nature to see how evolution works.

# II

### THE STRUCTURE AND DEVELOPMENT OF ANIMALS AS EVIDENCE OF EVOLUTION

In order to become acquainted with the way the structures of animals provide evidences of evolution, it is by no means necessary to review the entire range of their forms, because research has discovered that the principles of relationship are universal among animals, and that any group of examples will demonstrate what is taught by comparative anatomy as a whole. The commonest creatures may serve us best in order that we may come to view evolution as a process that involves each and every living thing that we know, and not as something which belongs only to the remote and unknown past.

Let us begin with the common cat and the group of carnivora or flesh-eating animals to which it belongs. As we pass along the streets of the city, we will see many cats which differ in some details, though they resemble one another closely. While they vary somewhat in form, the range in this quality is not so noticeable as in the matter of color; some of them will be gray, some maltese, while others will be yellowish or black, and they will differ in the striped or spotted character of their coloration. We readily classify them all as "cats" in spite of their differences, because they are alike in so many ways that we have learned to associate as the distinguishing characteristics of these animals, and to label—"cat." The animals which we might see in a walk of several blocks may reasonably be regarded as offspring of the same pair of ancestors of a few years back, even though they are dissimilar. We all know that the kittens of one and the same litter vary: no two of them are ever exactly alike in color or disposition or voice or size, nor is any one identical with either of its parents, although it may be necessary to employ exact means of measuring them in order to demonstrate their variation. The fact of difference, then, is surely not inconsistent with even the closest ties of blood, and we do not need to go beyond the scope of daily observation to find that this is true in nature wherever we look.

Should we extend our observations so as to include the cats of Boston and Philadelphia and San Francisco, the animals would probably vary over a wider range, but they would be so similar to New York cats in their make-up that we would have no difficulty in regarding them and all the others of the United States as the descendants of a single pairs of ancestors, perhaps brought over in the "Mayflower." But why does this view seem justified? Because experience has taught us that the living things which resemble each other most closely are those which are most intimately bound by ties of blood and common heritage. It is "natural" for relatives to resemble one another more than persons not related, and for brothers and sisters to be more alike than cousins. Science does not refer to something outside everyday observation when it states that *the possession by two animals of a great body of similar characters beneath their minor differences is an indication of their common ancestry*.

Thus at the very outset our simple illustration establishes the most fundamental principle of comparative anatomy. Let us see how it works further. The Manx cat possesses an abbreviated tail, although in other respects it is practically the same as the familiar long-tailed form; the Angora and the Persian differ in having long hair. All of these animals are so much alike in so many respects, and so closely resemble the wild cats, that it is not unreasonable to regard them all as the descendants of the same original wild ancestors, and as the varying products of lines which branched out from the same stock in different directions and at different times. It is, in a word, their "cat-*ness*" which demonstrates their relationships. But common sense need not stop here. Guided by the facts of anatomical similarity, it convinces us that the dun-colored lion and puma, the striped tiger and the spotted leopard are simply cats of a larger growth whose remoter ancestry is one with that of the previously cited forms. Not until we explore and compare their several systems do we see how thoroughgoing is their uniformity in structural plan. And because reason justifies the view regarding the origin of domestic cats from wild ancestors, the evolution of all the various members of the cat tribe must be acknowledged. These animals exhibit a fundamental likeness, which, to employ a musical analogy, is the "theme" of "cat-*ness*," and they are so many variations of this theme.

The members of another tribe of the familiar carnivora display in their own way the same kind of evidences of relationship. The varieties of domesticated dogs differ far more widely among themselves than do common cats, yet their community of ancestry is demonstrated not only by structural resemblances, but also by the striking fact that forms as diverse as the greyhound and the fox terrier can be crossed. Here again there are wild forms, like the wolf and fox and jackal, so like the domesticated members of the dog tribe that we cannot fail to recognize a common "dog-*ness*" and its significance as evidence of the relationship in ancestry of all these animals.

Extending our survey so as to include the other tribes of flesh-eaters, identical principles come to light. One is compelled to regard the polar and grizzly bears as obvious blood relatives of the brown bear, and even of the raccoon of our own territory. Instead of walking upon their toes like cats and dogs, these animals plant their feet flat upon the ground; and they agree in many other details of structure that place them together, but somewhat apart from the other tribes. The many kinds of seals and walruses and sea elephants form still another group displaying similar bodily characters, but differing more widely from the "cat theme" in these differences. They are all true carnivora, but in the course of their evolution they have progressively changed so as to be adapted to life in the water where they find their prey. The bones of the limbs are the same in number and arrangement as in the cat's limb, but the seal's anterior appendage or "arm" has altered in numerous ways so as to become an efficient flexible paddle, while the hind limbs have shifted posteriorly, very much as screw propellers have evolved in the history of steam vessels. How the members of the seal tribe have changed in their descent from purely terrestrial ancestors is partly explained by such intermediate animals as the otter. This form is adapted by its slender body and partly webbed feet to a semi-aquatic life; it seems to have halted at a point beyond which all of the seals have passed in their evolution.

Each one of these tribes by itself provides conclusive evidence of evolution, for it is most reasonable to regard the "theme" in every case as a product of common inheritance, while the variations of any theme are best understood as the results of adaptive changes in various directions. But the examples have disclosed a larger relation and a principle of wider scope, as indeed the assignment of all these tribes to the single natural group of the *carnivora* implies. These tribes are put together because comparative anatomy finds that the common characters of all cats are fundamentally like those of all dogs and bears and seals, and in these common qualities the carnivora differ from all other mammalia. Does this mean that the branches which bear respectively the various members of the several tribes are outgrowths of a single limb of the evolving animal tree? Science does not hesitate to give an affirmative answer, because, as in the case of the similar but varying domestic cats, no other explanation of tribal resemblance in structure seems so reasonable and natural.

So far the examples have been taken from one order of the highest class of backboned animals, called mammalia. When our survey is extended to other divisions of this class, additional laws of organic relationship are discovered. If in a series of evolving generations the line of modification proceeding from a terrestrial animal like a cat to semi-aquatic and marine types substantially like an otter and a seal should be carried further, it will inevitably lead to forms possessing characters such as those displayed by whales and the related porpoises, dolphins, and narwhals of the order cetacea. In their make-up all of these animals clearly possess the general characteristics of mammals, and they constitute collectively another limb which has sprung from the same stock as the carnivora, although at an earlier time. This we believe because of their plan of body and because their peculiar organization fits them even more perfectly than the seals for aquatic existence that is their only possible mode of life. In the case of the whales the bony framework of the fore limb is again like that of the cat's leg, although the whole structure is a flexible finlike paddle. The hind limb has disappeared as an efficient organ, but the significant fact is that small rudiments of hind limbs are present just where corresponding structures are placed in the seal. These vestiges cannot be reasonably accounted for, unless they are the degenerate hinder limbs of a remote four-footed ancestor. Furthermore the unborn whale possesses a complete coat of hair, which is afterwards replaced by blubber; but hair is a thatchlike coat to shed rain, as the way the hairs lie on a terrestrial mammal indicates. We are therefore forced to conclude that whales have originated from four-footed animals walking about on land, because no opposed explanation gives so reasonable an interpretation of the observed facts.

Another group of familiar animals materially reinforces the results already established. After what has been said, it will not be difficult to perceive the meaning of the resemblances among mice of the house and field, and of rats and rabbits and squirrels. All of them possess heavy curved gnawing teeth, or incisors, and lack the flesh-tearing or canine teeth. They agree in many other respects which distinguish them as a separate natural order of the mammals called the rodentia. Again we find a highly aberrant form in the flying squirrel, which leads toward an order with another plan of body. This animal is a true rodent, which lengthens its leap from branch to branch by means of a fold of skin stretching between its fore and its hind limbs. It is an animated aeroplane, and it shows in part how bats have originated. The wing of a bat is an elastic membrane stretching not only between the two legs of one side, but also between the greatly lengthened "fingers" of the fore limb. But the bones of arm, wrist, and fingers are almost precisely the same in number and relation as in walking forms. The fact that this peculiar wing adheres to a plan belonging to the anterior legs of walking or climbing types has no reasonable explanation save that of evolution.

The well-known group of hoofed animals, including horses and cattle, is also valuable for our present purposes, as well as in a later connection when the evidence of fossils is described. The elephant possesses five toes armed with well-developed nails or hoofs. A tapir has four or three toes, and it would seem that its ancestor had had five toes, of which one or two had been lost. A rhinoceros possesses three toes, and its foot is constructed internally like the elephant's with the outer elements absent. The horse comes last with one large toe and hoof, but on either side of the main bones of this digit are vestiges of what must have been toes in its ancestors. Among the even-toed forms the hippopotamus has four which reach the ground, with a vestige of a fifth, so this animal has apparently descended from a typical mammal with the full number along a different line from that taken by the odd-toed forms. A pig has a cloven hoof, made up of what we may call the third and fourth members of a series of five digits, but the second and fifth fingers and toes are present, though they are withdrawn from the ground so as to be no longer functional; this animal seems to have proceeded further along the same line taken by the hippopotamus. A deer, with still smaller rudiments at the sides of its double foot, leads in the comparative series to the camel with a cloven hoof devoid of any such relics.

We must pass with only brief mention the lower orders of mammalia, like the insect-eating forms to which armadillos and ant-bears belong. Of greater interest are the pouched mammals like the kangaroo and opossums, which live almost exclusively in the Australian realm. The kangaroo is endowed with a head somewhat like that of a goat, and well-developed hind legs that enable it to make leaps of astonishing length. Some of its relatives, such as the bandicoot, are like rats, or like bears, as in the case of the wombat. The Tasmanian wolf is another true marsupial, even though divergent adaptation has brought it to resemble the carnivora of the dog tribe in general appearance and in special structures like the teeth. Finally at the very bottom of the mammalian scale are two small forms living in the Australian faunal region. The duckbill or *Ornithorhynchus* is the better known animal, with its close fur, webbed feet, and flattened ducklike beak, while its only other near relative, the *Echidna*, is somewhat similar to the spiny hedgehog in external appearance. A unique peculiarity of these two forms is that they produce eggs much like those of reptiles and birds, and this fact, together with others of a structural nature, brings the whole group of mammals near to the lower classes of the Vertebrata.

Looking back on the several orders of mammals, it will be seen that the last mentioned are much less differentiated or specialized in their general organization. Above the level of the egg-layers and the pouched mammals, the higher orders branch out in different directions and reach up to various levels of the scale of animal organization.

The foregoing structural evidences of organic transformation in the past histories of cats and seals and whales insistently recall the analogies of the locomotive and the ship employed at the outset. All these animals, like the mechanical examples, have come to differ in their derivation from the same original parents, and their lines of descent have diverged so as to fit the products of evolutionary modification to diverse circumstances. Even the vestigial organs of animals have their counterparts in the machines. The cowcatcher was a large and important structure in the early days of railroading, but it has become relatively useless with the decrease of grade crossings and the construction of more complete lines of fence. The structure still persists, sometimes in a greatly reduced form. Even more obvious is the change of structure in the case of masts of vessels, which originally bore the sails for propelling the ship. When steam engines were employed to give motive power, masts did not disappear. They now provide the derrick supports of trading steamers; in battleships their function is changed to that of fighting tops and signal yards. Even the poles carried by canal boats to bear windmills must be regarded as the reduced vestiges of masts originally constructed to carry sails; and their adaptive evolution, like that of countless structures in animals, has been accomplished by degeneration.

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The birds are another class of backboned animals which exhibit identical principles of relationship. A heron has long legs and wide-spreading toes, which keep its body out of the water as it stalks about the marshes where it seeks its food; its bill is a long slender pincers. Compare it with an eagle; the latter has a short and heavily hooked beak to tear flesh, while its stout legs bear strongly curved talons to hold its struggling prey. Swimming birds like the swan and duck and loon possess feet which are constructed in general like those of the former examples, but they are webbed and shortened to serve as paddles. In the penguin we find a counterpart of the seal among mammals; its feathers are much reduced and its fore limbs are no longer wings enabling the animal to fly, but they are paddles which it uses when it swims in pursuit of fish. Finally the ostrich and wingless bird of New Zealand—the *Apteryx*—have wings that are useless vestiges, which, in the latter case, are hidden under the brushlike feathers covering the body. It is unnecessary to add more examples, for even these few illustrations establish exactly the same principles of relationship and evidences of evolution that are to be found in the series of mammalia.

Reptiles also are grouped, like the mammals and birds, as variations about a central theme. An ordinary lizard is perhaps the nearest in form to the remote ancestor from which all have sprung. Some lizards are long and very slender, with all four limbs of greatly reduced size. Others, which are still true lizards, have lost the hind limbs, or even all the legs, as in the "blind worms" of England. One step more, and an animal which has progressed further along a similar line of descent would be a snake. Just as whales as a group are derivable from forms which resemble types belonging to another order, so snakes as an order are to be regarded as more radically altered derivatives of some four-footed lizardlike creature. Alligators are very much like lizards in general form, and their order is a diverging branch from the same limb. Finally the evolution of turtles from the same ancestors is intelligible if we begin with a short stout animal like the so-called "horned toad" of Arizona, and proceed to the soft-shelled tortoise of the Mississippi River system; the establishment of a bony armor completes the evolution of the familiar and more characteristic turtle.

Frogs and salamanders constitute another lower class, called the amphibia, whose members are gilled during the earlier stages of development. An adult frog is essentially a salamander without a tail and with highly developed hinder limbs. The salamanders differ as regards the number of fishlike gill clefts that they all possess in their young stages, but which disappear entirely or in part during later life. In comparison with the lizard as a typical reptile, a salamander is more primitive in all of its inner organic systems, while in its nearly continuous body, with head and tail gradually merging into the trunk, it also displays a somewhat simpler form of body.

The fishes are the lowest among the common vertebrates, and they offer an abundance of independent testimony as to the truth of the principles of comparative anatomy. The common shark is perhaps the most fundamental form, with a hull-like body undivided into head, trunk, and tail, and from it have originated such peculiar variations as the hammerhead and skate. Among fishes with true bones, a cod or trout is the most typical in general features. Without ceasing to be true bony fishes, the trunk-fish and cow-fish are adapted by their peculiar characters of spine and armor plate to repel many enemies. The puff fish can take in a great amount of water, when disturbed, so as to become too large to be swallowed by some of its foes, illustrating another adaptive modification for self-defense. The wonderful colors and color patterns of the tropical fish of the reef, or of the open water forms like the mouse-fish of the Sargossa Sea, often render them more or less completely hidden from the foraging enemy. A flounder looks like a fish which was originally symmetrical, but which had come to lie flat on its side upon the bottom, whereupon the eye underneath had left its original place to appear on the upper surface. The difficult and unusual conditions of deep-sea existence have been met by fishes in two ways; some forms possess luminous frilled and weedlike fins, which lure their prey to within easy reach of their jaws, while others have enormous eyes, so as to make use of all possible rays of light in their pursuit of food organisms. But all of these diverse forms are true *fishes*, possessing a common heritage of structure which demonstrates their unity of origin.

The brief review of backboned animals has shown how comprehensive are the principles of relationship. The families and tribes of each order, such as the carnivora, are like branches arising from a single limb; the orders in their turn exhibit common qualities of structure which mean that they have grown from the same antecedents, while even the larger divisions or classes of mammals, birds, reptiles, amphibia, and fishes, possess a deep underlying theme whose dominant motif is the backbone, which proves their ultimate unity in ancestry. The greater and lesser branches have reached different levels, for the fish is clearly simpler in its make-up than the highly specialized bird. But the great fact is that structural evidences demonstrating the reality of genealogical affinities are displayed by the entire series of vertebrates; although they differ much or little in many or fewer respects they have one and the same ground-plan.

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The lower animals devoid of backbones, and therefore called invertebrates, are not so well-known except to the student of comparative anatomy, because they are not so often met with, and because they are usually very small or microscopic; but in many respects their importance to the evolutionist surpasses that of the vertebrates. Their structural plans are far more varied, and they range more widely from higher and relatively complicated organisms to the unitary one-celled animals. A knowledge of some of them is essential for our present purpose, which is to learn how sure is the basis for the principles of relationship and how complete is the structural evidence of evolution.

Worms are represented in the minds of most people by the common earthworm or sandworm. The body in either case is made up of a series of segments or joints which agree closely throughout the animal in external appearance and in internal constitution. A section of the digestive tract, a pair of nerve centers, two funnel-like tubes for excretion, and similar blood vessels occur in each portion.

Precisely similar features are displayed by the crustacea, which seem to be so different. Every one is familiar with the appearance of lobsters and crabs. Even in these animals the body is composed of segments, but these are not like one another, nor are they freely movable throughout the body. Five are fused in all crustacea to make a head; in lower members of the order the eight succeeding segments are free, but in the lobster they are joined together and united with the head. The hinder part of this animal is a long abdomen whose segments remain more primitive and independent. But in a crab, the whole plan has been modified by the shortening and broadening of the head-thorax, and by the reduction of the abdomen, which is also turned under the anterior part of the body. The internal organic systems are constructed upon a worm plan with modifications. Nearly every one of the segments bears one pair of appendages, which can be referred by their forked nature to the two-parted, oarlike flaps of sandworms, but the appendages of crustacea have departed from their prototypes in functional respects and in details of structure. They are variously feelers, jaws, legs, pincers, and swimming paddles, evolved to serve different purposes, just as the limbs of the vertebrates we have described have become variously arms, wings, flippers and paddles in apes, bats, seals, and whales.

Butterflies, beetles, bees, and grasshoppers seem at first sight to be entirely different, even though they agree in being more or less segmented. But all of them have heads with four pairs of appendages of the same essential plan, middle thoracic regions of three segments more or less united, bearing three pairs of legs and usually two pairs of wings, while the hinder part is a freely jointed abdomen without real limbs. In these respects the countless varieties of insects agree so that they also like crustacea of various kinds seem to have been derived from wormlike animals with more simply segmented bodies. Indeed spiders and scorpions and their relatives of the group arachnida prove for similar reasons to be derivatives of the same original stock, and own cousins of the insects.

In nearly every one of the invertebrate branches we find representatives which interest us chiefly because they appear to have reached their present condition by retrograde evolution. Barnacles are really crustacea, but they have lost their eyes as well as some other structures that are most useful in animals with a free existence, because they have adopted a fixed mode of life, which has also brought about the loss of the original freely jointed character of the body. A tapeworm as an example of internal parasites is an extremely degenerate form which lacks a digestive tract, because this is superfluous in an animal which lives bathed in the nutrient fluids of its host. Comparing it in other respects with other low wormlike creatures, it appears to be a relative of peculiar simple worms with complete organization and independence of life. All these degenerate forms enlarge our conception of adaptation by adding the essential point that progress is not always the result of evolution. Indeed we have learned this in the case of vestigial and rudimentary structures of higher forms like whales, and now we find that entire animals may degenerate as a result of changes no less adaptive than progressive modifications.

Passing by other invertebrate groups made up of species arranged like higher animals in smaller and larger branches according to their degree of fundamental similarity, we arrive at a place in the scale occupied by two-layer animals without the highly developed and clearly differentiated organic systems of the forms above. The fresh-water animal *Hydra* exemplifies the creatures of this level, where also we find sea-anemones and the soft polyps which form corals and coral reefs by their combined skeletons. *Hydra* is an animal to which we must return again and again as we study one or another aspect of organic evolution. In general form it is a hollow cylinder closed at one end, by which it attaches itself, while at the upper end, surrounded by a group of tentacles, is the mouth which leads to the central cavity. The wall of this simple body is composed of two layers of cells, between which there is a gelatinous layer rarely invaded by cells. The inner layer lines the central space into which food organisms are thrust by the tentacles, and it is concerned primarily with digestion. The outer layer comprises cells for protection and sensation primarily. Cells of both layers have muscular prolongations which by their operation enable the whole animal to change its form and to move from one place to another.

It may seem that such an animal is totally unlike any of the higher and more complex types. In certain respects, however, it is identical with the other forms inasmuch as it performs all of the eight biological tasks demanded by nature. It is also similar in so far as its inner layer, like the innermost sheet of cells in higher forms, is concerned with problems of taking and preparing food, while the protective outer layer resembles in function the outermost covering of all animals higher in the scale. Beyond these a still more fundamental agreement is found in its cellular composition.

At the lower end of the animal scale are organisms which consist of one cell and nothing more. *Amoeba*, to which we must refer again and again, is an example of this group which possesses an overwhelming importance to the comparative student because the origins of all the characteristics of animals higher in the scale are to be found within it. *Amoeba* itself is a naked mass of protoplasm, about 1/100 of an inch in diameter, enclosing a nucleus. Its form is not constant during activity, for fingerlike processes called pseudopodia are pushed out tentatively in many directions to be followed as circumstances direct by the materials of the whole cell body. Other protozoa differ in possessing constant forms, or in having constant vibratile processes, or shells of some kind, while in still other cases like individuals combine to make colonies which are more or less definite and permanent. Here at the very foot of the organic scale are found animals which seem to be entirely different from those above. Upon examination they, like *Hydra*, prove to be the same as regards the number and kind of functions they perform, but in structural regards their evolutionary relation to all higher animals is indicated solely by the fact that they are cells composed of protoplasm. Nevertheless the principle which states that resemblance means consanguinity still holds true, for cellular constitution is a unique possession of things of the living world,—something which demonstrates the common origin of all living things just as truly as the "cat-*ness*" of our first series of examples reveals for a smaller group the significance of likeness and the nature of the basic law of comparative anatomy.

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Employing a figure of speech, we have climbed down the animal tree from the higher regions where the mammals belong. Having reached the very foot of the trunk we are in a position to review and summarize the evidences which we have discovered all about us as we have descended. The various examples we have mentioned and the groups to which they belong clearly occupy different places in the scale which begins with the protozoa and extends upward to the most complicated and differentiated animals. *Hydra* takes its place above the protozoa for obvious structural reasons; worms belong to a still higher zone, surpassed by the more complex jointed animals like crustacea and insects. Far above these are the vertebrates, among which we have already demonstrated the occurrence of different grades of organization, from the fish up to the higher amphibia and reptiles, and beyond in two directions to the diverging birds and mammals. The basic characteristics of every group in a high position may be traced back to some one or another of the divisions at a lower level, so that the general sequence of the structural levels from low to high becomes intelligible as the order of their evolution.

To my mind the rudimentary and vestigial structures of animals are in themselves proof positive of a natural history of change. The few illustrations can be reinforced by countless examples offered by every group of living animals. If such structures have not evolved naturally by degenerating from more efficient counterparts in ancestors of earlier times, and if they have been specially created, they are utterly meaningless and their very existence is unreasonable. If common sense is to be employed, they demonstrate evolution.

Everywhere throughout the whole series animals place themselves in a treelike arrangement, for in their respective levels they occur like leaves at the ends of the lines of descent which have led up to them and which are comparable to the branches and limbs arising from the trunk of a tree. Thus the major and minor divisions of animals do not follow in the order of the rungs of a ladder, even though they must be assigned to different levels according to the complexity of their construction. The summary given above, namely, that the occurrence of lower and higher levels reveals an order of evolution, is amplified and not contradicted by the statement that the species of animals are group in a treelike arrangement. It is the task of the evolutionist, provided with all the facts of comparative anatomy and dealing only with the various species as separate leaves, so to speak, to reconstruct the now invisible but not unreal twigs and branches and limbs of the animal tree, and to show how they have diverged at one time or another as they have grown and spread to produce the species of the present day. This he may do in so far as he may find sufficient materials to enable him to employ the methods of comparative anatomy and the great natural principle established by this method—that essential likeness means consanguinity.

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No evidence of evolution could be more significant and interesting than the results provided by the comparative study of development. In the first place it is an obvious fact that every living thing changes in the course of its life-history, and if as an adult it occupies a high place in the animal scale, its embryological transformation is more elaborate and intricate than in the case of a lower form. Every one knows that organisms do develop, and yet I believe that few appreciate the tremendous significance of the mere fact that this is true, while still fewer are aware that the peculiar and characteristic early stages through which an animal passes in becoming an adult are even more striking than the fact of development itself. We shall learn something of these earlier conditions in the development of some of our most familiar animals, but at the outset nothing can be more important than an appreciation of the first great lesson of this department of natural history—namely that organic transformation is real and natural. We do not need to employ the methods of formal logic to know that in growing up a human infant undergoes the changes of childhood and adolescence, that kittens become cats, and that an oak tree is produced by an acorn, for we know these things directly by observing them. It is natural for development to take place under normal conditions, and if it does not, then something has interfered with nature. Inasmuch as "growing up" is accomplished by the alteration of an organic mechanism with one structure into an individual with a changed plan of body, it is in essence the actual process of evolution which the comparative study of grown animals of to-day demonstrates in the way we have learned. The study of animal structure discovers the process of evolution because the most reasonable interpretation of the similarities and minor differences exhibited everywhere by the various groups of animals is that descent with adaptive and divergent modification has taken place; the result is reached by inference, it is true, but by scientific and logical inference. With development it is otherwise. No reasoning is necessary to tell us that organic transformation is a real and a natural process. We see it everywhere about us and we ourselves have come to be what we are by a natural history of change. Can we consistently deny that it is possible for a species to alter in the long course of time when a few brief weeks are sufficient for the new-laid egg of the fowl to develop into a fledgling? Many indeed strain at the gnat of the longer process in the past when without hesitation they recognize the real and obvious fact of individual development in a brief period.

I have said that development is a "natural" process. We employ this word for the familiar and everyday occurrence or thing; it does not imply that everything is known about the object or phenomenon, because science knows that complete and final knowledge is impossible. We say that it is natural for rain to fall to the earth, and we speak of the law of gravitation according to which this takes place as a natural principle, but it may not have occurred to many to inquire *what* makes rain fall and *why* do masses of matter everywhere behave toward one another in the consistent manner described by the law in question. Sunshine is natural, but we do not know *why* light travels as it does from the sun to the earth, and this is another question which, like the inquiry into the ultimate cause of the familiar and natural phenomenon of gravitation, has not yet been answered. But it is still regarded as natural for the rain to fall and for the sun to shine. In the same way does science view development, denoting it natural because it is an ordinary everyday matter. And we are under no more obligation to postulate supernatural control for the changing forms in the life-history of a chick or a cat than we need to assume that gravitation and the radiation of light demand immediate supernatural direction. The embryology of no form is fully understood or described or explained, but no intelligent person would be willing to assert that because complete knowledge is lacking, it is unnatural for organic transformation to take place during growth. Whatever may be the ultimate origin and nature of the directing powers behind gravitation and development and other phenomena, we have no concern with such matters because they cannot be handled by scientific methods and one belief about them is on the same plane with any other. Our task is to deal with the everyday phenomena of life and the production of living species.

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It is not necessary to go far afield to find an animal which will introduce us to the general principles of embryology. In the present instance as in the case of comparative anatomy almost any form will disclose the meaning of development, for animate nature is uniform and consistent in its methods of operation throughout its wide range. We shall begin with the familiar frog which every one knows is a product of a tadpole; passing on to the chick we will learn more facts that will enable us to formulate the main principle of comparative embryology in definite terms; we will then be prepared to extend our survey so as to include somewhat less familiar facts and animals that are even more significant than the first illustrations.

If we should visit a woodland pond in early spring, we would find somewhere among the leaves and sticks in the water large masses of a clear jellylike consistency enclosing hundreds of little black spheres about an eighth of an inch in diameter. These are the egg masses and eggs of a common frog. Watching them day by day we see the small one-celled egg spheres divide into more and more numerous portions which are the daughter-cells, destined to form by their products the many varied tissues and organs of the developing larva and adult frog. After three or four days the egg changes from its globular form into an oval or elliptical mass, and from one end of this a small knob projects to become a flattened waving tail a few days later. On the sides of the larger anterior portion shallow grooves make their appearance and soon break through from the throat or pharynx to the exterior as gill-slits. Shortly afterwards the little embryo wriggles out of its encasing coat of jelly, develops a mouth, and begins its independent existence as a small tadpole, with eyes, nasal and auditory organs, and all other parts that are necessary for a free life. Thus the one-celled egg has transformed into something that it was not at first, and in doing this it has proved the possibility and the reality of organic reconstruction.

The tadpole breathes by means of its gills, and it is at first entirely devoid of the lungs which the adult frog possesses and uses. When we speak of the larval respiratory organs as gills we imply that they are like the organs of a fish which have the same name; they are truly like those of fishes, for the blood-vessels which go to them are essentially the same as in the lower types and they are supported by simple skeletal rods like the gill-bars of the fish. In a word, they are the same things.

The animal feeds and grows during the months of its first summer, and hibernates the following winter; with the warmth of spring it revives and proceeds further along the course of its development. Near the base of the tail two minute legs grow out from the hinder part of the body, and while these are enlarging two front legs make their appearance a little behind the gills. The tadpole now rises more frequently to the surface where it takes small mouthfuls of air. Meanwhile great changes are effected inside the body where the various systems of fishlike organs become remodeled into amphibian structures. A sac is formed from the wall of the esophagus, and this enlarges and divides to form the two simple lungs. The legs increase in size, the tail dwindles more and more, the gills close up, and soon the animal hops out on land as a complete young frog. From this time on it breathes by means of its lungs instead of gills, even though it returns to the water to escape its foes, to seek its prey, and to hibernate in the mud of the lake bed during the winter months.

All these changes are familiar and natural, but until science places them and similar facts in their proper relations their significance is lost to us. The tadpole is essentially a fish in its general structure and mode of life, even though its heritage is such that it can develop into a higher animal. When it does become a frog it proves beyond a doubt that there is no impassable barrier between fishes and amphibia. Our earlier comparison of the structures of these two classes of vertebrates led to the conclusion that the latter had evolved from antecedents like the former, and had thus followed them upon the earth; now that sequence seems to have some connection with the method by which a tadpole, obviously not a fish but nevertheless actually fishlike, changes into a frog, a member of a higher class of vertebrates. This method is employed by developing frogs apparently because it follows the ancestral order of events, and because, so to speak, the only way a frog knows how to become a frog is to develop from an egg first into a fishlike tadpole and then to alter itself as its ancestors did during their evolution in the past. We begin to see, then, that in addition to the impressive fact of development itself, the mode of organic transformation is far more conclusive evidence of evolution, because it reveals an order of events which parallels the order established by comparative anatomy as the evolutionary sequence.

However it is well to review some of the changes by which a chick comes into existence before attempting to comprehend fully the fundamental principle of development that the tadpole's history discloses to us. The egg of a common fowl is certainly not a chick. Within the calcareous shell are two delicate membranes that enclose the white or albumen; within this, swung by two thickened cords of the albumen, is the yellow yolk ball enclosed by a proper membrane of its own. In the earliest condition, even before the albumen and the shell are added and before the egg is laid, on one side of the yolk-mass there is a tiny protoplasmic spot which is at first a single cell and nothing more. The hen's egg is relatively enormous, but nevertheless, like that of the frog, it starts upon its course of development as a single unitary biological element—a cell. During the earliest subsequent hours the first cell divides again and again to form a small disk upon the surface of the yolk. Soon the cells along the middle line of this small sheet become rearranged to make an obvious streak or band, and about this line a simple tube is constructed which is destined to become the future brain and spinal cord. The whole disk continues to enlarge by further division of its constituent elements so that it encloses more and more of the yolk mass, but the little chick itself is made out of the cells along the central line of the original plate, from which it folds at the sides and in front and behind so as to lie somewhat above and apart from the flatter enclosing cell layers which partly surround the yolk.

At the sides of the primitive nerve-tube small blocks of cells arise to develop into primitive muscles and other structures. As nourishment is brought to the embryo from the surrounding layers enclosing the nutrient yolk, one system after another takes its shape and builds its several parts into organs which can be recognized as elementary structures of a chick. Among the more interesting ones are small clefts or slits formed in the side walls of the rudimentary throat or pharynx. Blood-vessels go forward from the simple heart to run up through the intervening bars exactly as in the tadpole and the fish. In brief, the young chick possesses a series of gill-slits, for these structures are the same in essential plan and relations as the clefts of tadpoles and fishes. Does this mean that even birds have descended from gill-breathing ancestors? Science answers in the affirmative, because evolution gives the only reasonable explanation of such facts as these. The case seems different from that of the frog, because gills are used by the tadpole, but gill-slits and gill-bars can have no conceivable value for the chick as organs concerned with the purification of the blood. None the less, if the transition from a gilled tadpole to the adult with lungs means an evolution of amphibia from fishlike ancestors, then the change of a chick embryo with gill-clefts into the fledgling without them is most reasonably interpreted as proof that birds as well as amphibia have had ancestors as simple as fishes.

As development progresses four small pads make their appearance; two of these lie on either side of the body back of the head and the other two arise near the posterior end. They are far from being wings and legs, but as day follows day they become molded into somewhat similar limbs, as much alike in general plan as the four legs of a lizard; subsequently the ones at the front change into real wings and the hinder ones become legs. Meanwhile the internal organs slowly transform from fishlike structures into things that display the characteristics of reptilian counterparts, and only later do they become truly avian. Last of all the finishing touches are made, and the whole creature becomes a particular kind of a bird which picks its way out of the shell and shifts for itself as a chick.

Only a few of the countless details have been mentioned which demonstrate the resemblance of the successive stages first to fishes, and later to amphibia and reptiles. We have a wide choice of materials, but even the foregoing brief list of illustrations shows that the order in which the stages follow is the one which comparative anatomy independently proves to be the order of the evolution of fishes, amphibia, reptiles, and birds. Why, now, should it be necessary for a developing bird to follow this order? The answer has been found in the immense array of embryological facts that investigators have verified and classified, that all tell the same story. It is, that birds have arisen by evolution from ancestors which were really as simple as the members of these lower classes. It seems then that the only way a bird of to-day can become itself is to traverse the path along which its progenitors had progressed in evolution. Stating its conclusions precisely, science formulates the principle in the following words: *individual development is a brief résumé of the history of the species in past times*, or, more technically, *ontogeny recapitulates phylogeny*. To be sure, the full history is not reviewed in detail, for the chick embryo does not actually swim in water and breathe by means of gills. Only a condensed account of evolution of its kind is presented by an embryo during its development; as Huxley and Haeckel have put it, whole lines and paragraphs and even pages are left out; many false passages of a later date are inserted as the result of peculiar larval and embryonic needs and adjustments. But in its major statements and as a general outline, the account is a trustworthy natural document submitted as evidence that higher species of to-day have evolved from ancestors which must have been like some of the present lower animals.

Coming now to the mammalia, it might seem that we have reached forms so highly developed that they would not exhibit the same kind of developmental history, but would have their own mode of growing up. This is not so, for like the adult fish, the larval tadpole, and the embryo chick, an embryo of a cat or a man is at one time constructed with a series of gill-clefts and with blood-vessels and skeletal supports of fishlike nature that are everywhere associated with gills. The embryos of wildcats and dogs, rabbits and rats, pigs, deer, and sheep, and of all other mammalia, possess similar structures. Thus they all pass through a stage which is found also in the development of reptiles, birds, and amphibia,—a stage which corresponds to the fish throughout its life. Unless these facts mean that the great classes of vertebrates have originated together from the same or closely similar ancestors, they are unintelligible; for we cannot see why a cat or a chick should have to be essentially fishlike at any time unless this is so. Comparative anatomy states as we have learned that the amphibia as a class have evolved from and have out-developed the fishes, that reptiles have progressed still higher, and that birds and mammals have originated from reptilian ancestors along roads that have diverged beyond the immediate parent class. Because the members of each class have to pass along the same path trodden by their many varied ancestors, although at express speed, as it were, the similarity of the earliest stages in their development is explained, for during these periods they are traversing a path over which their ancestors passed together.

The places where the developing embryos depart from the common mode show where the several divisions took leave of one another in their evolution,—a point that comes out with great clearness when the facts of mammalian development are broadly compared. The embryos of carnivora and rodents and hoofed animals are alike in their earlier development, and their agreement means a community of origin. At a certain point the cat and dog depart from the common mode, but they remain alike up to a far later stage than the one in which they are similar to the embryos of rats and sheep. The rat and squirrel and rabbit, on their part, remain together until long after they take leave of the carnivora and ungulates; while the sheep and cattle and pigs have their own branch line, which they follow in company after leaving the embryos of the other orders. The reasons for these facts seem to be that the members of the three orders exemplified have evolved from the same stock, which accounts for their embryonic similarity for a long time after they collectively come to differ from amphibia and reptiles, while the members in each order became differentiated only later, wherefore their embryonic paths coincide for a longer period. Thus the degree of adult resemblance which indicates the closeness of relationship corresponds with the degree of embryonic agreement; that is, the cat and dog are much alike and their modes of development are essentially the same to the latest stages, while the cat and horse agree only during the earliest and middle stages, and their lines diverge before those of the cat and dog on the one hand, or those of the horse and pig on the other.

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Like the fundamental principle of comparative anatomy in its sphere, the Law of Recapitulation, formulated as a summary description of the foregoing and similar facts, is one that holds true throughout the entire range of embryology and for every division of the animal series, however large or small. We have discussed its broader application, and now we may take up some of the more or less special cases mentioned in the earlier section of the present chapter, to see how it may work in detail.

The flounder was noted as a variant of the fish theme which seemed to be a descendant of a symmetrical ancestor because its structural plan was like that of other bony fishes. If this be true, and if in its development a flounder must review its mode of evolution as a species, the young fish ought to be symmetrical; and it actually is. The grotesque skate and hammerhead shark were demonstrated to be derivatives of a simpler type of shark; their embryos are practically indistinguishable from those of ordinary dogfish and sharks.

Among the jointed animals a wealth of interesting material is found by the embryologist. All crabs seemed to be modified lobsterlike creatures; to confirm this interpretation, based solely upon details of adult structure, young crabs pass through a stage when to all intents and purposes they are counterparts of lobsters. Even the twisted hermit crab, which has a soft-skinned hinder part coiled to fit the curve of the snail shell used as a protection, is symmetrical and lobster-like when it is a larva.

Among the insects many examples occur that are already familiar to every one. The egg of a common house-fly hatches into a larva called a maggot; in this condition the body destined to become the vastly different fly is composed of soft-skinned segments very much alike and also similar to the joints of a worm. Comparative anatomy demonstrates that the fly and all other insects have arisen from wormlike ancestors, whose originally similar segments later differentiated in various ways to become the diverse segments of adult insects; the embryonic history of flies of to-day corroborates these assertions, in so far as every individual fly actually does become a wormlike larva before it changes into the final and complete adult insect. The other kinds of insects are equally striking in their life-histories. All beetles, such as the potato bug and June bug, develop from grubs which, like the maggots of flies, are similar to worms in numerous respects. Butterflies and moths pass through a caterpillar stage having even more striking resemblances to worms. All the larvæ of insects are therefore like one another, and like worms also, in certain fundamental characters of internal and external structure; so the conclusion that the whole group of insects has arisen by evolution from more primitive ancestors resembling the worms of to-day is based upon mutually explanatory details of comparative anatomy and embryology.

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Let us now turn back to some of the earlier pages of the embryological record which we passed over in order that we might translate the later portions dealing with more familiar and intelligible structures like gills. Before the egg of the frog becomes an elliptical mass of cells, it is at one time a double-walled sac enclosing a central cavity; in this stage it is called a *gastrula*. Tracing back the mode of its formation, we find that it is produced from a hollow sphere of fewer cells that are essentially alike; this stage also is so important that the special term *blastula* is applied to it. Still earlier, there are fewer cells—128 or thereabouts, 64, 32, 16, 8, 4, 2, and 1. In other words, the starting point in the development of the frog is a *single biological unit*; this divides and its products redivide to constitute the many-celled blastula and the double-walled gastrula. All the other animals we have mentioned begin like the frog, as eggs which are single cells and nothing more; they too pass on to become blastulæ and gastrulæ, similar to those of the frog in all essential respects, particularly as regards the nature of the organs produced by each of the two primary layers, and the mode of their formation. Does the occurrence of blastulæ and gastrulæ and one-celled beginnings mean that the higher animals composed of numerous and much differentiated cells have evolved in company from two-layered saccular ancestors which were themselves the descendants of spherical colonies of like cells, and ultimately of one-celled animals?

Comparative anatomy has asserted that this is so, as we have already learned, for it finds that adult animals array themselves at different levels of a scale beginning at the bottom with the protozoa, continuing on to the two-layered animals like *Hydra* and jellyfish and sea-anemones, and then extending upwards to the region of the more complicated invertebrates and vertebrates. It was difficult perhaps to believe that these successive grades of organic structure indicated an order of evolution, because it seemed impossible that an animal so simple as a protozoan could produce offspring with the complex organization of a frog or a cat, even in long ages. But development delivers its evidence relating to this matter with telling and impressive force. How can we doubt the possibility of an evolution of higher animals from ancestors as simple as *Hydra* and *Amoeba* when a frog and a cat, like all other complicated organisms, begin individual existence as single cells, and pass through gastrula stages? If we deny it, we contradict the evidence of our senses, for the development is actually accomplished by the transformation of a single cell into a double-walled sac, and of this into different and more intricate organic mechanisms. The process *can* take place, for it *does* take place. Not until the investigator becomes familiar with a wide range of diverse animals and the peculiar qualities of their similar early stages, can he estimate the tremendous weight of the facts of comparative embryology. Were the statement iterated and reiterated on every page and in every paragraph, there would be no undue emphasis put upon the astounding fact that the apparently impassable gap between a one-celled animal like *Amoeba* and a mammal like a cat is actually compassed during the development of the last-named organisms from single cells. The occurrence of gill-slits in the embryos of lizards, birds, and mammals now seems a small thing when compared with the correspondences disclosed by the earliest stages of development. But in spite of their complexity, all the changes of "growing up" are explained and understood by the simple formula that the mode of individual development owes its nature primarily to the hereditary influence of earlier ancestors back to the original animals which were protozoa.

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Embryology as a distinct division of zoölogy has grown out of studies of classification and comparative anatomy. Its beginnings may be found in medieval natural history, for as far back as 1651 Harvey had pointed out that all living things originate from somewhat similar germs, the terse dictum being "Ex ovo omnia." By the end of the eighteenth century many had turned to the study of developing organisms, though their views by no means agreed as to the way an adult was related to the egg. Some, like Bonnet, held that the germ was a minute and complete replica of its parent, which simply unfolded and enlarged like a bud to produce a similar organism. Even if this were true, little would be gained, for it would still remain unknown how the germinal miniature originated to be just what it was conceived and assumed to be. Wolff was the originator of the view that is now practically universal among naturalists, namely, that development is a real process of transformation from simpler to more complex conditions.

The subject of comparative embryology grew rapidly during the nineteenth century as the field of comparative anatomy became better known, and when naturalists became interested in animals, not only as specific types, but also as the finished products of an intricate series of transformations. When life-histories were more closely compared, the meaning of the resemblances between early stages of diverse adult organisms was read by the same method which in comparative anatomy finds that consanguinity is expressed by resemblance. The great law of recapitulation, stated in one form by Von Baer and more definitely by Haeckel in the terms employed in the foregoing sections, was for a time too freely used and too rigidly applied by naturalists whose enthusiasm clouded their judgment. A strong reaction set in during the latter part of the nineteenth century, when attention was directed to the anachronisms of the embryonic record and to the alterations that are the results of larval or embryonic adaptation as short cuts in development. Nevertheless, it is not seriously questioned, I believe, that the main facts of a single life-history owe their nature to the past evolution of the species to which a given animal belongs.

Nowadays the problems in this well-organized department are concerned not only with more accurate accounts of the development of animals, but also with the mechanics of development, with the relative value of external and internal influences, and above all with the physical basis of inheritance. It is clear that the factors that direct the development of a wood frog's egg so that it becomes a wood-frog and not a tree-toad must lie in the egg itself, as derivatives from the two parent organisms. Weismann and his followers have proved that a peculiar substance in the nuclei of the egg and its daughter-products contains the essential factors of development, whatever these may be. Experiments dealing with the phenomena of heredity in pure and mixed breeds have largely confirmed Weismann's doctrine, and they have prepared the way for a deeper investigation of the marvelous process of biological inheritance.

However much he may be interested in the details of embryological science, the general student of natural history is more concerned with the bearing of its primary laws upon the great problem of evolution. In the foregoing brief review of the fundamental facts and principles of this subject, the purpose has been to show how the phenomena of development are viewed by men of science, and how they take their place in the doctrine of organic evolution. And it has also been made plain that comparative anatomy and comparative embryology support and supplement one another in countless ways and places, although each in itself is a complete demonstration that evolution is a real and a natural process.

# III

**THE EVIDENCE OF FOSSIL REMAINS**

Few natural objects appeal to the interest and imagination of the student with more force than the fragments of animals and plants released from the rocks where they have been entombed for ages. Our lives are so brief that it is impossible for us to comprehend the full duration of the slow process which constructed the burial shrouds of these creatures of long ago. We try to picture the earth and its inhabitants as they were when lizards were the highest forms of animals, and we wonder how life was lived in the dense forests of the coal age. Science can never learn all about the ancient history of the earth and of the organisms of bygone times; yet it has been able to accomplish much through its endeavors to reconstruct the past, for its method is one by which sure results can always be obtained whenever there are definite facts with which it can work. In our present study of evolution we reach the point when we must examine the testimony of the rocks, and the results and methods of that department of knowledge called palæontology, which is concerned with fossils and their interpretation.

The word "palæontology" means literally the "science of living things of long ago." It deals directly with the remains of animals and plants found as fossils, and it interprets them through its knowledge of the way modern animals are constructed and of the changes the earth's crust has undergone. A skull-like object may be found in a coal field and may come into the hands of the palæontologist: from his acquaintance with the head skeletons of recent types he will be able to assign the extinct creature which possessed the skull to a definite place in the animal scale and to understand its nearer or wider affinities with other animals of later times and of earlier epochs. In doing these things palæontology employs the methods of comparative anatomy with which we have now become familiar. In the performance of its other tasks, however, palæontology must work independently. It is necessary to know when a fossilized animal lived, not that its time need be measured by an absolute number of a few thousands or millions of years antedating our own era, for that is impossible. But the important thing is to know its relative age, and whether it preceded or followed other similar animals of its own group or of different divisions. The rocks themselves must be understood, how they have been formed and how they are related in mineralogical nature and in historical succession. Palæontology also deals with a number of subjects that are not in themselves biological, such as the combination of circumstances necessary for the adequate preservation of fossil relics. In so far as it is concerned with physical matters, as contrasted with strictly biological data, it is one with geology. Indeed, the investigators in these two departments must always work side by side and render mutual assistance to one another in countless ways, for each division needs the results of the other in order to accomplish its own distinct purposes. It must be evident to every one that it is impossible to understand the meaning of fossils and the place of the testimony of the rocks in the doctrine of evolution without knowing much about the geological history of the earth and the influences at work in the past. For these reasons palæontology differs somewhat from the other divisions of zoölogy where direct observation gives the materials for arrangement and study; in this case the individual data, that is, the fossil fragments themselves, can be made available only through a knowledge of their exact situations, of the reasons for their occurrence in particular places in the rock series and of the way rocks themselves are constructed and worked over by natural agencies. Our task is therefore twofold: certain physical matters of a geological nature must first be investigated before the biological facts can be described.

No doubt most people feel justified in believing that the whole doctrine of evolution must stand or fall according to the cogency of the palæontological evidences. Plain common sense says that the owners of shelly or bony fragments found in the deeply-laid strata of the earth must have lived countless years ago, and if the evolutionist asserts that primitive organic forms of ancient times have produced changed descendants of later times, it would seem that fossil evidence would be supremely and overwhelmingly important. It is true, of course, that this evidence is peculiarly significant, because in some ways it is more direct than that of the other categories already outlined. But it must not be forgotten that the doctrine is already securely founded upon the basic principles of anatomy and embryology. Science must treat the data of this category by different methods and must view them in different ways. Therefore we are interested in palæontology because of the way it tells the story of evolution in its own words, and because we are justified in expecting that its account should include a description of some such order of events as that revealed by the developing embryos of modern organisms and that demonstrated by the comparative anatomy of the varied species of adult animals.

It is true that palæontology gives direct testimony about the evolutionary succession of animals in geologic time. But we now know that embryology is even more direct in its proof that organic transformation is natural and real; while at the same time there is a completeness in the full series of developmental stages connecting the one-celled egg with the adult creature that must be forever lacking in the case of the fossil sequence of species. If paragraphs and pages are missing from the brief embryonic recapitulation, whole chapters and volumes of the fossil series have been lost for all time. The investigators whose task it has been to decipher the story of the earth's evolution have had to meet numerous and exasperating difficulties which do not confront the embryologist and anatomist who study living materials. Nevertheless the library of palæontological documents is one which has been founded for over a century, and it has grown fast during recent decades, so that consistent accounts may now be read of the great changes in organic life as the earth has altered and grown older. And in all this record, there is not a single line or word of fact that contradicts evolution. What definite evidence there is tells uniformly in favor of the doctrine, for it is possible, in the first place, to work out the order of succession of many of the great groups of animals, and this order is found to be the same as that established by the other bodies of evidence. Secondly, some fossil groups are astonishingly complete, so that the ancient history of a form like the horse can be written with something approaching fullness. Finally, the remains of certain animals have been found so situated in geological ways, and so constructed anatomically, that the zoölogist is justified in denoting them "missing links," because they seem to have been intermediate between groups that have diverged so widely during recent epochs as to render their common ancestry scarcely credible.

With these general results in mind, we must now become acquainted with such subjects as the interpretation of fossils, the causes for the incompleteness of the series, the conditions for fossilization, the forces of geological nature, and other matters that make the fossils themselves intelligible as scientific evidence.

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Many views have been entertained regarding the actual nature of the relics of antiquity exhumed from the rocks or exposed upon the surface by the wear and tear of natural agencies. In earliest times such things were variously considered as curious freaks of geological formation, as sports of nature, or as the remains of the slain left upon the battle-ground of mythical Titans. Some of the Greeks supposed that fossils were parts of animals formed in the bowels of the earth by a process of spontaneous generation, which had died before they could make their way to the surface. They were sometimes described as the bones of creatures stranded upon the dry land by tidal waves, or by some such catastrophe as the traditional flood of the scriptures. In medieval times, and even in our own day, some people who have been opposed to the acceptance of any portion of the doctrine of evolution have actually defended the view that the things called fossils were never the shells or bones of animals living in bygone times, but that they only simulate such things and have been created as such together with the layers of rock from which they may have been taken. If we employed the same arguments in dealing with the broken fragments of vases and jewelry taken from the Egyptian tombs or from the buried ruins of Pompeii, we would have to believe that such pieces were created as fragments and that they were never portions of complete objects, just because no one alive to-day has ever seen the perfect vessel or bracelet fashioned so long ago. Common sense directs us to discard such a fantastic interpretation in favor of the view that fossils are what they seem to be—simply relics of creatures that lived when the earth was younger.

Until this common sense view was adopted there was no science of palæontology. Cuvier was the first great naturalist to devote particular attention to the mainly unrelated and unverified facts that had been discovered before his time. He was truly the originator of this branch of zoölogy, for he brought together the observations of earlier men and extended his own studies widely and surely, emphasizing particularly the necessity for noting carefully the geological situation of a fossil in rocks of an older or later period of formation. His great result was the demonstration that many groups of animals existed in earlier ages that seem to have no descendants of the same nature to-day, and also that many or most of our modern groups are not represented in the earliest formed sedimentary rocks, although these recent forms possess hard parts which would surely be present somewhere in these levels if the animals actually existed in those times. But the meaning of these facts escaped Cuvier's mind. He was a believer in special creation, like Linnæus and all but a few among his predecessors, and he explained the diversity of the faunas of different geological times in what seems to us a very simple and naïve way. In the beginning, he held, when the world was created, it was furnished with a complete set of animals and plants. Then some great upheaval of nature occurred which overwhelmed and destroyed all living creatures. The Creator then, in Cuvier's view, proceeded to construct a new series of animals and plants, which were not identical with those of the former time, but were created according to the same general working plans or architectural schemes employed before. Another cataclysm was supposed to have occurred, which destroyed the second series of organisms and laid a new covering of rocks over the earth's surface for a subsequent period of relative quiet; and so the process was continued. By this account, Cuvier endeavored to reconcile the doctrine of supernatural creation and intervention with the obvious facts that organisms have differed at various times in the earth's history. Although he saw that animals of successive periods displayed similar structures, like the skeleton of vertebrates, which testified to some connection, Cuvier could not bring himself to believe that this connection was a genealogical one.

Mainly through the influence of the renowned English man of science, Charles Lyell, the students of the earth came to the conclusion that its manifold structures had developed by a slow and orderly process that was entirely natural; for they found no evidence of any sudden and drastic world-wide remodeling such as that postulated by the Cuvierian hypothesis of catastrophe. The battle waged for many years; but now naturalists believe that the forces, of nature, whose workings may be seen on all sides at the present time, have reconstructed the continents and ocean beds in the past in the same way that they work to-day. The long name of "uniformitarianism" is given to Lyell's doctrine, which has exerted an influence upon knowledge far outside the department of geology. Darwin tells us how much he himself was impressed by it, and how it led him to study the factors at work upon organic things to see if he could discern evidence of a biological uniformitarianism, according to which the past history of living things might be interpreted through an understanding of their present lives.

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What, now, are the reasons why the palæontological evidence is not complete and why it cannot be? In the first place the seeker after fossil remains finds about three fifths of the earth's surface under water so that he cannot explore vast areas of the present ocean beds which were formerly dry land and the homes of now extinct animals. Thus the field of investigation is seriously restricted at the outset, but the naturalist finds his work still more limited, in so far as much of the dry land itself is not accessible. The perennial snows of the Arctic region render it impossible to make a thorough search in the frigid zone, and there are many portions of the temperate and torrid zones that are equally unapproachable for other reasons. But even where exploration is possible, the surface rocks are the only ones from which remains can be readily obtained, for the layers formed in earlier ages are buried so deeply that their contents must remain forever unknown in their entirety. Only a few scratches upon the earth's hard crust have been made here and there, so it is small wonder that the complete series of extinct organisms has not been produced by the palæontologist.

A brief survey of the varied groups of animals themselves is sufficient to bring to light many biological reasons which account for still more of the vacant spaces in the palæontological record. We would hardly expect to find remains of ancient microscopic animals like the protozoa, unless they possessed shells or other skeletal structures which in their aggregate might form masses like the chalk beds of Europe. Jellyfish and worms and naked mollusks are examples of the numerous orders of lower animals having no hard parts to be preserved, and so all or nearly all of the extinct species belonging to these groups can never be known. But when an animal like a clam dies its shell can resist the disintegrating effects of bacteria and other organic and inorganic agencies which destroy the soft parts, and when a form like a lobster or a crab, possessing a body protected by closely joined shell segments, falls to the bottom of the sea, the chances are that much of the animal's skeleton will be preserved. Thus it is that corals, crustacea, insects, mollusks, and a few other kinds of lower forms constitute the greater mass of invertebrate palæontological materials because of their supporting structures of one kind or another. Perhaps the skeletal remains of the vertebrates of the past provide the student of fossils with his best facts, on account of the resistant nature of the bones themselves, and because the backboned animals are relatively modern; then, too, the rocks in which their remains occur have not been so much altered by geological agencies, or buried so deeply under the strata formed later. Of course only the hardest kinds of shells would remain as such after their burial in materials destined to turn into rock; in the majority of cases, an entombed bone is infiltrated or replaced by various mineral substances so that in time little or nothing of the original thing would remain, though a mold or a cast would persist.

But even if an animal of the past possessed hard structures, it must have satisfied certain limited conditions to have its remains prove serviceable to students of to-day. A dead mammal must fall upon ground that has just the right consistency to receive it; if the soil is too soft, its several parts will be separated and scattered as readily as though it had fallen upon hard ground where it would be torn to pieces by carnivorous animals. The dead body must then be covered up by a blanket of silt or sand like that which would be deposited as the result of a freshet. If a skeleton is too greatly broken up or scattered, it may be difficult or even impossible for its discoverer to piece together the various fragments and assemble them in their original relations. Very few individuals have been so buried and preserved as to meet the conditions for the formation of an ideal fossil. To realize how little may be left of even the most abundant of higher organisms, we have only to recall that less than a century ago immense herds of bison and wild horses roamed the Western plains, but very few of their skulls or other bones remain to be enclosed and fossilized in future strata of rocks. When we appreciate all these difficulties, both geological and biological, we begin to see clearly why the ancient lines of descent cannot be known as we know the path and mode of embryonic transformation. The wonder is not that the palæontological record is incomplete, but that there is any coherent and decipherable record at all. Yet in view of the many and varied obstacles that must be surmounted by the investigator, and the adverse factors which reduce the available evidence, the rapidly growing body of palæontological facts is amply sufficient for the naturalist to use in formulating definite and conclusive principles of evolution.

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For the purposes of palæontology, the most essential data of geology are those which indicate the relative ages of the strata that make up the hard outer crust of the earth, for only through them can the order of animal succession be ascertained. It does not matter exactly how old the earth may be. While it is possible to determine the approximate length of time required for the construction of sedimentary rocks like those which natural agencies are producing to-day, there are few definite facts to guide speculation as to the mode or duration of the process by which the first hard crystalline surface of the earth was formed. But palæontology does not care so much about the earliest geological happenings, for it is concerned with the manifold animal forms that arose and evolved after life appeared on the globe. Questions as to the way life arose, and as to the earliest transformations of the materials by which the earth was first formed are not within the scope of organic evolution, although they relate to intensely interesting problems for the student of the process of cosmic evolution.

According to the account now generally accepted, the original material of the earth seems to have been a semi-solid or semi-fluid mass formed by the condensation of the still more fluid or even gaseous nebula out of which all the planets of the solar system have been formed and of which the sun is the still fiery core. As soon as the earth had cooled sufficiently its substances crystallized and wrinkled to form the first mountains and ridges; between and among these were the basins which soon filled with the condensing waters to become the earliest lakes and oceans. The wear and tear of rains and snows and winds so worked upon the surfaces of the higher regions that sediments of a finer or coarser character like sand and mud and gravel were washed down into the lower levels. These sediments were afterwards converted into the first rocks of the so-called stratified or sedimentary series, as contrasted with the crystalline or plutonic rocks like the original mass of the earth and the kinds forced to the surface by volcanic eruptions. Later the earth wrinkled again in various ways and places so that new ridges and mountains were formed with new systems of lakes and oceans and rivers; and again the elements continued to erode and partially destroy the higher masses and to lay down new and later series of sedimentary rocks upon the old.

It seems scarcely credible that the apparently weak forces of nature like those we have mentioned are sufficiently powerful to work over the massive crust of the earth as geology says they have. Our attention is caught, as a rule, only by the greater things, like the earthquakes at San Francisco and Valparaiso, and the tidal waves and cyclones of the South Seas; but the results of these sporadic and local cataclysms are far less than the effects of the persistent everyday forces of erosion, each one of which seems so small and futile. When we look at the Rocky Mountains with their high and rugged peaks, it seems almost impossible that rain and frost and snow could ever break them up and wear them down so that they would become like the rounded hills of the

Appalachian Mountain chain, yet this is what will happen unless nature's ways suddenly change to something which they are not now. A visitor to the Grand Cañon of the Colorado sees a magnificent chasm over a mile in depth and two hundred miles long which has actually been carved through layer after layer of solid rock by the rushing torrents of the river. Perhaps it is easier to estimate the geological effects of a river in such a case as Niagara. Here we find a deep gorge below the famous falls, which runs for twenty miles or so to open out into Lake Ontario. The water passing over the brim of the falls wears away the edge at a rate which varies somewhat according to the harder or softer consistency of the rocks, but which, since 1843, has averaged about 104 inches a year. Knowing this rate, the length of the gorge, and the character of the rocky walls already carved out, the length of time necessary for its production can be safely estimated. It is about 30,000 to 40,000 years, not a long period when the whole history of the earth is taken into account. A similar length of time is indicated for the recession of the Falls of St. Anthony, of the Mississippi River, an agreement that is of much interest, for it proves that the two rivers began to make their respective cuttings when the great ice-sheet receded to the north at the end of the Glacial epoch.

What has become of the masses washed away during the formation of these gorges? As gravel and mud and silt the detritus has been carried to the still waters of the lower levels, to be laid down and later solidified into sandstone and slate and shale. All over the continents these things are going on, and indefatigable forces are at work that slowly but surely shear from the surface almost immeasurable quantities of earth and rock to be transported far away. In some instances it is possible to find out just how much effect is produced in a given period of time, especially in the case of the great river systems. For example, the mass of the fine particles of mud and silt carried in a given quantity of the water of the Mississippi as it passes New Orleans can be accurately measured, and a satisfactory determination can also be made of the total amount of water carried by in a year. From these figures the amount of materials in suspension discharged into the Gulf of Mexico becomes known. It is sufficient to cover one square mile to the depth of 269 feet; in twenty years it is one cubic mile, or five cubic miles in a century. Turning now to the other aspect of this process, and the antecedent causes which produce these effects, it appears that the area of the Mississippi River basin is 1,147,000 square miles—about one third of the total area of the United States. Knowing this, and the annual waste from its surface, it is easy to demonstrate that it will take 6000 years to plane off an average of one foot of soil and rock from the whole of this immense area. Of course only an inch or a few inches will be taken from some regions where the ground is harder or rockier, or where little rain falls, while many feet will be washed away from other places. The waters of the Hoang-ho come from about 700,000 square miles of country, from which one foot of soil is washed away in 1464 years. The Ganges River, draining about 143,000 square miles, carries off a similar depth of eroded materials from its basin in 823 years! Should we add to the above figures those that specify the bulk of the chemical substances in solution carried by these waters, the total would be even greater. We know that in the case of the Thames River, calcareous substances to the amount of 10,000 tons a year are carried past London, and all this mineral has been dissolved by rain-water from the chalky cliffs and uplands of England, so that the land has become less by this amount. Thus we learn that vast alterations are being made in the structure of great continents by rain and rivers, as well as by glaciers and other geological agencies. And at the same time that old strata are undergoing destruction new ones are in process of construction at other places, where animal remains can be embedded and preserved as fossils. The forces at work seem weak, but they continue their operations through ages that are beyond our comprehension and they accomplish results of world-building magnitude.

Thus the whole process of geological construction is such that older exposed strata continually undergo disintegration, but this involves the destruction of any fossils that they might contain. The very forces that preserve the relics of extinct animals at one time undo their work at a later period. There are many other influences besides that destroy the regularity of rock layers or change their mineralogical characters by metamorphosis. It is easier to see how volcanic outbursts alter their neighboring territory. The intense subterranean heat and imprisoned steam melt the deeper substances of the earth's crust, so that these materials boil out, as it were, where the pressure is greatest, and where lines of fracture and lesser resistance can be found. Because so much detritus is annually added to the ocean floors—enough to raise the levels of the oceans by inches in a century—it is natural that greater pressures should be exerted in these areas than in the slowly thinning continental regions. These are some of the reasons why volcanoes arise almost invariably along the shores or from the floors of great ocean beds. The chain that extends from Alaska to Chili within the eastern shore of the Pacific Ocean, and the many hundreds of volcanoes of the Pacific Islands bring to the surface vast quantities of eruptive rocks which break up and overlie the sedimentary strata formed regularly in other ways and at other times. The volcanoes of the Java region alone have thrown out at least 100 cubic miles of lava, cinders, and ashes during the last 100 years—twenty times the bulk of the materials discharged into the Gulf of Mexico by the Mississippi River in the same period of time.

From these and similar facts, the naturalist finds how agencies of the present construct new rocks and alter the old; and so in the light of this knowledge, he proceeds with his task of analyzing the remote past, confident that the same natural forces have done the work of constructing the lower geological levels because these earlier products are similar to those being formed to-day. After learning this much, he must immediately undertake to arrange the strata according to their ages. This might seem a difficult or even an impossible task, but the rocks themselves provide him with sure guidance.

Wherever a river has graven its deep way through an area of hard rocks, as in the case of Niagara, the walls display on their cut surfaces a series of lines and planes showing that they are superimposed layers formed serially by deposits that have differed some or much at different times according to the circumstances controlling the erosion of their constituent particles. A layer of several feet in thickness may be composed of compact shale, while above it will be a zone of limestone, and again above this another layer of shale. Successive strata like these, where they are parallel and obviously undisturbed, are evidently arranged in the order of their formation and age. But by far the most impressive demonstration of the basic principle of geology employed for the determination of the relative ages of rocks is the mighty Cañon of the Colorado. As the traveler stands on the winding rim of this vast chasm, his eye ranges across 13 miles of space to the opposite walls, which stretch for scores of miles to the right and left; upon this serried face he will see zone after zone of yellow and red and gray rock arranged with mathematical precision and level in the same order as on the steep slopes beneath him. Plain common sense tells him that the great sheets of rock stretched continuously at one time between the now separate walls, and that the various strata of sandstone and limestone were deposited in successive ages from below upwards in the order of their exposure. When now he extends his explorations to another state like Utah or Wyoming, he may find some but not all of the series exhibited in the Grand Cañon, overlaid or underlaid by other strata which in their turn can be assigned to definite places in the sequence. By the same method, the geologist correlates and arranges the rocks not only of different parts of the same state, or of neighboring states, but even those of widely separated parts of North America and of different continents. But he learns that he must refrain from over-hasty conclusions, for he soon finds that the sedimentary rocks have not been constructed at the same rate in different places during one and the same epoch, and that rocks formed even at one period are not always identical in nature. But his guiding principle is sensible and reasonable, and by employing it with due caution he provides the palæontologist with the requisite knowledge for his special task, which is to arrange the extinct animals whose remains are found as fossils of various earth ages in the order of their succession in time.

**CONDENSED TABLE OF PALAEONTOLOGICAL FACTS**

| | | |
YEARS | NUMBER OF | | | ORDER OF
NECESSARY FOR | FEET IN | GEOLOGICAL | GEOLOGICAL | APPEARANCE OF
FORMATION | THICKNESS | AGE | EPOCH | CHARACTERISTIC
| | | | GROUPS
_______________|___________|______________|_______________|________________
| | | |
| | | | M B R A F I
| | | | a i e m i n b
| | | | m r p p s v r
| | Recent | | m d t h h e a
| | or | | a s i i e r t
| | Quaternary | | l l b s t e
| | | | s e i e s
| | | | s a -

_______________|____________|_______________|________________||||||_____
| | | | | | | | | |
| | | Pleistocene | | | | | | |
| | Cenozoic | Pliocene | | | | | | |
5,000,000 | 25,000 | or | Miocene | | | | | | |
| | Tertiary | Oligocene | | | | | | |
| | | Eocene | | | | | | |
_______________|____________|_______________|________________||||||_____
| | | | | | | | | |
| | Mesozoic | Cretaceous | | | | | | |
4,000,000 | 23,000 | or | Jurassic | | | | | | |
| | Secondary | Triassic | | | | | |
_______________|____________|_______________|________________|______|||_|_____
| | | | | | | |
| | | Permian | | | | |
| | Palæozoic | Carboniferous | | | |
21,000,000 | 106,000 | or | Devonian | | |
| | Primary | Silurian | | |
| | | Cambrian | | |
_______________|____________|_______________|________________|_________________
| | | |
20,000,000 | 30,000 | Azoic | Archæn |
_______________|____________|_______________|________________|_________________

After what seems an unduly long preparation, we now come to the actual biological evidence of evolution provided by the results of this division of zoölogical science. But all of the foregoing is fundamentally part of this department of knowledge and it is absolutely essential for any one who desires to understand what the fossils themselves demonstrate.

The oldest sedimentary rocks are devoid of fossil remains and so they are called the Azoic or Archæan. They comprise about 30,000 feet of strata which seem to have required at least 20,000,000 years for their formation. This period is roughly two-fifths of the whole time necessary for the formation of *all* the sedimentary rocks, and this proportion holds true even if the entire period of years should be taken as 100,000,000 instead of 50,000,000 or less. The earth during this early age was slowly organizing in chemical and physical respects so that living matter could be and indeed was formed out of antecedent substances—but this process does not concern us here. The important fact is that the second major period, called the Palæozoic, or "age of ancient animals," saw the evolution of the lowest members of the series,—the invertebrates,—and the most primitive of the backboned animals, like fishes and amphibia. The rocks of this long age include about 106,000 feet of strata, demanding some 21,000,000 or 22,000,000 years for their deposition. Thus it is proved that the invertebrate animals were succeeded in time by the higher vertebrates, which is exactly what the evidences of the previous categories have shown. When we remember that the lower animals are devoid as a rule of skeletal structures that might be fossilized, and when we recall the fact that the strata of the palæozoic provided the materials out of which the upper layers were formed afterwards, we can understand why the ancient members of the invertebrate groups are not known as well as the later and higher forms like vertebrates. Yet all the fossils of these relatively unfamiliar creatures clearly prove that no complex animal appears upon a geological horizon until after some simple type belonging to a class from which it may have taken its origin; in brief, there are no anachronisms in the record, which always corresponds with the record written by comparative anatomy, wherever the facts enable a comparison to be made.

But the extinct animals of the third and fourth ages are more interesting to us, because there are more of them and because they are more like the well-known organisms of our present era. These two ages are called the Mesozoic or Secondary, and the Cenozoic or Tertiary. The former is so named because it was a transitional age of animals that are intermediate in a general way between the primitive forms of the preceding age and those of the next period; the latter name means the "recent-animal" age, when evolution produced not only the larger groups of our present animal series, but also many of the smaller branches of the genealogical tree like orders and families to which the species of to-day belong.

Confining our attention to the large vertebrate classes, the testimony of the rocks proves, as we have said, that fishes appeared first in what are called the Silurian and Devonian epochs, where they developed into a rich and varied array of types unequaled in modern times. At that period, they were the highest existing animals—the "lords of creation," as it were. To change the figure, their branch constituted the top of the animal tree of the time, but as other branches grew upwards to bear their twigs and leaves, as the counterparts of species, the species of the branch of fishes decreased in number and variety, as do the leaves of a lower part of a tree when higher limbs grow to overshadow them.

Following the fishes, the amphibia arose during the coal age or Carboniferous, usurping the proud position of the lower vertebrate class. The reptiles then appeared and gained ascendancy over the amphibia, to become in the Mesozoic age the highest and most varied of the existing vertebrates. At that time there were the great land dinosaurs with a length of 80 feet, like *Brontosaurus*; aquatic forms like *Ichthyosaurus* and *Plesiosaurus*, whose mode of evolution from terrestrial to swimming habits was like that of seals and penguins of far later eras. Flying reptiles also evolved, to set an example for the bats of the mammalian class, for both kinds of flying organisms converted their anterior limbs into wings, although in different ways.

During the Triassic and Jurassic periods of the Mesozoic age, the first birds and mammals appeared to follow out their diverging and independent lines of descent. Palæontology makes it possible to trace the origin and development of many of the different branches that grew out of the mammalian limb from different places and at different times during the Mesozoic and the following age, called the Cenozoic, or age of recent animals. It is unnecessary, however, for us to review more of the details: the main result is obvious; namely, that the appearance of the great classes of vertebrates is in the order of comparative anatomy and embryology. Not only, then, is the fact of evolution rendered trebly sure, but the general order of events is thrice and independently demonstrated to be one and the same. Surely we must see that no reasonable explanation other than evolution can be given for these basic facts and principles.

Turning now to the second division of palæontological evidence, we come to those groups where abundant materials make it possible to arrange the animals of successive epochs in series that may be remarkably complete. For the reasons specified, the backboned animals provide the richest arrays of these series, and such histories as those of horses and elephants have taken their places in zoölogical science as classics. But even among the invertebrates significant cases may be found. For example, in one restricted locality in Germany the shells of snails belonging to the genus *Paludina* have been found in superimposed strata in the order of their geological sequence. The ample material shows how the several species altered from age to age by the addition of knobs and ridges to the surface of the shell, until the fossils in the latest rocks are far different from their ancestors in the lowermost levels. Yet the intervening shells fill in the gaps in such a way as to show almost perfectly how the animals worked out their evolutionary history. This example illustrates the nature of many other known series of mollusks and of brachiopods, extending over longer intervals and connecting more widely separated ages like the Secondary and the present period.

Since the doctrine of evolution and its evidences began to occupy the thoughts of the intellectual world at large, no fossil forms have received more attention than the ancient members of the horse tribe. As we have learned, a modern horse is described by comparative anatomy as a one-toed descendant of remote five-toed ancestors. When the hoofed animals of modern times were reviewed as subjects for comparative anatomical study, the odd-toed forms arranged themselves in a series beginning with an animal like an elephant with the full number of five digits on each foot and ending at the opposite extreme with the horse. A reasonable interpretation of these facts was that the animals with fewer toes had evolved from ancestors with five digits, of which the outer ones had progressively disappeared during successive geological periods, while the middle one enlarged correspondingly. The facts provided by palæontology sustain this contention with absolutely independent testimony. Disregarding some problematical five-toed forms like *Phenacodus*, the first type of undoubted relationship to modern horses is *Hyracotherium*, a little animal about three feet long that lived during the Eocene period of the Cenozoic epoch. Its forefeet had four toes each, and its hinder limbs ended with three toes armed with small hoofs, but one of its relatives of the same time has a vestige of another digit on the hind foot. By the geological time mentioned, therefore, the earliest true horses had already lost some of the toes that their progenitors possessed. In the Miocene the extinct species, obviously descended from the Eocene forms, had lost more of their toes; still higher, that is, in the rocks formed during succeeding periods of time, the animals of this division are much larger and each of their feet has only three toes, of which the middle one is the largest while the ones on the sides are small and withdrawn from the ground so as to appear as useless vestiges. To produce modern horses and zebras from these nearer ancestors, few additional changes in the structure of the feet are necessary, for the lateral toes need only to become a little more reduced and the middle one to enlarge slightly to give the one-toed limb of modern types, with its splint-like vestiges still in evidence to show that the ancestor's foot comprised more of these terminal elements. Comparing the animals of successive periods, these and other skeletal structures demonstrate that the ancestry of each group of species is to be found in the animals of the preceding epoch, and that the whole history of horses is one of natural transformation,—in a word, of evolution.

No less interesting in their own way are the remains of other hoofed forms that lead down to the elephants of to-day and to the mammoth and mastodon of relatively recent geologic times. Common sense would lead to the conclusion that a form like a modern tapir was the prototype from which these creatures have arisen, and common sense would lead us to expect that if any fossils of the ancestors of the modern group of elephants occurred at all they would be like tapirs. Thus a fossil of much significance in this connection is *Moeritherium*, whose remains have been found in the rocks exposed in the Libyan desert, for this creature was practically a tapir, while at the same time its characters of muzzle and tusk mark it as very close to the ancestors of the larger woolly elephants of later geological times, when the trunk had grown considerably and the tusks had become greatly prolonged. Again the fossil sequence confirms the conclusions of comparative anatomy, regarding the mode by which certain modern animals have evolved.

The fossil deer of North America, as well as many other even-toed members of the group of mammalia possessing hoofs, provide the same kind of conclusive evidence. The feature of particular interest in the case of their horns, is a correspondence between the fossil sequence and the order of events in the life-history of existing species,—that is, between the results of palæontology and of embryology. Horns of the earliest known fossil deer have only two prongs; in the rocks above are remains of deer with additional prongs, and point after point is added as the ancient history of deer is traced upwards through the rocks to modern species. We know that the life-history of a modern species of animals reviews the ancestral record of the species, and what happens during the development of deer can be directly compared with the fossil series. It is a matter of common knowledge that the year-old stag has simple spikes as horns, and that these are shed to be replaced the following year by larger forked horns. Every year the horns are lost and new ones grow out, and become more and more elaborately branched as time goes on, thus giving a series of developmental stages that faithfully repeats the general order of fossil horns. Even Agassiz, who was a believer in special creation and an opponent of evolution, was constrained to point out many other instances, mainly among the invertebrata, where there was a like correspondence between the ontogeny of existing species and their phylogenetic history as revealed by the fossil remains of their ancestors.

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In the last place, we must give more than a passing consideration to some of the extinct types of animals that occupy the position of "links" between groups now widely separated by their divergence in evolution from the same ancestors. Perhaps the most famous example is *Archæopteryx* found in a series of slates in Germany. This animal is at once a feathered, flying reptile, and a primitive bird with countless reptilian structures. Its short head possesses lizard-like jaws, all of which bear teeth; its wings comprise five clawed digits; its tail is composed of a long series of joints or vertebræ, bearing large feathers in pairs; its breastbone is flat and like a plate, thus resembling that of reptiles and differing markedly from the great keeled breastbone of modern flying birds, whose large muscles have necessitated the development of the keel for purposes of firm attachment. In brief, this animal was close to the point where reptiles and birds parted company in evolution, and although it was a primitive bird, it is in a true sense a "missing link" between reptiles and the group of modern birds. Other fossil forms like *Hesperornis* and *Ichthyornis*, whose remains occur in the strata of a later date, fill in the gap between *Archæopteryx* and the birds at the present time, for among other things they possess teeth which indicate their origin from forms like *Archæopteryx*, while in other respects they are far nearer the birds of later epochs. That these links are not unique is proved by numerous other examples known to science, such as those which connect amphibia and reptiles, ancient reptiles and primitive mammals, as well as those which come between the different orders of certain vertebrate classes.

In summarizing the foregoing facts, and the larger bodies of evidence that they exemplify, we learn how surely the testimony of the rocks establishes evolution in its own way, how it confirms the law of recapitulation demonstrated by comparative embryology, and how it proves that the greater and smaller divisions of animals have followed the identical order in their evolution that the comparative study of the present day animals has independently described.

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The facts of geographical distribution constitute the fifth division of zoölogy, and an independent class of evidences proving the occurrence of evolution. This department of zoölogy assumed its rightful status only after the other divisions had attained considerable growth. Many naturalists before Darwin and Wallace and Wagner had noticed that animals and plants were by no means evenly distributed over the surface of the globe, but until the doctrine of evolution cleared their vision they did not see the meaning of these facts. As in the case of all the other departments of zoölogy the immediate data themselves are familiar, but because they are so obvious the mind does not look for their interpretation but accepts the facts at their face value. While the phenomena of distribution are no less fascinating to the naturalist, and no less effective in their demonstration of evolution, their comprehensive treatment would demand more space than the whole purpose of the present description of organic evolution would justify. Thus a brief outline only can be given of the salient principles of this subject in order that their bearing upon the problem of species may be indicated.

Even as children we learn many facts of animal distribution; every one knows that lions occur in Africa and not in America, that tigers live in Asia and Malaysia, that the jaguar is an inhabitant of the Brazilian forests, and that the American puma or mountain lion spreads from north to south and from east to west throughout the American continents. The occurrence of differing human races in widely separated localities is no less familiar and striking, for the red man in America, the Zulu in Africa, the Mongol and Malay in their own territories, display the same discontinuity in distribution that is characteristic of all other groups of animals and of plants as well. As our sphere of knowledge increases, we are impressed more and more forcibly by the diversity and unequal extent of the ranges occupied by the members of every one of the varied divisions of the organic world. Another fact which becomes significant only when science calls our attention to it is the absence from a land like Australia of higher mammals such as the rabbit of Europe. The hypothesis of special creation cannot explain this absence on the assumption that the rabbit is unsuited to the conditions obtaining in the country named, for when the species was introduced into Australia by man, it developed and spread with marvelous rapidity and destructive effect. It may seem impossible that facts like these could possess an evolutionary significance, but they are actual examples of the great mass of data brought together by the naturalists who have seen in them something to be interpreted, and who have sought and found an explanation in the formularies of science.

The general principles of distribution appear with greatest clearness when an examination is made of the animals and plants of isolated regions like islands. The Galapagos Islands constitute a group that has figured largely in the literature of the subject, partly because Darwin himself was so impressed by what he found there in the course of his famous voyage around the world in the "Beagle." They form a cluster on the Equator about six hundred miles west of the nearest point of the neighboring coast of South America. Although the lizards and birds that live in the group differ somewhat among themselves as one passes from island to island, on the whole they are most like the species of the corresponding classes inhabiting South America. Why should this be so? On the hypothesis of special creation there is no reason why they should not be more like the species of Africa or Australia than like those of the nearest body of the mainland. The explanation given by evolution is clear, simple, and reasonable. It is that the characteristic island forms are the descendants of immigrants which in greatest probability would be wanderers from the neighboring continent and not from far distant lands. Reaching the isolated area in question the natural factors of evolution would lead their offspring of later generations to vary from the original parental types, and so the peculiar Galapagos species would come into being. The fact that the organisms living on the various islands of this group differ somewhat in lesser details adds further justification for the evolutionary interpretation, because it is not probable that all the islands would be populated at the same time by similar stragglers from the mainland. The first settlers in one place would send out colonies to others, where independent evolution would result in the appearance of minor differences peculiar to the single island. In this manner science interprets the general agreement between the animals of the Azores Islands and the fauna of the northwestern part of Africa, the nearest body of land, from which it would be most natural for the ancestors of the island fauna to come.

The land-snails inhabiting the various groups of islands scattered throughout the vast extent of the Pacific Ocean provide the richest and most ideal material for the demonstration of the principles of geographical distribution. In the Hawaiian Islands snails of the family of Achatinellidæ occur in great abundance, and like the lizards of the Galapagos Islands different species occur on the different members of the group. Within the confines of one and the same island, they vary from valley to valley, and the correlation between their isolation in geographical respects and specific differences on the other hand, first pointed out by Gulick, makes this tribe of animals classical material. In Polynesia and Melanesia are found close relatives of the Achatinellidæ, namely, the Partulæ, which are thus in relative proximity to the Achatinellidæ and not on the other side of the world. Furthermore, the Partulæ are not alike in all of the groups of Polynesia where they occur; the species of the Society Islands are absolutely distinct from those of the Marquesas, Tonga, Samoan, and Solomon Islands, although they agree closely in the basic characters that justify their reference to a single genus. The geological evidence tells us that these islands were once the peaks of mountain ranges rising from a Pacific continent which has since subsided to such an extent that the mountain tops have become separate islands. Thus the resemblances between Hawaiian and Polynesian snails, and the closer similarities exhibited by the species of the various groups of Polynesia, are intelligible as the marks of a common ancestry in a widespread continental stock, while the observed differences show the extent of subsequent evolution along independent lines followed out after the isolation of the now separated islands. The principle may be worked out in even greater detail, for it appears that within the limits of one group diverse forms occupy different islands, evolved in different ways in their own neighborhoods; while in one and the same island, the populations of the different valleys show marked effects of divergence in later evolution, precisely as in the case of the classic Achatinellidæ of the Hawaiian Islands.

The broad and consistent principle underlying these and related facts is this: *there is a general correspondence between the differences displayed by the organisms of two regions and the degree of isolation or proximity of these two areas*. Thus the disconnected but neighboring areas of the Galapagos Islands and South America support species that resemble each other closely, for the reasons given before; long isolated areas like Australia and its surroundings possess peculiar creatures like the egg-laying mammals, and all of the pouched animals or marsupials with only one or two exceptions like our own American opossum,—a correlation between a geological and geographical discontinuity on the one hand and a peculiarity on the other that reinforces our confidence in the faunal evolutionary interpretation of the facts of distribution.

It is true that the various classes of animals do not always appear with coextensive ranges. The barriers between two groups of related species will not be the same in all cases. A range like the Rocky Mountains will keep fresh-water fish apart, while birds and mammals can get across somewhere at some time. All these things must be taken into account in analyzing the phenomena of distribution, and many factors must be given due attention; but in all cases the reasons for the particular state of affairs in geographical and biological respects possess an evolutionary significance.

Having then all the facts of animal natural history at his disposal, and the uniform principles in each body of fact that demonstrate evolution, it is small wonder that the evolutionist seems to dogmatize when he asserts that descent with adaptive and divergent modification is true for all species of living things. The case is complete as it stands to-day, while it is even more significant that every new discovery falls into line with what is already known, and takes its natural place in the all-inclusive doctrine of organic evolution. Because this explanation of the characteristics of the living world is more reasonable than any other, science teaches that it is true.

# IV

**EVOLUTION AS A NATURAL PROCESS**

The purpose of the discussions up to this point has been to present the reasons drawn from the principal classes of zoölogical facts for believing that living things have transformed naturally to become what they now are. Even if it were possible to make an exhaustive analysis of all of the known phenomena of animal structure, development, and fossil succession, the complete bodies of knowledge could not make the evolutionary explanation more real and evident than it is shown to be by the simple facts and principles selected to constitute the foregoing outline. We have dealt solely with the evidences as to the fact of evolution; and now, having assured ourselves that it is worth while to so do, we may turn to the intelligible and reasonable evidence found by science which proves that the familiar and everyday "forces" of nature are competent to bring about evolution if they have operated in the past as they do to-day. Investigation has brought to light many of the subsidiary elements of the whole process, and these are so real and obvious that they are simply taken for granted without a suspicion on our part of their power until science directs our attention to them.

For one reason or another, those who take up this subject for the first time find it difficult to banish from their minds the idea that evolution, even if it ever took place, has been ended. They think it futile to expect that a scrutiny of to-day's order can possibly find influences powerful enough to have any share in the marvelous process of past evolution demonstrated by science. The naturalists of a century ago held a similar opinion regarding the earth, viewing it as an immutable and unchanged product of supernatural creation, until Lyell led them to see that the world is a plastic mass slowly altering in countless ways. It is no more true that living things have ceased to evolve than that mountains and rivers and glaciers are fixed in their final forms; they may seem everlasting and permanent only because a human life is so brief in comparison with their full histories. Like the development of a continent as science describes it, the origin of a new species by evolution, its rise, culmination, and final extinction may demand thousands of years; so that an onlooker who is himself only a conscious atom of the turbulent stream of evolving organic life does not live long enough to observe more than a small fraction of the whole process. Therefore living species seem unchanged and unchangeable until a conviction that evolution is true, and a knowledge of the method of science by which this conviction is borne upon one, guide the student onwards in the further search for the efficient causes of the process.

The biologist employs the identical methods used by the geologist in working out the past history of the earth's crust. The latter observes the forces at work to-day, and compares the new layers of rock now being formed with the strata of deeper levels; these are so much alike that he is led to regard the constructive influences of the past as identical with those he can now watch at work. Similarly the biologist must first learn, as we have done, the principles of animal construction and development, and of other classes of zoölogical facts, and then he must turn his attention from the dead object of laboratory analysis to the workings of organic machines. The way an organism lives its life in dynamic relations to the varied conditions of existence, as well as the mutual physiological relations of the manifold parts of a single organism, reveal certain definite natural forces at work. Therefore his next task is to compare the results accomplished by these factors in the brief time they may be seen in operation with the products of the whole process of organic evolution, to learn, like the geologist in his sphere, that the present-day natural forces are able to do what reason says they have done in the past.

When the subject of inquiry was the reality of evolution, it was perhaps surprising to find that even the most familiar animals like cats and frogs provided adequate data for science to use in formulating its principles. So it is with the matter of method; it is unnecessary to go beyond the observations of a day or a week of human life to find forces at work, as real and vital as animal existence and organic life themselves. This is true, because evolution is true, and because the lives of all creatures follow one consistent law. Our task is therefore much more simple than most people suppose it to be; let us look about us and classify what we may observe, increasing our knowledge from the wide array of equally natural facts supplied by the biologist.

The analogies of the steamship and the locomotive proved useful at many times during the discussion of the fact of evolution, and even in the present connection they will still be of service. The evolution of these dead machines has been brought about by man, who, as an element of their environment, has been their creator as well as the director of their historical transformations. The result of their changes has been greater efficiency and better adjustment or adaptation to certain requirements fixed by man himself. The whole process of improvement has been one, in brief, of trial and error; new inventions have often been worthless, and they have been relegated to the scrap-heap, while the better part has been finally incorporated in the type machine. In brief, then, the important elements in the evolution of these examples have been three; first, *adaptation*, second, the *origination of new parts*, and third, the *retention of the better invention*.

Are the creatures of the living world so constituted that biological equivalents of these three essential elements of mechanical evolution can be found? Are organisms adapted to the circumstances controlling their lives, and are they capable of changing naturally from generation to generation, and of transmitting their qualities to their offspring? These are definite questions that bring us face to face with the fundamental problems relating to the dynamics or workings of evolution. We need not ask for or expect to find complete answers, for we know that it is impossible to obtain them. But we may expect to accomplish our immediate object, which is to see that evolution is natural. Our attention must be concentrated upon the three biological subjects of *adaptation*, *variation,* and *inheritance*, and we must learn why science describes them as real organic phenomena and the results of natural causes.

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At the very outset, when the general characteristics of living things were considered, much was said on the subject of adaptation as a universal phenomenon of nature. It was not contended that perfection is attained by any living mechanism, but it was held that no place exists in nature for an organism that is incapable of adjusting itself to the manifold conditions of life. A *modus vivendi* must be established and some satisfactory degree of adaptation must be attained, or else an animal or a species must perish. With this fundamental point as a basis, we look to nature for two kinds of natural processes or factors, first, those which may originate variations as *primary factors*,—the counterparts of human ingenuity and invention in the case of locomotive evolution,—and the *secondary factors* of a preservative nature which will perpetuate the more adaptive organic changes produced by the first influences; it is clear that the latter are no less essential for evolution than the first causes for the appearance of variations.

The term "variation" is employed for the natural phenomenon of being or becoming different. It is an obvious fact that no child is ever exactly like either of its parents or like any one of its earlier ancestors; while furthermore in no case does an individual resemble perfectly another of its own generation or family. This departure from the parental condition, and the lack of agreement with others even of its closest blood-relatives, are two familiar forms of variation. As a rule, the degree to which a given organism is said to vary in a given character is most conveniently measured by the difference between its actual condition and the general average of its species, even though there is no such thing as a specimen of average nature in all of its qualities. In brief, then, variation means the existence of some differences between an individual and its parents, its fraternity, and, in a wider sense, all others of its species.

Passing now to the causes of variation, all of the countless deviations of living things can be referred to three kinds of primary factors; namely, the *environmental*, *functional*, and *congenital* influences that work upon the organism in different ways and at different times during its life. We shall learn that the evolutionary values of these three classes are by no means equal, but we take a long step forward when we realize that among the things we see every day are facts demonstrating the reality of three kinds of natural powers quite able to change the characters of organic mechanisms.

The "environment" of an organism is everything outside the creature itself. In the case of an animal it therefore includes other members of its own kind, and other organisms which prey upon its species or which serve it as food, as well as the whole series of inorganic influences which first come to mind when the term is used. For example, the environment of a lion includes other lions which are either members of its own family, or else, if they live in the same region, they are its more or less active rivals and competitors. In the next place, other kinds of animals exist whose lives are intimately related to the lion's life, such as the antelopes or zebras that are preyed upon, and the human hunter to whom the lion itself may fall a victim. In addition, there are the contrasted influences of inorganic nature which demand certain adjustments of the lion's activities. Light and darkness, heat and cold, and other factors have their direct and larger or smaller effects upon the life of a lion, although these effects are less obvious in this instance than in the case of lower organisms.

The reality of variations due to the inorganic elements of the environment is everywhere evident. Those who have spent much time in the sun are aware that sunburn may result as a product of a factor of this class. The amount of sunlight falling upon a forest will filter through the tree-tops so as to cause some of the plants beneath to grow better than others, thus bringing about variations among individuals that may have sprung from the myriad seeds of a single parent plant. In times of prolonged drought, plants cannot grow at the rate which is usual and normal for their species, and so many variations in the way of inhibited development may arise.

Then there are the variations of a second class, more complex in nature than the direct effects of environment,—namely, the functional results of use and disuse. A blacksmith uses his arm muscles more constantly than do most other men, and his prolonged exercise leads to an increase of his muscular capacity. All of the several organic systems are capable of considerable development by judicious exercise, as every one knows. If the functional modifications through use were unreal, then the routine of the gymnasium and the schoolroom would leave the body and the mind as they were before. Furthermore, we are all familiar with the opposite effects of disuse. Paralysis of an arm results in the cessation of its growth. When a fall has injured the muscles and nerves of a child's limb, that structure may fail to keep pace with the growth of the other parts of the body as a result of its disuse. These are simple examples of a wide range of phenomena exhibited everywhere by animals and even by the human organism, demonstrating the plasticity of the organic mechanism and its modification by functional primary factors of variation.

But by far the greater number of variations seem to be due to the so-called congenital causes, which are sharply contrasted with the influences of the first and second classes. It is quite true that the influences of the third class cannot be surely and directly demonstrated like the others, but however remote and vague they themselves may appear to be, their effects are obvious and real, while at the same time their effects are to be clearly distinguished from the products of the other two kinds. Congenital factors reside in the physical heritage of an organism, and their results are often evident before an individual is subjected to environmental influences and before it begins to use its various organs. For example, it is a matter of common observation that a child with light hair and blue eyes may have dark-eyed and brown-haired parents. The fact of difference is a phenomenon of variation; the causes for this fact cannot be found in any other category than that comprising the hereditary and congenital influences of parent upon offspring. *How* the effect is produced by such causes is less important in the present connection than the natural *fact* of congenital variation. Science, however, has learned much about the causes in question, as we shall see at a later point.

Thus the first step which is necessary for an evolution and transformation of organic mechanisms proves to be entirely natural when we give only passing attention to certain obvious phenomena of life. The fact of "becoming different" cannot be questioned without indicting our powers of observation, and we must believe in it on account of its reality, even though the ultimate analysis of the way variations of different kinds are produced remains for the future.

Having learned that animals are able to change in various ways, the next question is whether variations can be transmitted to future generations through the operation of secondary factors. Long ago Buffon held that the direct effects of the environment are immediately heritable, although the mode of this inheritance was not described; it was simply assumed and taken for granted. Thus the darker color of the skin of tropical human races would be viewed by Buffon as the cumulative result of the sun's direct effects. Lamarck laid greater stress upon the indirect or functional variations due to the factors of use and disuse, and he also assumed as self-evident that such effects were transmissible as "acquired characters." This expression has a technical significance, for it refers to variations that are added during individual life to the whole group of hereditary qualities that make any animal a particular kind of organism. If evolution takes place at all, any new kind of organism originating from a different parental type must truly acquire its new characteristics, but few indeed of the variations appearing during the lifetime of an animal owe their origin to the functional and environmental influences, whose effects only deserve the name of "acquired characters" in the special biological sense.

In sharp contrast to Lamarckianism, so called,—although it did not originate in the mind of the noted man of science whose name it bears,—is the doctrine of natural selection, first proposed in its full form by Charles Darwin. This doctrine presents a wholly natural description of the method by which organisms evolve, putting all of the emphasis upon the congenital causes of variation, although the reality of other kinds of change is not questioned. But the contrast between Darwinism and the other descriptions of secondary factors can best be made after a somewhat detailed discussion of the former, which has gained the adherence of the majority of the naturalists of to-day. However, we must not pass on without pointing out that however much the explanations given by various men of science may differ, they all agree in expressly recognizing the complete naturalness of the secondary as well as of the primary factors of evolution.

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The doctrine of natural selection forms the best basis for the detailed discussion of the way evolution has come about in the past and how it is going on to-day. This is true because it was the first description of nature's program to carry conviction to the scientific world, and because its major elements have stood the test of time as no other doctrine has done. Much has been added to our knowledge of natural processes during post-Darwinian times, and new discoveries have supplemented and strengthened the original doctrine in numerous ways, although they have corrected certain of the minor details on the basis of fuller investigation.

At the outset it must be clearly understood that Darwin's doctrine is concerned primarily with the *method* and not with the evidences as to the actual *fact* of evolution. Most of those who are not familiar with the principles of science believe that Darwin discovered this process; but their opinion is not correct. The reality of natural change as a universal attribute of living things had been clearly demonstrated long before Darwin wrote the remarkable series of books whose influence has been felt outside the domains of biology and to the very confines of organized knowledge everywhere. The "Origin of Species" was published in 1859, and only the last of its fourteen chapters is devoted to a statement of the evidence that evolution is true. In this volume Darwin presented the results of more than twenty-five years of patient study of the phenomena of nature, utilizing the observations of wild life in many regions visited by him when he was the naturalist of the "Beagle" during its famous voyage around the world. He also considered at length the results of the breeder's work with domesticated animals, and he showed for the first time that the latter have an evolutionary significance. Because his logical assembly of wide series of facts in this and later volumes did so much to convince the intellectual world of the reasonableness of evolution, Darwin is usually and wrongly hailed as the founder of the doctrine. It is interesting to note in passing that Alfred Russel Wallace presented a precisely similar outline of nature's workings at about the same time as the statement by Darwin of his theory of natural selection. But Wallace himself has said that the greater credit belongs to the latter investigator who had worked out a more complete analysis on the basis of far more extensive observation and research.

The fundamental point from which the doctrine of natural selection proceeds is the fact that all creatures are more or less perfectly adapted to the circumstances which they must meet in carrying on their lives; this is the reason why so much has been said in earlier connections regarding the universal occurrence of organic adaptation. An animal is not an independent thing; its life is intertwined with the lives of countless other creatures, and its very living substance has been built up out of materials which with their endowments of energy have been wrested from the environment. Every animal, therefore is engaged in an unceasing struggle to gain fresh food and new energy, while at the same time it is involved in a many-sided conflict with hordes of lesser and greater foes. It must prevail over all of them, or it must surrender unconditionally and die. There is no compromise, for the vast totality we individualize as the environment is stern and unyielding, and it never relents for even a moment's truce.

To live, then, is to be adapted for successful warfare; and the question as to the mode of origin of species may be restated as an inquiry into the origin of the manifold adaptations by which species are enabled to meet the conditions of life. Why is adaptation a universal phenomenon of organic nature?

The answer to this query given by Darwinism may be stated so simply as to seem almost an absurdity. It is, that if there ever were any unadapted organisms, they have disappeared, leaving the world to their more efficient kin. Natural selection proves to be a continuous process of trial and error on a gigantic scale, for all of living nature is involved. Its elements are clear and real; indeed, they are so obvious when our attention is called to them that we wonder why their effects were not understood ages ago. These elements are (1) the universal occurrence of variation, (2) an excessive natural rate of multiplication, (3) the struggle for existence entailed by the foregoing, (4) the consequent elimination of the unfit and the survival of only those that are satisfactorily adapted, and (5) the inheritance of the congenital variations that make for success in the struggle for existence. It is true that these elements are by no means the ultimate causes of evolution, but their complexity does not lessen their validity and efficiency as the immediate factors of the process.

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Taking up the first proposition, we return to the subject of variation that has been discussed previously for the purpose of demonstrating its reality. The observations of every day are enough to convince us that no two living things are ever exactly alike in all respects. The reason is that the many details of organic structure are themselves variable, so that an entire organism cannot be similar to another either in material or in functional regards, while furthermore it would be impossible for an animal to be related to environmental circumstances in the same way as another member of its species unless it was possible for two things to occupy the same space at the same time! Individual differences in physical constitution are displayed by any litter of kittens, with identical parents; it needs only a careful examination to find the variations in the shape of the heads, the length of their tails, and in every other character. Sometimes the differences are less evident in physical qualities than in disposition and mental make-up, for such variations can be found among related kittens just as surely as among the children belonging to a single human family.

Not only do all organisms vary, but they seem to vary in somewhat similar ways. While modern investigations have thrown much light upon the relations between variations and their causes, of particular value in the case of the congenital phenomena, the greatest advance since Darwin's time consists in the demonstration by the naturalists who have employed the laborious methods of statistical analysis that the laws according to which differences occur are the same where-ever the facts have been examined. A single illustration will suffice to indicate the general nature of this result. If the men of a large assemblage should group themselves according to their different heights in inches, we would find that perhaps one half of them would agree in being between five feet eight inches and five feet nine inches tall. The next largest groups would be those just below and above this average class,—namely, the classes of five feet seven to eight inches and five feet nine to ten inches. Fewer individuals would be in the groups of five feet five to six inches and five feet ten to eleven inches, and still smaller numbers would constitute the more extreme groups on opposite sides of these. If the whole assemblage comprised a sufficient number of men, it would be found that a class with a given deviation from the average in one direction would contain about the same number of individuals as the class at the same distance from the average in the opposite direction. Taking into account the relative numbers in the several classes and the various degrees to which they depart from the average, the mathematician describes the whole phenomenon of variation in human stature by a concise formula which outlines the so-called "curve of error." From his study of a thousand men, he can tell how many there would be in the various classes if he had the measurements of ten thousand individuals, and how many there would be in the still more extreme classes of very short and very tall men which might not be represented among one thousand people.

It is not possible to explain why variation should follow this or any other mathematical law without entering into an unduly extensive discussion of the laws of error. The mathematicians themselves tell us in general terms that the observations they describe so simply by their formulæ follow as the result of so-called chance, by which they mean that the combined operation of numerous, diverse, and uncorrelated factors brings about this result, and not, of course, that there is such a thing as an uncaused event or phenomenon.

Whenever any extensive series of like organisms has been studied with reference to the variations of a particular character, the variations group themselves so as to be described by identical or similar curves of error. It is certainly significant that this is true for such diverse characters, cited at random from the lists of the literature, as the number of ray-flowers of white daisies, the number of ribs of beech leaves, and of the bands upon the capsules of poppies, for the shades of color of human eyes, for the number of spines on the backs of shrimps, and for the number of days that caterpillars feed before they turn into pupæ.

To summarize the foregoing facts, we have learned that variation is universal throughout the living world, and that the primary factors causing organic difference—the counterparts of human ingenuity in the case of dead mechanisms—are the natural influences of the environment, of organic physiological activity, and of congenital inheritance. These factors are accorded different values in the evolution of new species, as we may see more clearly at a later juncture, but the essential point here is that they are not unreal, although they may not as yet be described by science in final analytical terms.

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We come now to the second element of the whole process of evolution, namely, what we may call overproduction or excessive multiplication. Like variation and so many other phenomena of nature, this is so real and natural that it escapes our attention until science places it before us in a new light. The normal rate of reproduction *in all species of animals* is such that if it were unchecked, any kind of organism would cumber the earth or fill the sea in a relatively short time. That this is universally true is apparent from any illustration that might be selected. Let us take the case of a plant that lives for a single year, and that produces two seeds before it withers and dies; let us suppose that each of these seeds produces an adult plant which in its turn lives one year and forms two seeds. If this process should continue without any interference, the twentieth generation after as many years would consist of more than one million descendants of the original two-seeded annual plant, provided only that each individual of the intervening years should live a normal life and should multiply at the natural rate. But such a result as this is rendered impossible by the very nature which makes annual plants multiply in the way they do. Let us take the case of a pair of birds which produce four young in each of four seasons. Few would be prepared for the figures enumerating the offspring of a single pair of birds at the end of fifteen years, if again all individuals lived complete and normal lives: at the end of the time specified there would be more than two thousand millions of descendants. The English sparrow has been on this continent little more than fifty years; it has found the conditions in this country favorable because few natural enemies like those of its original home have been met, and as a consequence it has multiplied at an astounding rate so as to invade nearly all parts of North America, driving out many species of song birds before it. About twenty years ago David Starr Jordan wrote that if the English sparrow continued to multiply at the natural rate of that time, in twenty years more there would be one sparrow to every square inch of the state of Indiana; but of course nature has seen to it that this result has not come about. A single conger-eel may produce fifteen million eggs in a single season, and if this natural rate of increase were unchecked, the ocean would be filled solid with conger-eels in a few years. Sometimes a single tapeworm, parasitic in the human body, will produce three hundred million embryos; the fact that this animal is relatively rare diverts our attention from the alarming fertility of the species and the excessive rate of its natural increase. Perhaps the most amazing figures are those established by the students of bacteria and other micro-organisms. Many kinds of these primitive creatures are known where the descendants of a single individual will number sixteen to seventeen millions after twenty-four hours of development under ordinarily favorable conditions. Though a single rodlike individual taken as a starting-point may be less than one five-thousandth of an inch in length, under natural circumstances it multiplies at a rate which *within five days* would cause its descendants *to fill all the oceans to the depth of one mile*. This is a fact, not a conjecture; the size of one organism is known, and the rate of its natural increase is known, so that it is merely a matter of simple arithmetic to find out what the result would be in a given time.

Even in the case of those animals that reproduce more slowly, an overcrowding of the earth would follow in a very short time. Darwin wrote that even the slow-breeding human species had doubled in the preceding quarter century. An elephant normally lives to the age of one hundred years; it begins to breed at the age of thirty, and usually produces six young by the time it is ninety. Beginning with a single pair of elephants and assuming that each individual born should live a complete life, only eight hundred years would be requisite to produce nineteen million elephants; a century or two more and there would be no standing room for the latest generation of elephants. It is only too obvious that such a result is not realized in nature, but it is on account of other natural checks, and not because the natural rate of reproductive increase is anything but excessive.

The third element of the process of natural selection is the struggle for existence which is to a large extent the direct consequence of over-multiplication. Because nature brings more individuals into existence than it can support, every animal is involved in many-sided battles with countless foes, and the victory is sometimes with one and sometimes with another participant in the conflict. A survivor turns from one vanquished enemy only to find itself engaged in mortal combat with other attacking forces. Wherever we look, we find evidence of an unceasing struggle for life, and an apparently peaceful meadow or pond is often the scene of fierce battles and tragic death that escape our notice only because the contending armies are dumb.

A community of ants, often comprising more individuals than an entire European state, depends for its national existence upon its ability to prevail over other communities with which it may engage in sanguinary wars where the losses of a single battle may exceed those of Gettysburg. The developing conger-eels find a host of enemies which greatly deplete their numbers before they can grow even into infancy. An annual plant does not produce a million living offspring in twenty years because seeds do not always fall upon favorable soil, nor do they always receive the proper amount of sunlight and moisture, or escape the eye of birds and other seed-eating animals. These three illustrations bring out the fact that there are three classes of natural conditions which must be met by every living creature if it is to succeed in life. In detail, the struggle for existence is *intra-specific*, involving some form of competition or rivalry among the members of a single species; it is *inter-specific*, as a conflict is waged by every species with other kinds of living things; and finally it involves an adjustment of life to *inorganic environmental* influences. While it may seem unjustifiable to speak of heat and cold and sunlight as enemies, the direct effects produced by these forces are to be reckoned with no less certainty than the attacks of living foes.

The three divisions of the struggle for existence are so important not only in purely scientific respects, but also in connection with the analysis of human biology, that we may look a little further into their details, taking them up in the reverse order. Regarding the environmental influences, the way that unfavorable surroundings decimate the numbers of the plants of any one generation has already been noted, and it is typical of the vital situation everywhere. English sparrows are killed by prolonged cold and snow as surely as by the hawk. The pond in which bacteria and protozoa are living may dry up, and these organisms may be killed by the billion. Even the human species cannot be regarded as exempt from the necessity of carrying on this kind of natural strife, for scores and hundreds die every year from freezing and sunstroke and the thirsts of the desert. Unknown thousands perish at sea from storm and shipwreck, while the recorded casualties from earthquakes and volcanic eruptions and tidal waves have numbered nearly one hundred and fifty thousand in the past twenty-eight years. The effects of inorganic influences upon all forms of organic life must not be underestimated in view of such facts as these.

In the second place, the vital struggle includes the battles of every species with other kinds of living things whose interests are in opposition. The relations of protozoa and bacteria, conger-eels and other fish, English sparrows and hawks, plants and herbivorous animals, are typical examples of the universal conflict in which all organisms are involved in some way. Again it is only too evident that human beings must participate every day in some form of warfare with other species. In order that food may be provided for mankind the lives of countless wild organisms must be sacrificed in addition to the great numbers of domesticated animals reared by man only that they may be destroyed. The wolf and the wildcat and the panther have disappeared from many of our Eastern states where they formerly lived, while no longer do vast herds of bison and wild horses roam the Western prairies. Because one or another human interest was incompatible with the welfare of these animals they have been driven out by the stronger invaders.

That the victory does not always fall to the human contestant is tragically demonstrated by the effects of the incessant assaults upon man made by just one kind of living enemy,—the bacillus of tuberculosis. Every year more than one hundred and twenty-five thousand people of the United States die because they are unable to withstand its persistent attacks; five million Americans now living are doomed to death at the hands of these executioners, and the figures must be more than doubled to cover the casualties on the human side in the battles with the regiments of all the species of bacteria causing disease.

The competition between and among the individuals of one and the same species is the third part of the struggle for existence, and it is often unsurpassed in its ferocity. When two lion cubs of the same litter begin to shift for themselves, they must naturally compete in the same territory, and their contest is keener than that which involves either of them and a young lion born ten or fifteen miles away. The seeds of one parent plant falling in a restricted area will be engaged in a competitive struggle for existence that is much more intense than many other parts of nature's warfare. In brief, the intensity of the competition will be directly proportional to the similarity of two organisms in constitution and situation, and to the consequent similarity of vital welfare. The interests of the white man and the Indian ran counter to each other a few hundred years ago, and the more powerful colonists won. The assumption of the white man's burden too often demonstrates the natural effect of diversity of interest, and the domination of the stronger over the weaker. In any civilized community the manufacturer, farmer, financier, lawyer, and doctor must struggle to maintain themselves under the conditions of their total inorganic and social environments; and in so far as the object of each is to make a living for himself, they are competitors. But the contest becomes more absorbing when it involves broker and broker, lawyer and lawyer, financier and magnate, because in each case the contestants are striving for an identical need of success.

Although the severity of the conflict imposed by nature is somewhat modified in the case of social organisms, where community competes with community and nation with nation, no form of social organization has yet been developed where the individual contest carried on by the members of one community has been done away with. It is an inexorable law of nature that all living things must fight daily and hourly for their very lives, because so many are brought into the world with each new generation that there is not sufficient room for all. No organism can escape the struggle for existence except by an unconditional surrender that results in death. Everywhere we turn to examine the happenings of organic life we can find nothing but a wearisome warfare in which it is the ultimate and cruel lot of every contestant to admit defeat.

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What now are the results of variation, over-multiplication, and competition? Since some must die because nature cannot support all that she produces, since only a small proportion of those that enter upon life can find a foothold or successfully meet the hordes of their enemies, which will be the ones to survive? Surely those that have even the slightest advantage over their fellows will live when their companions perish. It is impossible that the result could be otherwise; it must follow inevitably from what has been described before. The whole process has its positive and its negative aspects: the survival of the fittest and the elimination of the unfit. Perhaps it would be more correct to say the more real element is the negative one, for those which are least capable of meeting their living foes and the decimating conditions of inorganic nature are the first to die, while the others will be able to prolong the struggle for a longer or shorter period before they too succumb. Thus the destruction of the unfit leaves the field to the better adapted, that is, to those that vary in such a way as to be completely or at least partially adapted to carry on an efficient life. In this way Darwinism explains the universal condition of organic adjustment, showing that it exists because there is no place in nature for the incompetent.

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Finally we come to the process of inheritance as viewed by Darwin, and its part in the production and perfection of new species. In every case, Darwin said, the efficiency or inefficiency of an animal depends upon its characteristics of an inherited or congenital nature. Variations in these qualities provide the array of more or less different individuals from which impersonal nature selects the better by throwing out first the inferior ones. An organism can certainly change in direct response to environmental influence or by the indirect results of use and disuse, but not unless it is so constituted by heredity as to be able to change adaptively. Therefore the final basis of success in life must be sought in the inherited constitutions of organic forms.

For the reason that the qualities which preserve an animal's existence are already congenital, they are already transmissible, as Darwin contended. Since his time much has been learned about the course of inheritance and its physical basis, and the new discoveries have confirmed the essential truth of Darwin's statement that the congenital characters only possess a real power in the evolution of species.

We must devote some time to the subject of inheritance at a later juncture, but before leaving the matter an additional point must be established here; the selective process deals immediately with congenital results, as the heritable characters that make for success or failure in life, but by doing this it really selects the group of congenital factors behind and antecedent to their effects. For example, an ape that survives because of its superior cunning, does so because it varies congenitally in an improved direction; and the factors that have made it superior are indirectly but no less certainly preserved through the survival of their results in the way of efficiency. Hereditary strains are thus the ultimate things selected through the organic constitutions that they determine and produce.

Natural selection, as the whole of this intricate process, is simply trial and error on a gigantic scale. Nature is such that thousands of varying individuals are produced in order that a mere handful or only one survivor may be chosen to bear the burden of carrying on the species for another generation. The effect of nature's process is judicial, as it were. We may liken the many and varied conditions of life to as many jurymen, before which every living thing must appear for judgment as to its fitness or lack of it. A unanimous verdict of complete or partial approval must be rendered, or an animal dies, for the failure to meet a single vital condition results in sure destruction. Of course, we cannot regard selection as involving anything like a primitive conscious choice. It is because we individualize all of the complex totality of the world as "Nature" with a capital N that so many people unconsciously come to think of it as a human-like personality. He who would go further and hold that all of nature is actually conscious and the dwelling-place of the supernatural ultimate, must beware of the logical results of such a view. What must we think of the ethical status of such a conscious power who causes countless millions of creatures to come into the world and ruthlessly compels them to battle with one another until a cruel and tragic death ends their existence?

But that is a metaphysical matter, with which we need not concern ourselves in this discussion; the important point is that among the everyday happenings of life are processes that are quite competent to account for the condition of adaptation exhibited by various animal forms. These processes are real and natural, not imaginative or artificial, and so they will remain even though it will become clear that much is still to be learned about the causes of variation and the course of biological inheritance. Darwin was the first to contend that natural selection is but a part of nature's method of accomplishing evolution. As such it is content to recognize variations and does not concern itself with the origin of modifications; it accepts the obvious fact that congenital variations are inherited, although it leaves the question as to how they are inherited for further examination. Because the doctrine of natural selection does not profess to answer all the questions propounded by scientific inquisitiveness, it must not be supposed that it fails in its immediate purpose of giving a natural explanation of how evolution may be partly accounted for.

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Before proceeding to the post-Darwinian investigations that have done so much to amplify the account of natural evolution, let us consider the contrasted explanation given by Lamarck and his followers. As we have stated earlier, Lamarckianism is the name given to the doctrine that modifications other than those due to congenital factors may enter into the heritage of a species, and may add themselves to those already combined as the peculiar characteristics of a particular species. Let us take the giraffe and its long neck as a concrete example. The great length of this part is obviously an adaptive character, enabling the animal to browse upon the softer leafy shoots of shrubs and trees. The vertebral column of the neck comprises just the same number of bones that are present in the short-necked relatives of this form, so that we are justified in accepting as a fact the evolution of the giraffe's long neck by the lengthening of each one of originally shorter vertebræ. The Lamarckian explanation of this fact would be that the earliest forms in the ancestry of the giraffe as such stretched their necks as they fed, and that this peculiar function with its correlated structural modification became habitual. The slight increase brought about by any single individual would be inherited and transmitted to the giraffes of the next generation; in other words, an individually acquired character would be inherited. The young giraffes of this next generation would then begin, not where their parents did, but from an advanced condition. Thus, by continued stretching of the neck and by continued transmission of the elongated condition, the great length of this part of the body in the modern giraffe would be attained.

The explanation of natural selection would be quite different. The Darwinian would say that all the young giraffes of any one generation would vary with respect to the length of the neck. Those with longer necks would have a slight advantage over their fellows in the extended sphere of their grazing territory. Being better nourished than the others, they would be stronger and so they would be more able to escape from their flesh-eating foes, like the lion. For the reason that their variation would be congenital and therefore already transmissible, their offspring would vary about the advanced condition, and further selection of the longer necked individuals would lead to the modern result.

The Lamarckian explanation encounters one grave difficulty which is not met by the second one, in so far as it demands some method by which a bodily change may be introduced into the stream of inheritance. So far, this difficulty has not been overcome, and the present verdict of science is that the transmission of characters acquired as the result of other than congenital factors is not proved. It would be unscientific to say that it cannot be proved in the future, but there are good *a priori* grounds for disbelief in the principle, while furthermore the results of experiments that have been undertaken to test its truth have been entirely negative. Rats and mice have had their tails cut off to see if this mutilation would have its effect upon their young, and though this has been done for more than one hundred successive generations the length of the tail has not been altered. Quite unconscious of the scientific problem, many human races have performed precisely similar experiments through centuries of time. In some classes of Chinese, the feet of young girls have been bound in such a way as to produce a small, malformed foot, but this has not resulted in any hereditary diminution in the size of the feet of Chinese females. Many other similar mutilations have been practised, as for example, the flattening of the skull of some North American Indians, but the deformity must be produced again with each recurring generation. One after another, the cases that were supposed to give positive evidence have been reinvestigated, with the result that has been stated above. It would seem, therefore, that heredity and congenital modification must play by far the greater part in the evolution of species.

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The doctrine of natural selection took form in the mind of Darwin mainly on account of three potent influences; these were, first, the geological doctrine of uniformitarianism proposed by Lyell, second, his own observations of wild life in many lands and his analysis of the breeder's results with domesticated animals, and third, the writings of Malthus dealing with overpopulation. As Darwin had read the works of Buffon, Lamarck, and Erasmus Darwin, his grandfather, who had written a famous treatise under the title of "Zoonomia," he was familiar with the evidences known in his student days tending to prove that organic evolution was a real natural process. Lyell's doctrine of uniform geological history made an early and deep impression upon his mind, and it led him to ask himself whether the efficient causes of past evolution might not be revealed by an analysis of the present workings of nature. As naturalist of the "Beagle" during its four years' cruise around the world, Darwin saw many new lands and observed varied circumstances under which the organisms of the tropics and other regions lived their lives. The fierce struggle for existence waged by the denizens of the jungle recalled to him the views of Malthus regarding overpopulation and its results. These and other influences led him to begin the remarkable series of note-books, from which it is interesting indeed to learn how the doctrine of natural selection began to assume a definite and permanent form in his mind, as year followed year, and evidence was added to evidence. And it is a valuable lesson to the student of science that for twenty-five years Darwin devoted all his time to the acquisition of facts before he gave his doctrine to the world in the famous "Origin of Species."

Darwin was particularly impressed by the way mankind has dealt with the various species of domesticated animals, and he was the first naturalist to point out the correspondence between the breeder's method of "artificial selection," and the world-wide process of natural selection. As every one knows, the breeder of race horses finds that colts vary much in their speed; discarding the slower animals, he uses only the swifter for breeding purposes, and so he perfects one type of horse. With other objects in view, the heavy draught horse, the spirited hackney, and the agile polo pony have been severally bred by exactly the same method. Among cattle many kinds occur, again the products of an artificial or human selection; hornless breeds have been originated, as well as others with wide-spreading or sharply curved horns; the Holstein has been bred for an abundant supply of milk as an object, while Jerseys and Alderneys excel in the rich quality of their milk. Various kinds of domesticated sheep and rabbits and cats also owe their existence to the employment of the selfsame method, unconsciously copied by man from nature; for men have found variations arising naturally among their domesticated animals, and they have simply substituted their practical purposes or their fancy for nature's criterion of adaptive fitness, preserving those that they wish to perfect and eliminating those unfitted to their requirements or ideas.

In the case of many of these and other examples, wild forms still occur which seem to be like the ancestral stock from which the domesticated forms have been produced. All the varied forms of dogs—from mastiff to toy-terrier, and from greyhound to dachshund and bulldog—find their prototypes in wild carnivora like the wolf and jackal. In Asia and Malaysia the jungle fowl still lives, while its domesticated descendants have altered under human direction to become the diverse strains of the barnyard, and even the peculiar Japanese product with tail feathers sometimes as long as twenty feet. That far-reaching changes can be brought about in a relatively short time is proved by the history of the game cock, which has nearly doubled in height since 1850, while at the same time its slender legs, long spurs, and other qualities have been perfected for the cruel sport for which it has been bred. Again, the wild rock pigeon seems to be the ancestral form from which the fantail and pouter and carrier-pigeon with their diverse characters have taken their origin.

It is true that some biologists have urged certain technical objections to the employment of domesticated animals and their history as analogies to the processes and results in wild nature. To my mind, however, artificial selection is truly a part of the whole process of natural selection. Man is but one element of the environment of tame forms, and his fancy or need is therefore one of the varied series of external criteria that must be met if survival is to be the result; failing this, elimination follows as surely as under the conditions of an area uninhabited or uninfluenced by mankind. Congenital variation is real, selection is real and the heredity of the more fit modification is equally real. Surely Darwin was right in contending that the facts of this class amplify the conception of natural selection developed on the basis of an analysis of wild life.

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Knowing the elements of the selective process, it is possible to analyze and to understand many significant phenomena of nature, and to gain a clearer conception of the results of the struggle for existence, especially when the human factor is involved. Let us see how much is revealed when the foregoing results are employed in a further study of some of nature's vital situations.

As a consequence of the many-sided struggle for existence, the interrelations of a series of species will approach a condition of equilibrium in an area where the natural circumstances remain relatively undisturbed for a long time. For example, among the field-mice of one generation, just as many individuals will survive as will be able to find food and to escape hereditary foes such as cats and snakes and owls. The number of owls, in their turn, will be determined by the number of available mice and other food organisms, as well as by the severity of the adverse circumstances that cause elimination of the less fit among the fledglings brought into the world. The vital chain of connections is sometimes astonishingly long and intricate. One remarkable illustration is given by Fiske, as an elaboration of an example cited by Darwin. He points out that the fine quality of the traditional roast beef of England is directly determined by the number of elderly spinsters in that country. The chain of circumstances is as follows: the quality of the clover fields, furnishing the best food for cattle, depends largely upon the visits to the clover-blossoms by wild bees, that accomplish the fertilization of the flowers by carrying pollen upon their bodies from one plant to another. Field-mice devour the young in the nests of these bees, so if there are few field-mice there will be many bees, and consequently better grazing for the cattle. The number of field-mice will vary according to the abundance of cats, and so the number of these domestic animals will exert an influence upon the whole foregoing chain of forms. But, as Fiske points out, cats are the favorite companions of elderly spinsters; therefore, if there are many of the latter, there will be more cats, fewer field-mice, more bees, richer clover fields, and finer cattle! Each link is real and the whole chain is a characteristic example of the countless ways that the natural destinies of living things are interrelated and intertwined.

The reality of such organic interrelationships is revealed with wonderful clearness in the numerous instances where some disturbing factor has altered one or another element of the balanced system. The invasion of the new world by Europeans has directly led to the partial or complete extinction of the tribes of Indians to whom the land formerly belonged; they have disappeared almost entirely from our state of New York, together with the bear and wolf and many other species of animals that formerly existed here. Wild horses and bison have also vanished before the advances of civilization and the alteration of their homes. Sometimes the extermination of one pest has resulted in an increase in the number of another through human interference with nature's equilibrium. In some of our Western states, a bounty was offered for the scalps of wolves, so as to lessen the number of these predatory foes of sheep. But when the wolves were diminished in number, their wild food-animals, the prairie dogs, found their lot much bettered, and they have multiplied so rapidly that in some places they have become even more destructive than the wolves.

One of the most remarkable illustrations is that of the rabbits introduced into Australia. This island continent was cut off from the surrounding lands long before the higher mammals evolved in far distant regions, so that the balance of nature was worked out without reference to animals like the rabbit. When the first of these were introduced they found a territory without natural enemies where everything was favorable. They promptly multiplied so rapidly that within a few years their descendants were numerous enough to eat up practically every green thing they could reach. Two decades ago, the single province of Queensland was forced to expend $85,000,000 in a vain effort to put down the rabbit plague. The remarkable statement has been made that in some places nature has taken a hand in causing a new type of rabbit to evolve. Finding the situation desperate, some of the animals have begun to develop into tree-climbing creatures. The animals exist in such numbers that the available food upon the ground is insufficient for all, and so some elimination results. But the young rabbits with longer claws, varying in this way on account of congenital factors, have an advantage over their fellows because they can climb some of the trees and so obtain food inaccessible to the others. If the facts are correctly reported, and if the process of selection on the basis of longer claws and the climbing habit is continued, the original type of animal is splitting up into a form that will remain the same and live upon the ground, and another that will be to all intents and purposes a counterpart of our familiar squirrel. All the evidence goes to show that squirrels have evolved from terrestrial rodents; if the data relating to Australian rabbits are correct, nature is again producing a squirrel-like animal by evolution in a region where the former natural situation has been interfered with by man.

The laws of biological inheritance have received close and deep study by numerous investigators of Darwinian and post-Darwinian times, because from the first it was clearly recognized that a complete description of nature's method of accomplishing evolution must show how species maintain the same general characteristics from generation to generation, and also how new qualities may be fixed in heredity as species transform in the course of time. Before our modern era in biology, the fact of inheritance was accepted as self-sufficient; now much is known that supplements and extends the incomplete account given by natural selection of the way evolution takes place.

It is not possible in the present brief outline to describe all the results of recent investigations, but some of them are too important to be passed over. Perhaps the most interesting one is that the laws of heredity seem to be the same for man and other kinds of living creatures, as proved by Galton and Pearson and many others who have dealt with such characters as human stature, human eye color, and an extensive series of the peculiarities of lower animals and even of plants.

The researches dealing with the physical basis of inheritance and its location in the organism have yielded the most striking and brilliant results. Darwin himself realized that the doctrine of natural selection was incomplete, as it accepted at its face value the inheritance of congenital racial qualities without attempting to describe the way an egg or any other germ bears them, and he endeavored to round out his doctrine of selection by adding the theory of pangenesis. According to this, every cell of every tissue and organ of the body produces minute particles called gemmules, which partake of the characters of the cells that produce them. The gemmules were supposed to be transported throughout the entire body, and to congregate in the germ-cells, which in a sense would be minute editions of the body which bears them, and would then be capable of producing the same kind of a body. If true, this view would lead to the acceptance of Lamarck's or even Buffon's doctrine, for changes induced in any organ by other than congenital factors could be impressed upon the germ-cell, and would then be transported together with the original specific characters to future generations. Darwin was indeed a good Lamarckian.

But the researches of post-Darwinians, and especially those of the students of cellular phenomena, have demonstrated that such a view has no real basis in fact. Many naturalists, like Naegeli and Wiesner, were convinced that there was a specific substance concerned with hereditary qualities as in a larger way protoplasm is the physical basis of life. It remained for Weismann to identify this theoretical substance with a specific part of the cell, namely, the deeply staining substance, or chromatin, contained in the nucleus of every cell. Bringing together the accumulating observations of the numerous cytologists of his time, and utilizing them for the development of his somewhat speculative theories, Weismann published in 1882 a volume called "The Germ Plasm," which is an immortal foundation for all later work on inheritance. The essential principles of the germ-plasm theory are somewhat as follows. The chromatin of the nucleus contains the determinants of hereditary qualities. In reproduction, the male sex-cell, which is scarcely more than a minute mass of chromatin provided with a thin coat of protoplasm and a motile organ, fuses with the egg, and the nuclei of the two cells unite to form a double body, which contains equal contributions of chromatin from the two parental organisms. This gives the physical basis for paternal inheritance as well as for maternal inheritance, and it shows why they may be of the same or equivalent degree. When, now, the egg divides, at the first and later cleavages, the chromatin masses or chromosomes contained in the double nucleus are split lengthwise and the twin portions separate to go into the nuclei of the daughter-cells. As the same process seems to hold for all the later divisions of the cleavage-cells whose products are destined to be the various tissue elements of the adult body, it follows that all tissue-cells would contain chromatin determinants derived equally from the male and female parents. As of course only the germ-cells of an adult organism pass on to form later generations, and as their content of chromatin is derived not from the sister organs of the body, but from the original fertilized egg, there is a direct stream of the germ plasm which flows continuously from the germ-cell to germ-cell through succeeding generations. It would seem, therefore, that the various organic systems are, so to speak, sister products in embryonic origin. The reproductive organs are not produced by the other parts of the body, but their cells are the direct descendants of the common starting-point namely, the egg. As the cells of the reproductive organs are the only ones that pass over and into the next and later generations, it will be evident, in the first place, that the germ plasm of their nuclei is the only essential substance that connects parent and offspring. This stream of germ plasm passes on in direct continuity through successive generations—from egg to the complete adult, including its own germ-cells, through these to the next adult, with its germ-cells, and so on and on as long as the species exists. It does not flow circuitously from egg to adult and then to new germ-cells, but it is direct and continuous, and apparently it cannot pick up any of the body-changes of an acquired nature. Now we see why individual acquisitions are not transmitted. The hereditary stream of germ plasm is already constituted before an animal uses its parts in adult life; we cannot see how alterations in the structure of mature body parts through use and adjustment to the environment can be introduced into it to become new qualities of the species.

It must be clear, I am sure, that this theory supplements natural selection, for it describes the physical basis of inheritance, it demonstrates the efficiency of congenital or germ-plasmal factors of variation in contrast with the Lamarckian factors, and finally in the way that in the view of Weismann it accounts for the origin of variations as the result of the commingling of two differing parental streams of germ plasm.

At first, for many reasons, Weismann's theories did not meet with general acceptance, but during recent years there has been a marked return to many of his positions, mainly as the result of further cytological discoveries, and of the formulation of Mendel's Law and of De Vries's mutation theory. The first-named law was propounded by Gregor Mendel on the basis of extensive experiments upon plants conducted during many years, 1860 and later, in the obscurity of his monastery garden at Altbrünn, in Austria. It was rescued from oblivion by De Vries, who found it buried in a mass of literature and brought it to light when he published his renowned Mutation Theory in 1901. Mendelian phenomena of inheritance, confirmed and extended by numerous workers with plants and animals, prove that in many cases portions of the streams of germ plasm that combine to form the hereditary content of organisms may retain their individuality during embryonic and later development, and that they may emerge in their original purity when the germ-cells destined to form a later generation undergo the preparatory processes of maturation. They demonstrate also the apparent chance nature of the phenomena of inheritance. To my mind the most striking and significant result in this field is the demonstration that a particular chromosome or chromatin mass determines a particular character of an adult organism, which is quite a different matter from the reference of all the hereditary characters to the chromatin as a whole. Wilson and others have brought forward convincing proof that the complex character of sex in insects actually resides in or is determined by particular and definite masses of this wonderful physical basis of inheritance.

Mendel's principles also account in the most remarkable way for many previously obscure phenomena, like reversion, or a case where a child resembles its grandparent more than it does either of its parents; such phenomena are due, so to speak, to the rise to the surface of a hidden stream of germ plasm that had flowed for one or many generations beneath its accompanying currents. I believe that the law is replacing more and more the laws of Galton and Pearson, formulated as statistical summaries of certain phenomena of human inheritance taken *en masse*. According to Galton's celebrated law of ancestral inheritance, the qualities of any organism are determined to the extent of a certain fraction by its two parents taken together as a "mid-parent," that a smaller definite fraction is contributed by the grandparents taken together as a mid-grandparent, and so on to earlier generations. But Mendel's Law has far greater definiteness, it explains more accurately the cases of alternative inheritance, and it may be shown to hold for blended and mosaic inheritance as well.

De Vries's new "mutation theory" is clearly not an alternative but a complementary theory to natural selection, the Weismannian and Mendelian theories. Like these last, it emphasizes the importance of the congenital hereditary qualities contained in the germ plasm, though unlike the Darwinian doctrine it shows that sometimes new forms may arise by sudden leaps and not necessarily by the slow and gradual accumulation of slight modifications or fluctuations. The mutants like any other variants must present themselves before the jury of environmental circumstances, which passes judgment upon their condition of adaptation, and they, too, must abide by the verdict that means life or death.

From what has been said of these post-Darwinian discoveries, the Lamarckian doctrine, which teaches that acquired non-congenital characters are transmitted, seems to be ruled out. I would not lead you to believe that the matter is settled. I would say only that the non-transmission of racial mutilations, negative breeding experiments upon mutilated rats and mice, the results of further study of supposedly transmitted immunity to poisons—that all these have led zoölogists to render the verdict of "not proved." The future may bring to light positive evidence, and cases like Brown-Séquard's guinea-pigs, and results like those of MacDougal with plants, and of Tower with beetles, may lead us to alter the opinion stated. But as it stands now most investigators hold that there are strong general grounds for disbelief in the principle, and also that it lacks experimental proof.

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The explanation of natural evolution given by Darwinism and the principles of Weismann, Mendel, and De Vries, still fails to solve the mystery completely, and appeal has been made to other agencies, even to teleology and to "unknown" and "unknowable" causes as well as to circumstantial factors. A combination of Lamarckian and Darwinian factors has been proposed by Osborn, Baldwin, and Lloyd Morgan, in the theory of organic selection. The theory of orthogenesis propounded by Naegeli and Eimer, now gaining much ground, holds that evolution takes place in direct lines of progressive modification, and is not the result of apparent chance. Of these and similar theories, all we can say is that if they are true, they are not so well substantiated as the ones we have reviewed at greater length.

The task of experimental zoölogy is to work more extensively and deeply upon inheritance and variation, combining the methods and results of cellular biology, biometrics, and experimental breeding. We may safely predict that great advances will be made during the next few years in analyzing the method of evolution; and that a few decades hence men will look back to the present time as a period of transition like the era of reawakened interest and renewed investigation that followed the appearance of the "Origin of Species." For the present, we can justly say "that evolution, so far as it is understood, is a real and natural process."

# V

#### THE PHYSICAL EVOLUTION OF THE HUMAN SPECIES AND OF HUMAN RACES

The teachings of science that relate to the origin and history of the human species constitute for us the most important part of the whole doctrine of organic evolution and now, having completely outlined this doctrine as a general one, we are brought to the point where we must deal frankly and squarely with the insistent questions arising on all sides as to the way that mankind is involved in the vast mechanism of nature's order. These questions have been ignored heretofore, in order that the natural history of animals in general might be discussed without any interference on the part of purely human interest and concern. It now becomes our privilege, and our duty as well, to employ and apply the principles we have learned in order to understand more completely the origin of the human body as an organic type, the history of human races, the development of human faculty and of social institutions, and the evolution finally of even the highest elements of human life. These are scientific problems, and if we are to solve them we must employ the now familiar methods of science which only yield sure results.

We must not underestimate the many difficulties to be encountered, for the field before us is a vast territory of complex human life and of manifold human relations. Without prolonged exercise in scientific methods, it is impossible to view our own kind impersonally, as we do the creatures of lower nature. Furthermore it seems to many that an analysis of human life and biological history, even if it is possible, must alter or degrade mankind in some degree; this is no more true than that a knowledge of the principles of engineering according to which the Brooklyn Bridge has been constructed renders that structure any different or unsafe for travel. Man remains man, whether we are in utter ignorance of his mode of origin, or whether we know all about his ancestry and about the factors that have made him human. It is because our species appears to occupy a superior and isolated position above the rest of nature that the mind seems reluctant to follow the guidance of science when it conducts its investigations into the history of seemingly privileged human nature. And it is feared also, that if evolution is proven for man as well as for all other kinds of animals, our cherished ideas and our outlook upon many departments of human life must be profoundly affected. This may be so, but science endeavors only to find out the truth; it cannot alter truth, nor does it seek to do so. We might well wish that the world were different in many respects and that we were free from the control of many natural laws besides that of evolution, but if the real is what it is, then our duty is plain before us; as we think more widely and deeply on the basis of ripened experience, it becomes ever clearer that a knowledge of human history gives the only sure guidance for human life.

To the zoölogist it seems strange that so many are opposed to a scientific inquiry into the facts of human evolution, and to the conclusions established by such an inquiry,—though, to be sure, this opposition is directly proportional to ignorance or misunderstanding of the nature and purpose of scientific investigation and of human evolution. The naturalist comes to view our species as a kind of animal, and as a single one of the hundreds of thousands of known forms of life; thus the question of human origin is but a small part of organic evolution, which is itself only an episode in the great sweep of cosmic evolution, endless in past time and in the future. Were we some other order of beings, and not men, human evolution would appear to us in its proper scientific proportions, namely, as a minute fraction of the whole progress of the world.

While the foregoing statements are true, it is nevertheless right that a close study should be made of the particular case of mankind. No doubt much of the naturalist's interest in nature at large is due to his conviction that the laws revealed by the organisms of a lower sphere must hold true for man, and may explain many things that cannot be so clearly discerned when only the highest type is the subject of investigation. It is only too evident that little more than a general outline can be given of the wide subject or group of subjects included under the head of human evolution. We must divide the subject logically into parts, so that each one may be taken up without being complicated by questions relating to topics of another category, although the findings in any one department must surely be of importance for comparison with the results established in another section; for if evolution is universally true, the main conclusion in any case must assist the investigation of another, just as comparative anatomy and embryology supplement and corroborate each other in the larger survey of organic evolution. As before, the illustrations of each department of the subject must be selected from the stock of everyday observation and information that we already possess, for we gain much when we realize that evolution includes all the happenings of everyday life and thought, as well as the occurrences of the remote past.

For the present, then, the questions relating to the higher aspects of human life must be put aside, only that they may be taken up at the last. Social evolution likewise finds its place in a later section, after the phenomena of mind and mental evolution receive due attention and description. At the present juncture, the human species presents itself as a subject for organic analysis and classification, merely as a physical organism. Just as the study of locomotives must begin with the detailed structure of machines in the workshop before they can be profitably understood as working mechanisms, so the physical evolution of mankind must first be made intelligible before it is possible to prosecute successfully the studies dealing with the psychology, social relations, and higher conceptions that seem at first to be the exclusive properties of our species.

The problems of physical evolution of man and of men fall into two groups. Those of the first deal with the origin of the human species as a unit, and its comparative relation to lower organisms, while those of the second part are concerned with the further evolution of human races that have come to be different in certain details of structure since the human type as such arose. In the first part, all men will be assumed to be alike and the members of a homogeneous species whose fundamental attributes are to be compared with those of other animals; only afterwards will attention be directed to the differences, previously ignored, that divide human beings into well-marked varieties. It must be evident even at this point that the mode of evolution demonstrated by the first investigation will be likely to bear some close relation to the methods by which human races have evolved to their present diverse anatomical situations.

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The foregoing classification of the problems concerned with the nature and origin of the human species renders it possible to restrict the immediate inquiry to a definite and precise question. It is this: does the evidence relating to the physical characteristics of our species prove that man is the product of a supernatural act of creation, or does it show that man's place in nature has been reached by a gradual process of natural evolution? In order to obtain an equally precise and definite answer to this question, referring to the particular case of most concern to us, it is obvious that the method to be employed is the one which has given us an understanding of organic evolution as an all-inclusive natural process. The data must be verified, related, and classified, so that their meaning may be concisely stated in the form of scientific principles. What are the facts of human structure, comparatively treated? How does the human body develop? Does palæontology throw any light on the antiquity of man? Do the rules of nature's order control the lives of men? Our course is now clear; we shall take up serially the anatomy, embryology, and fossil history of the human species, in order to see that there is ample proof of the actual occurrence of evolution, and then, as before, we may look about for the causes which have produced this result by natural methods.

While it is necessary to treat the subject directly, namely, by examining the actual evidences relating to the particular case in question, it is worthwhile before doing so to point out that, as the whole includes a part, human evolution has already been proved beyond question. This conclusion must be accepted, unless reasons can be given for excluding mankind from the rest of the living world as an absolutely unique type, supreme and isolated because of some peculiar endowments not shared with the rest of animate nature. If these reasons are lacking, and the unity of organic nature be recognized, human evolution cannot be denied unless some interpretation more reasonable and logical than evolution can be given for the whole mass of facts exemplified and discussed in the foregoing chapters. We may accordingly approach the main questions by asking if there are any reasons for regarding the human species as a unique and isolated type of organism.

At the outset, we must recognize that in so far as the human body is material, its movements and mass relations are controlled by physical principles, like all other masses of matter. It is well, indeed, that this is so, for if gravitation and the laws of inertia were not consistent and reliable principles holding true at all times and not intermittently, it would be difficult to order our lives with confidence. In the next place, the general principles of biology hold true for the structure and physiology of the human species as they do for all other living things. A human body is composed of eight systems of organs, whose functions are identical with the eight vital tasks of every other animal. All these organs are made up of cells as ultimate vital units, and the materials of which human cells are composed belong to the class of substances called protoplasm. Human protoplasm, like all other living materials, must replenish itself, and respire and oxidize in obedience to biological laws that have been found to be uniform everywhere. Thus the human organism is no more unique in fundamental organic respects than it is apart from the world of physical processes and laws.

How does the matter stand when the general structural plan of a human being is examined? Is it entirely different from everything else? It is a fact of common knowledge that the human body is supported by a bony axis, the vertebral column, to which the skull is articulated and to which also the skeletal framework of the limbs is attached. These characteristics place man inevitably among the so-called vertebrata; he is certainly not an invertebrate, nor is the basic structure of his body such that a third group, outside the invertebrata and vertebrata, can be made to include only the single type—man.

Passing now to the classes that make up the group of vertebrates, we meet first the lampreys or cyclostomes without jaws, and the others with jaws, such as the fishes, amphibia, reptiles, birds, and mammals, each class distinguished by certain definite characters in addition to the vertebral column. The fishes have gills and scales; amphibia of to-day are scaleless, and they are provided with gills when they are young and lungs as adults; reptiles have scales and lungs; birds are warm-blooded and feathered; while mammals are warm-blooded and haired. Is the human species a unique kind of vertebrate, or does it find a place in one of these classes? The occurrence of hair, of a four-chambered heart which propels warm blood, of mammary glands, and of other systematic characters marks this species as a kind of mammal and not as a vertebrate in a section by itself.

The members of the class mammalia differ much among themselves; and now that we recognize clearly that man is a mammalian vertebrate, the next question is whether an order exists to which our type must be assigned, or whether we have at last reached a point where it is justifiable to establish an isolated division to contain the human species alone. We are familiar with many representatives of different mammalian orders and with the kind of structural characteristics that serve as convenient distinctions in denoting their relationships. Horses and cattle, sheep, and goats and pigs resemble one another in many respects besides their hoofs, and they form one natural order; the well-developed gnawing teeth of rats and rabbits and squirrels place these forms together in the order rodentia; the structures adapting their possessors for a flesh-eating and predatory life unite the tribes of the lion, wolf, bear, and seal, in the order carnivora. Among these and other orders of mammalia is one to which the lemurs, monkeys, and apes are assigned, because all these forms agree in certain structural respects that place them apart from the other mammalia, in the same way, for example, that the races of white men may be recognized as a group distinct from the black and red races. But comparative studies, prosecuted not only by those who have been forced to adopt the evolutionary interpretation, but also by believers in special creation like Linnæus and Cuvier and other more modern opponents of evolution, have shown that the peculiar qualities of this order are shared by the human species. Indeed, the name of primates was given to this section by Linnæus himself, because the human body found a place in the array which begins at the lower extreme with the lemurs and the monkeys and ends with man at the other end. Again it is found that no separate order of mammals exists to include only the genus *Homo*.

To one unacquainted with the facts of vertebrate comparative anatomy, the distinguishing characteristics of the primates seem to be trivial in nature. It is surprising to find how insignificant are the details to which appeal must be made in order to draw a line between our own division of mammalia and the others. It is well to review them as they are given in the standard text-books of comparative anatomy. Primates are eutheria, or true mammalia possessing a placental attachment of the young within the parent. The first digits, namely, the "great toe" and the "thumb," are freely movable and opposable to the others, so that the limbs are prehensile and clasping structures; usually but not always the animals of this order are tree-dwellers in correlation with the grasping powers of the feet and hands. The permanent teeth succeed a shorter series of so-called "milk teeth," and they are diverse in structure, being incisors, canines, or "eye teeth," premolars, and molars; the particular numbers of each kind are almost invariable throughout the order and markedly different from those of other orders. The number of digits is always five, and with few exceptions they bear nails instead of claws. The clavicles, or "collar bones," are well developed in correlation with the prehensile nature of the fore limbs; a bony ring surrounds the orbit or eye socket. Finally there are two mammary glands by which the young are suckled. It is because any other details of difference between man and other forms are far less marked than the agreements in these respects, that the human species must be regarded as a primate mammalian vertebrate.

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The comparative study of the human organism as a structural type has now been narrowed down to a review of the various members of the order of primates. It is the duty of science to arrange these organisms according to the minor differences beneath the agreements in major qualities, and to show how they are related in an order of evolution. It will appear, when this is done, that the supreme place is given to the human species on account of four and only four characteristics; these are (1) an entirely erect posture, (2) greater brain development, (3) the power of articulate speech, and (4) the power of reason. As we are treating the human body as a subject for comparative structural study, the third and fourth characters do not concern us here; but it is well to point out that they depend entirely upon the second, and that they are the functional concomitants of the improved type of brain belonging to the highest type. Two characters remain, and in both cases it is significant that differences in degree only are to be found by even the closest analysis. The human brain is the same kind of brain that lower primates possess; its structure is unique in no general respect. And as regards the first-mentioned character, comparative anatomy shows, in the first place, that this also is something differing only in degree, and in the second place, that it is due directly to the development of the brain. For these reasons a survey of the various members of the order of primates must deal largely with the progressive elaboration of the brain and the entailed effects of this enlargement.

The order of primates is subdivided as follows :—

Sub-order 1. *PROSIMII*. Lemurs.
Sub-order 2. *ANTHROPOIDEA*.
  Family 1. *Hapalidæ*. The marmosets.
  Family 2. *Cebidæ*. The American or tailed monkeys.
  Family 3. *Cercopithecidæ*. The baboons.
  Family 4. *Simiidæ*. The true apes.
  Family 5. *Hominidæ*. The human species. Primates

Each one of these subdivisions is interesting in its own way, either because its members depart from the typical condition of the whole order in some respects, or because of some character that foreshadows and leads to a more developed element of the animals placed in the higher sections.

The lemurs are small animals very much like squirrels in their general form and in their tree-climbing habits. They live now almost exclusively on the island of Madagascar, but palæontology shows that they were more widely spread at an earlier time. Their teeth are exactly like our own, except that there is one more premolar on each side of each jaw. The "fingers" and "toes" bear nails like ours, again with an exception in the case of the second digits of the hind limbs, which bear claws. The details of structure that set these animals apart from all the rest of the primates are too small to deserve comment in the present connection.

Passing to the true anthropoids, or man-like primates and man himself, the first forms encountered are the little marmosets, which are like the lemurs in some ways, but in other respects they resemble the familiar tailed monkeys. They are peculiar in having three premolars and two molars on either side of both upper and lower jaws, and also in the fact that the "thumb" is not opposable to the other fingers, while all the digits except the "great toes" bear claws instead of manlike nails. The proportion of brain-case and face does not differ much from that in the lemurs and even lower forms like cats, for the brain has not increased greatly in total mass, though the cerebrum is more convoluted than in the lower forms.

The true monkeys, or Cebidæ, are more interesting, and at the same time they are much more familiar to every one, as they are the commonest anthropoids of the menagerie and circus. Their wonderful agility and sureness in climbing about is partly due to the perfect grasping power of the lower limb. To all intents and purposes the foot is a hand; the first toe is shorter than the others, and its free motion is unrestricted as in the thumb of the hand. These animals usually possess a long tail which they can use as a prehensile organ, curling it about the branch of a tree with hand-like ease and grasp. When they run on all fours, they plant the palms and soles flat upon the ground. The feature of primary importance in a comparative sense is the advanced structure of the skull. These anthropoids are much more intelligent than the lower forms, which is a correlate of their larger and more convoluted brains. The increase in the total bulk of the brain has wrought considerable change, not only in the head, but also in the relation of head to the trunk. The cranium, or brain-case of bone, is relatively larger than the "face," and it bulges upward so as to lie no longer behind the latter as it does in the lower mammalia. In consequence of this cranial enlargement, the face and eyes are swung downward, as it were, so that the line of vision is not straight ahead, but depressed below the horizontal. In order to look to the front and to the immediate foreground to which it is progressing or to where its food or enemies may be, the monkey must bend back its head; if it is still, it finds greater ease in the upright sitting posture which it assumes readily and naturally.

The next division, called the Cercopithecidæ, includes the baboons of the Old World. These animals also run upon all fours, and their feet are handlike as before, but the tail is much reduced. The general appearance of the head is doglike, and the brain-case arches little more than it does in the monkeys, but the face projects forward as a long muzzle, with terminal nostrils close together. In some respects the baboons stand somewhat away from the line leading from the lower to higher anthropoids; in other characters they approach the latter, for in the teeth especially they are identical with the apes and with the human species.

The Simiidæ, or true apes, possess an overwhelming importance, far beyond that of the baboons and monkeys. There are only four principal kinds now existing, namely, the gibbon, orang-outang, chimpanzee, and the gorilla, of which the first is much less familiar than the others. The known species of gibbons occur in Indo-China and the Malay Peninsula. The typical animal stands about three feet high; its overarching braincase, enlarged in conformity with the much greater brain development, has pushed the eyes and face still further around underneath, so that if the animal walks upon all fours the eyes look almost straight into the ground. Therefore it must bend back its head at an extremely uncomfortable angle if it is to remain upon all four feet, but it prefers to raise itself up into the human sitting posture, or, when it walks, it stands erect upon its hind limbs. Hence we who are accustomed to think of ourselves as the only erect animals must revise our opinion, for we find in the gibbon an organism that is nearly, if not quite, as advanced in this respect as we are. One peculiar difference may be pointed out,—the walking gibbon stretches out its great long arms to the sides in order to preserve its balance. The animal seems awkward to us, perhaps, but it is possible that the human method of balancing the body by vigorously swinging the arms might seem quite as awkward to a gibbon as its grotesque posture does to us.

The orang-outang comes next in this series. It inhabits the islands of Borneo and Sumatra, where we find two distinct species. It is a reddish colored animal standing about four feet four inches high, with rather long hair. It is bulky, slow and deliberate in action, and when it walks in a semi-erect position it rests its knuckles upon the ground, swinging its long arms as crutch-like supports. Like the gibbon, it does not walk upon all four feet in the way that the monkeys and baboons do, and we find in the still further development of the brain and the higher arch of the cranium the reasons for its semi-erectness. It cannot remain with its hands and feet upon the ground and bend back its head so as to direct its vision forward.

The chimpanzee of intertropical Africa brings us to a still less monkey-like and more manlike stage. This creature attains the height of five feet, which is more than that of some of the lower races of man. It possesses large ears and heavy overarching brows; its thumb and great toe are more like those of man, though its foot is still practically a hand. Its lower limb curves like those of the other apes, and its soles are turned toward one another; in brief, it is naturally bow-legged, a character that adapts it for a tree-climbing life. This animal also is nearly, though not quite, erect. It shows a most marked advance in the matter of the brain, for the cerebrum is richly folded or convoluted, and with this higher degree of physical complexity is correlated its superior intelligence; it is well known that chimpanzees can be taught to wear clothing and to use a cup and spoon and bowl like a human child. Indeed, in mental respects, the chimpanzee surpasses all of the other mammalia, with the sole exception of man. An eminent psychologist has stated that it is about the equal, in mental ability, of a nine months' old human infant.

The last form among the apes, the gorilla, is one that brings us to a realization of our own human physical degeneracy. The animal lives in West Equatorial Africa, and it is a veritable giant in bulk, though its height may not exceed five feet six inches. The heavy ridges over the eyes, the upturned nostrils and triangular nose, place it near to the orang-outang, but it is superior to that form in its relatively greater brain-box, and in the fact that its heavy lower jaws do not protrude so greatly. It, too, is semi-erect, so that the line of the vertebral axis makes an angle with the plane of the ground of about seventy degrees. Its anterior limbs, or arms, are again very long and bulky; and like the chimpanzee, it rests its knuckles upon the ground in walking.

It is a short step further to the human organism, whose brain has become larger and more complex, with a corresponding advance in the functional powers of reason and the like that owe their existence to the improved structural basis. After what has been said earlier regarding the relation between the erect attitude in walking and the increased size of the cranial part of the skull as compared with the face, it will not be difficult to see how inevitably the former is the result of the latter. Should we get upon the ground upon our hands and knees in the position of a tailed monkey, the eyes look straight into the ground, for the bulging cranium has pushed out over the jaws and face so that they lie *under* the brain-case instead of in front. A person in this position can bend back the head so as to look ahead, but the strain is too great for comfort. Rising to the knees, and lifting the hands from the ground, a feeling of ease at once succeeds that of tension. In the course of evolution accomplished primarily by the increase of the higher portions of the brain, the erect position has been assumed gradually and naturally, and to maintain it has necessitated many other changes in skeleton and muscles; for example, the pelvis has broadened to support the intestines, which bear downwards instead of upon the abdominal walls; a double curve has arisen in the axis of the vertebral column, giving an easier balance to the upper part of the body and the head. Countless structures of the human frame testify to an originally four-footed position and to a rotation of the longer axis through an angle of ninety degrees, as evolution has produced the human type.

The conclusion that the human brain has made mankind is thus established as one of fundamental importance. Proceeding further, we learn that this organ proves to be essentially the same as the brain of lower primates; it does not gain its greater size and efficiency by the origination of wholly new and unique parts, but solely by the further elaboration of the ones present in lower forms. In a word, it is only a difference in *degree* and not in essential *kind* that separates man from the apes and other primates. Human nature is animal nature, and human structure is animal structure, for nowhere can final and absolute differences be found. This does not mean that no differences appear, for it would be absurd to contend that man and the apes are identical in every respect; but it does mean that the resemblances are fundamental and comprehensive, and any details of dissimilarity are in the degree of complexity only. The supreme place in nature attained by man is therefore due to progressive evolution in the nervous system. The other systems have degenerated to a greater or less degree, but such regressive changes are more than compensated for by the superior control exerted by the improved brain. In purely physical and mechanical respects, the human body is a degenerate as compared with a gorilla; the arm of the latter is more powerful than the lower limb of the former, while the gorilla's chest is more than twice as broad as the human, and more than four times as capacious. It is not through superior physique, but by superior ability to direct the activities of his body, that man excels in the struggle for existence with the lower animals.

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Moreover, the human body is a veritable museum of rare and interesting relics of antiquity. This characterization is justified by those vestigial and rudimentary structures that represent organs of value to human relatives among the lower animals, though they play a less active part at the present time in human economy. There is scarcely a single system that does not exhibit many or fewer of these rudimentary structures, but only a few need be specified. As compared with those of the apes, the human wisdom teeth are degenerate; in the gorilla they are cut at the same time as the other molars; and in the lower human races they come through the gums in early youth, while in the more advanced Caucasic races they are cut only in later life or not at all. The reduced vermiform appendix of man, a source of much ill health, is another structure that is a counterpart of a relatively larger and useful part of the digestive tract in the lower primates and other animals. Furthermore, the human tail is a reality, not a fiction. Now and then an individual is born with a tail that may reach a length in later life of eight or ten inches; such structures are, of course, abnormal. But in every normal human being there is a series of little bones at the lower end of the vertebral column, constituting the coccyx, and this is just where the abbreviated tail of the ape and the still longer prehensile tail of the monkey arises from the body. Unless the coccyx is a tail, what can it be? And if it does not represent a reduced counterpart of the tails of other mammals, what does it represent?

Many of the vestigial structures of man appear more clearly in infancy and in embryonic development. The human embryo possesses a complete coat of hair, called the lanugo, which usually disappears before birth. This hair cannot be regarded as any less significant than the coat of hair which the infant whale possesses; it means a completely haired ancestor. The elements of this coat are arranged precisely as they are in the apes; upon the arm, for example, they point from shoulder to elbow and from wrist to elbow. Unless the anterior limb of the hairy human ancestor was held in the position of the climbing ape's, this arrangement would be disadvantageous, for the hair as a rain-shedding thatch would be effective only upon the upper arm, while the hairs upon the forearm would catch the rain. In a word, this vestigial coat indicates in the clearest possible manner that the ancestor of the human species was not only hairy, but also arboreal in its mode of life.

Every human infant is bow-legged at birth, and the natural position of its curved limbs is like that of the gorilla's, for the soles of the feet are turned toward one another. Again, the so-called great toe is at first shorter than the others, and for a time it retains the power of free movement that indicates a handlike character of the lower limb in the ancestor. Many savage human races, however, whose feet remain unshod, make use of the primitive grasping power of the foot which the higher races lose completely. An Australian and Polynesian can pick up small objects with the foot very much as we may with the hand.

Among the wonderful reminiscent characters displayed by the human infant is the firm clasping power of the hand, which it possesses for a time after birth and which enables it to hang suspended for several minutes from a stick placed in its grasp. The muscles which enable the infant to do this gradually dwindle, so that the two-year-old child can hang suspended for only a few seconds. This grasping muscle is a heritage from the ape, where there is an obvious necessity for the newborn individual to have a firm hold upon the hairy coat of its tree-climbing mother. When the newborn child hangs in this way, it bends its curved lower limbs so that the soles of the feet are turned toward one another, thus increasing its resemblance to the ape.

Let us realize that these curious relics found in so many places in the framework of man are not unique, and that they are reduced counterparts of larger and more valuable structures in the ape. Unless evolution is true, they have absolutely no sensible reasons for existence. Science prefers the evolutionary explanation of their occurrence because this explanation is more in harmony with the facts known about other organisms, and it is more reasonable than any other.

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When we dealt with the general doctrine of natural transformation, it appeared that the evidence of embryology was in many respects more cogent and conclusive than that derived from the comparative study of animal structures. In the case of man, as before, no one could demand any surer or more convincing proof that an organic mechanism with one structure can change into an organic mechanism with a different structure, than the obvious facts of development. The embryo, which is not an infant or an adult, becomes an infant which must work its way onward by the gradual accumulation of slight changes here and there and everywhere in its anatomy, until it becomes mature. Each and every one of us has actually undergone the process of organic change in becoming what we are, and we cannot deny the reality of such a process without challenging the evidence of our senses.

When the full import of this history is realized, and when we look further into the nature of these preliminary conditions through which the human organism passes in development, we are forcibly impressed by other facts than the one to which I have directed your attention, for not only do we find natural transformation, as in the other mammals, but the embryonic stages are marvelously similar to the earlier conditions in other mammals. Not very long before birth the human embryo is strikingly similar to the embryo of the ape; still earlier, it presents an appearance very like that of the embryos of other mammals lower in the scale, like the cat and the rabbit,—forms which comparative anatomy independently holds to be more remote relatives of the human species. Indeed, as we trace back the still earlier history, more and more characters are found which are the common properties of wider and wider arrays of organisms, for at one time the embryo exhibits gill-slits in the sides of its throat which in all essential respects are just like those of the embryos of birds and reptiles and amphibia, as well as of other embryo mammals and these gill-slits are furthermore like those of the fishes which use them throughout life. All the other organic systems exhibit everywhere the common characteristics in which the embryos of the so-called higher animals agree with one another and with the adult forms among lower creatures; the human embryo possesses a fishlike heart and brain and primitive backbone, fishlike muscles and alimentary tract. Can we reasonably regard these resemblances as indications of anything else but a community of ancestry of the forms that exhibit them?

Yet a still more wonderful fact is revealed by the study of the very earliest stages of individual development. The human embryo begins its very existence as a single cell,—nothing more and nothing less; in general structure the human egg, like the eggs of all other many-celled organisms, is just one of the unitary building blocks of the entire organic world. And yet the egg may ultimately become the adult man. Does this mean that man and all the other higher forms have evolved from protozoa in the course of long ages? Science asks if it can mean anything else. When the comparative anatomist bids us look upon the wide and varied series of adult animals lower than man as his relatives, because they display similar structural plans beneath their minor differences, it may be difficult at first to obey him. But in the brief time necessary for the human egg to develop into an adult, the entire range is compassed from the single cell to the highest adult we know. There are no breaks in the series of embryonic stages like those between the diverse adult animals of the comparative array. I do not think we could ask nature for more complete proof that human beings have evolved from one-cell ancestors as simple as modern protozoa beyond the obvious facts of human transformation during development. They at least are real and not the logical deductions of reason; yet their very reality and familiarity render us blind to the deeper meaning revealed to us only when science places the facts in intelligible order.

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And now, in the third place, we may look to nature for fossil evidence regarding the ancestry of our species. Much is known about the remains of many kinds of men who lived in prehistoric times, but we need consider here only one form which lived long before the glacial period in the so-called Tertiary times. In 1894 a scientist named Dubois discovered in Java some of the remains of an animal which was partly ape and partly man. So well did these remains exhibit the characters of Haeckel's hypothetical ape-man, *Pithecanthropus*, that the name fitted the creature like a glove. Specifically, the cranium presents an arch which is intermediate between that of the average ape and of the lowest human beings. It possessed protruding brows like those of the gorilla. The estimated brain capacity was about one thousand cubic centimeters, four hundred more than that of any known ape, and much less than the average of the lower human races. Even without other characters, these would indicate that the animal was actually a "missing link" in the scientific sense,—that is, a form which is near the common progenitors of the modern species of apes and of man. We would not expect to find a missing link that was actually intermediate in all respects between modern apes and modern men, any more than we should look for actual connecting bands of tissue between any two leaves upon a tree. A missing link, in the true sense, is like a bud of earlier years which stood near the point from which two twigs of the present day now diverge. So *Pithecanthropus* is a part of the chain leading to man, not far from the place where the human line sprang from a lower primate ancestor.

Of the fossil remains of true prehistoric men, little need be said. We cannot know whether the races now living in the regions where these remains are found are really the descendants of the older types, and so a direct comparison cannot be made. It is true that the brain capacities of the man of Spy, of the Neanderthal, and of the English caverns are lower than those of modern civilized races, but the differences are not so striking and not so clearly indicative of the apelike ancestor of man as in the case of the previous comparison of *Pithecanthropus* with apes and men.

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The foregoing facts illustrate the conclusive evidence brought forward by science that human evolution in physical respects is true. Even if we wished to do so, we cannot do away with the facts of structure and development and fossil history, nor is there any other explanation more reasonable than evolution for these facts. If now we should inquire into the causes of this process, we would find again that the present study of man and men reveals their subjection to the laws of nature which accomplish evolution elsewhere in the organic world.

The fact of human variation requires no elucidation; it is as real for men as for insects and trees. Indeed, some of the most significant facts of variation have been first made out in the case of the human species. The struggle for existence can be seen in everyday life. We cannot doubt its reality when scores perish annually because of their failure to withstand the extreme degrees of temperature during midwinter and midsummer; when starvation causes so many deaths, and when the incessant combat with bacterial enemies alone brings the list of casualties on the human side in our own country to more than two hundred and fifty thousand a year. As in nature at large, the more unfit are eliminated as a result of this struggle, while the more adapted succeed. In the long run, that particular applicant for a clerkship or any other work who may be the more fitted is the one who gets it. While the severity of competition may be somewhat mitigated as the result of social organization, and while our altruistic charitable institutions enable many to prolong a more or less efficient existence, the struggle for existence cannot be entirely done away with. Heredity also is a real human process, and it follows the same course as in animals at large; as in the case of variation, some of the fundamental laws of its operation have been first worked out in the case of human phenomena, and have been found subsequently to be of general application.

Reverting to the specific question as to the earliest divergence of man from the apes, we can readily see how the superior development of the ape-man's brain gave him a great advantage over his nearest competitors, and how truly human ingenuity enabled the earliest men to employ weapons and crude instruments instead of brute force. Thus the gap between men and apes widened more and more, as reasoning power increased through successive generations. This is another aspect of the statement that the supreme position of man has been gained, not by superior organization in physical respects outside of the nervous system, but by the superior control of human organization by the higher organs of this system.

The unity of nature and of its processes is established more and more surely as the naturalist classifies the facts of structure, development, fossil history, and evolutionary method. Our own species is not unique; it takes its high place among other organic forms whose lives are controlled in every way by the uniform consistent laws of the world.

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The physical evolution of human races is the next major division of the large subject before us. Heretofore the obvious differences displayed by various races have been disregarded and the species has been treated as a unit, in order that its evolution from pre-human ancestors might be made clear. Knowing now how the facts of structure show that the supreme position of our kind has been attained mainly as the result of the progressive elaboration of the higher portions of the brain, and not because new and unique structures have been developed, we are prepared to turn our attention to the diverse characteristics of human races; and during this inquiry anatomical matters will still be the only ones to be reviewed. The intellectual and social characters of numerous races belong to the category of physiological or functional phenomena, which are to receive due consideration at a later time. It is the meaning of the facts of racial diversity for which we are now to look.

For many reasons this subject is more difficult to describe in a concise outline than those taken up before. It is true that every one is familiar with different types of human beings, such as the Negro and Japanese and Chinese, while furthermore the obvious differences between such races as the Norwegian and Italian are sufficiently marked to strike the attention of any one who looks about at his fellow-passengers in a crowded street car. But few indeed have a comprehensive knowledge of the wider range of racial variation in which these familiar examples find their place. Anthropology, or the science of mankind, is a large and well-organized department of knowledge, dealing with the entire array of structural and physiological characters of all men. One of its subdivisions, anthropometry, is almost an independent discipline with methods of its own; it describes the characteristics of human races as these are determined by statistical methods of a somewhat technical nature. There is still another science, ethnology, which deals more particularly with institutions, customs, beliefs, and languages rather than with physical matters, although it is clear that ethnology and anthropology cannot be sharply separated, and that each must employ the results of the other for its own particular purposes.

Because men have always been interested in the study of themselves, the subject of racial evolution is literally enormous, and the attempt to give anything like a complete description of what is known would obviously be futile. But it is possible to obtain a clear conception of certain of the fundamental principles that fall into line with the other parts of the doctrine of organic evolution with which we have now become acquainted. The main questions, therefore, may be stated in simple terms. The first deals with the evidences as to the reality of evolution during the historical and prehistoric development of the various types of man from earlier common ancestors; the second asks whether the lines of racial evolution are further continuations of the line leading from ape-like ancestors to the human species as a type. In order to give the proper perspective, it will be well to state at the present juncture, first, that the various kinds of men do not vary from each other in a chance manner so as to show all possible types and varieties, but that they fall into natural groups or families distinguished by certain common characteristics, just as do all other kinds of species of animals; in the second place, it appears that some of the differences between the races denoted higher on structural accounts and the lowest forms of man are of the same nature as those observed in the review of the various species of primates from the lemurs to man.

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It is best to look at the whole question in a very simple and common-sense way before undertaking an extended examination of the details of human diversity. The most casual survey of the peoples that we know best because of our own individual nearness to them enables us to realize that the races now upon the earth have not existed forever and ever, or even for the age of 6000 years as contended by Archbishop Ussher. They have all come into existence as such, and they differ from their known antecedents; so that at the very outset common-sense leads us to accept evolution as true, if we admit that human races have changed during the course of recent centuries. We know, for example, that the so-called Mexicans of to-day are a people produced by a fusion of Spanish conquerors and Indian aborigines the Mexican is neither Spaniard nor Indian, though he may resemble both in certain respects; he is a product of natural evolution, accomplished in this case by an amalgamation of two contrasted types. When we speak of the American people, we must realize that it too has come into existence as such, and even, indeed, that it is in the actual process of evolution at the present time. The various foreign elements that have been added during the last few decades by the hundreds of thousands are becoming merged with the people who preceded them, just as the Dutch and the French and the English coalesced during the days of early settlement to form the young American nation. Perhaps most of us call ourselves Anglo-Saxon, but we are in reality somewhat different even in physical respects from the Englishmen of Queen Elizabeth's time, who alone deserved the name Anglo-Saxon. This very term indicates an evolution of a type that differs from both the Angles and the early Saxons of King Alfred's age. These are simple examples which illustrate many features of the universal history of human races wherever they are to be found. Even in the comparatively peaceful times of our modern era the history of any race is a veritable turmoil of constant changes; conquerors impress their characters upon the vanquished, while the victors often adopt some of the features of the conquered. Colonies split off from the mother nation to follow out their destinies under other conditions. Nowhere does the naturalist find evidence of long-established permanence, or an unentwined course of an uninterrupted and unmodified line of racial descent.

It is the task of the student of human evolution to unravel the tangled threads of human histories. The task is relatively simple when it is concerned with recent times where the aid of written history may be summoned but when the events of remote and prehistoric ages are to be placed in order, the difficulties seem well-nigh insuperable. All is not known, nor can it ever be known; but wherever facts can be established, science can deal with them. By a study of the present races of mankind, much of their earlier history can be worked out, for their genetic relations may be determined by employing the principle that likeness means consanguinity. Let us suppose an alien visitor to reach our planet from somewhere else; if he were endowed with only ordinary human common-sense, he would very soon ascertain the common origin of the English-speaking people in Canada, the United States, Australia and New Zealand, South Africa, and many other places. Even if he could not understand a word of the English language, he would be justified in regarding them all as the descendants of common ancestors because they agree in so many physical qualities. The anthropologist works according to the same common-sense principle, obtaining results that find no explanation other than evolution when the varying characters that are used to determine social relationship are properly classified and related. It is to these characters that we must now give some attention.

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The average stature of adults varies in different races from four feet one inch in certain blacks to nearly six feet and seven inches, as among the Patagonians. These are the extreme values for normal averages, although dwarfs only fifteen inches high have been known, while "giants" sometimes occur with a height of nine feet and five inches. Such individuals are of course rare and abnormal, and are not to be taken into account in establishing the average stature of a race for use in comparison with that of another group.

The color of the skin is another criterion of racial relationship, though it is more variable in races of common descent than we are wont to assume. We are familiar with the fair and florid skin of the northern European, the fair and pale skin in middle and southern Europe, the coppery red of the American Indian, the brown of the Malay, of the Polynesian and of the Moor, the yellowish cast of the Chinese and Japanese, and the deeper velvety black of the Zulu; but it has been found that many of the close relatives of the black are lighter in skin color than some of our Caucasian relatives, so that this character cannot be taken by itself as a single criterion of racial affinity.

Perhaps the most conservative and most reliable character that serves for the broad classification of the human races is the shape of the individual hairs of the head. We are familiar with the straight lank hair of the Mongolian peoples and of the various tribes of American Indians, in whom the hair possesses these peculiarities because each element grows as a nearly perfect cylinder from the cells of the skin at the bottom of a tiny pit or hair-follicle. The familiar wavy hair of white men owes its character to the fact that the individual elements are formed by the skin, not as pencil-like rods, but as flattened cylinders. They are oval or elliptical in cross-section, and when they emerge from the skin they grow into a long spiral. If, now, the hair is formed as a very much flattened rod about one-half as wide in one diameter as in the other, it curls into a very tight close spiral and gives the frizzly or woolly head-covering of the Papuan and of the Negro.

In the next place, the shape of the cranium is a character of much value. This is determined as the proportion between the transverse diameter of the skull above the ears to the long diameter, namely, the line that runs from the middle of the brow to the most posterior point of the skull. In the so-called "long-headed" or dolichocephalic races, the proportion is seventy-five to one hundred, while in those forms that have more rounded or brachycephalic heads, like the Polynesian and the black pygmy, the relation is eighty-three to one hundred. The cranial capacity again varies considerably, from nine hundred cubic centimeters to twenty-two hundred cubic centimeters. Many striking variations are also found in the projection of the jaws. A line drawn from the lower end of the nose to the chin makes a certain angle with the line drawn from the chin to the posterior end of the lower jaw; if the jaw projects very greatly, this angle will be much less than when they do not. In most of the Caucasian peoples, the lines meet at an angle of eighty-nine degrees, or very nearly a right angle, but in some of the lower races the figure may be only fifty-one degrees. Additional characters of the teeth and of the palate are also taken into account, and have proved their utility. Finally, the nose exhibits a wide range of variation from the small delicate feature of the Chinaman to the large, well-arched nose of the Indian. It may be hollowed out at the bridge instead of arched; again, it may be nearly an equilateral triangle in outline, as in the Veddahs, and the nostrils may open somewhat forward instead of downward. As many as fifteen distinct varieties of the human nose have been catalogued by Bertillon.

These are the principal bodily characters which the anthropologist uses to distinguish races and by their means to determine the more immediate or remote community of origin of comparable types. Many of these characteristics, as indeed we may already see, are decidedly important in connection with the second problem specified above, for in the case of the flat triangular nose and projecting jaws of a low negroid we may discern clear resemblances to certain features of the apes.

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Long before the doctrine of evolution was understood and adopted, students of the human races had been deeply impressed by their natural resemblances. As early as 1672 Bernier divided human beings according to certain of these fundamental similarities into four groups; namely, the white European, the black African, the yellow Asiatic, and the Laplander. Linnæus, in the eighteenth century, included *Homo sapiens* in his list of species, recognizing four subspecies in the European, Asiatic, African, and Indian of America. Blumenbach in 1775 added the Malay, thus giving the five types that most of us learned in our school days. But the different varieties of men recognized by these observers were believed to be created in their modern forms and with their present-day characteristics; the common character of skin color exhibited by any group of peoples of a single continent was to them only a convenient label for purposes of description and classification. It was not until years later that fundamental resemblances were recognized as indicating an actual blood relationship of the races displaying them, and therefore of evolution. Since the doctrine of human descent and of the divergence of human races in later evolution has been accepted, those who have attempted to work out fully the complete ancestry of different peoples have found that no single character can be taken by itself, while the various criteria themselves differ in reliability; the color of the skin is not so sure a guide as the character of the hair and skull, wherefore the classifications of recent times, notably those of Huxley and Haeckel, have been based largely upon the latter. The latest systems have been more rigidly scientific and more in accord with the most modern conceptions of organic relationships in general, as evidenced by the thoroughgoing methods of Duckworth in his recent treatise on human classification.

It now remains to present the salient facts regarding the genetic relationships of typical human races, although it is obviously impossible to go into all of the details of the subject. But these are not essential for the main purpose, which is to show that the evolutionary explanation is the only one that is reasonable and self-consistent. Opinions are sometimes widely at variance regarding countless minor points, but no anthropologist of to-day can be anything but an evolutionist, because the main principles upon which the specialists agree fall directly into line with those established elsewhere in zoölogy. It seems best to state these principles without reverting to controversial matters which find their place in the monographs of the experts. Any comprehensive account such as that of Keane, even if it may not give the final word, will be entirely sufficient to demonstrate how fruitful are the methods of evolution when they are employed for the study of human races, and indeed how impossible it is to discuss human histories without finding conclusive evidences of their evolutionary nature.

The facts that are available indicate that the first members of our species evolved in an equatorial continent which is now submerged, and which occupied a position between the present continents of Asia and Africa. From this center hordes of primitive men migrated to distant centers where they differentiated into three primary and distinct groups. The first of these was gradually resolved into the darker-skinned peoples most of whom now live in the continent of Africa, although many dwell also in the islands of the western Pacific Ocean. The second branch divided almost immediately to produce, on the one hand, the Indians of the new world and, on the other, the yellow-skinned inhabitants of Asia and other places. The third branch developed as such in the neighborhood of the Mediterranean Sea, and produced the series of so-called Caucasian peoples, which are by far the most familiar to us and to which most of us belong. But so early did the second branch divide that there are virtually four main divisions of the human species that are to be examined in serial order.

It is best to begin with our own division, because its greater familiarity makes it easier to become acquainted with the methods and results of anthropology, on the basis of facts that we already know. Three subordinate types exist, located primarily in northern, central, and southern Europe respectively, but many other races dwell elsewhere that are assignable to one or another of these subdivisions. In northeastern Europe we find people such as the Norwegians, Swedes, Danes, and north Germans, that average five feet eight inches in height. They have the long, wavy, and soft hair which is a general characteristic of the whole Caucasian group, although its light flaxen color is distinctive. The blue eye and florid complexion accompany the light color of the hair. The skull is of the longer type, the jaws and forehead are straight and square, the nose is large and long without a distinct arch, and the teeth are relatively small. It is not so well known that the Scandinavian type is so closely copied by many people of Asia, such as the western Persians, Afghans, and certain of the Hindus, living in a continent that we are inclined to assign to the Mongol only. In the possession of these characters the Northern Europeans and other races specified display evidences of their common ancestry and evolution quite as conclusively as in the case of the cats discussed in an earlier chapter where the meaning of essential likeness was first demonstrated.

A broad zone may be drawn from Wales, across Europe and Asia, and even to the eastern islands of the South Seas, in which we find peoples that are obviously of Caucasian descent, but they differ from the members of the first group in some details of structure. On the average they are about five feet five or six inches in height, the hair is dark and wavy, but it is not the pencil-like structure of the Mongol. The complexion is pale, the skull is rounder, and the eyes are usually brown in color. These peoples agree also in their volatile temperament and vivacious manner and are thus markedly different from the more stolid northerners. To this minor branch of the Caucasian stock belong the Welsh, most of the French, South Germans and Swiss, Russians and Poles, Armenians, eastern Persians, and finally some of the inhabitants of Polynesia. The last, it is true, form a well-marked group of darker-skinned and taller races, but in spite of the admixture of these and other unusual features, we can still discern the bodily characters that supplement their traditions, telling of an Asian origin, in demonstrating their common ancestry with round-headed Persians and middle Europeans. Below the zone of middle Europe and Asia is another broad region inhabited by the "Mediterranean" type of Caucasian. The Spaniard, Italian, Greek, and Arab are sufficiently familiar to illustrate the distinctive qualities of this subdivision. These people have the smaller stature, dark hair, dark eyes, and paler skin of the middle Europeans, but the skull is of the long instead of the rounded type. A well-marked subordinate group is formed by the so-called Semitic peoples, such as the Arabs and their Hebrew relatives. The Berbers and other North African races possess a darker skin probably because of the admixture of Ethiopian stock, and they, too, are so well characterized that they form a clearly marked outlying group as the so-called Hamites. Passing over into Asia we find relatives of the Mediterranean man in the Dravidas and Todas of India, possibly in the degenerate Veddahs of Ceylon, and finally in the Ainus or "hairy men" of some of the Japanese islands. The last-named people certainly possess some Mongolian features, but these seem to have been added to a more fundamental form of body that is distinctly Caucasian.

All of the races we have mentioned, together with their relatives, may be compared to the leaves borne upon three branches that take their origin from a single limb of the widespread human part of the tree. They cannot be classified in any mode on the basis of their primary and secondary resemblances without employing the treelike plan of arrangement, which to the man of science is a sure indication of their evolutionary relationships.

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The people of the second or Mongolian group agree in certain well-marked characteristics in such a way as to be well separated from the other divisions of mankind; these characteristics we may speak of as constituting a second "theme," of which the various peoples of the group are so many variations. To visualize them we need only to recall the appearance of the Chinaman, perhaps the most familiar example of the entire series. Here the hair is coarse and black, and straight because of its round transverse section; the mustache and beard of the Caucasians are seldom found except in later life; the skin is a fleshy yellow in color; the skull is round, indeed, it is one of the roundest that we know; the jaws are not so straight as in the Caucasian, for the angle at the point of the chin is about sixty-eight degrees. The cheek bones project laterally, with greater or less prominence; the nose is very small, tilted up slightly at the end, and is usually hollowed instead of arched. The eyes are small and black in color, set somewhat obliquely, and the upper lid is drawn down over the eye at its inner corner so as to make the obliquity still more marked. The teeth are larger than those of the Caucasian. Finally, the Mongol is below the average of all men as regards height, being usually about five feet four inches tall.

The original Mongolians probably developed the characteristic features we have just noted in a Central Asiatic region, and then almost immediately they divided into two great groups. Each of these evolved along certain lines of its own, one sweeping northward to develop into what are now called the Northern Mongols, the other working its way eastward and southward to produce the peoples of China proper, Indo-China, and many parts of Malaysia. Considering first the peoples of the Northern Mongolian division, we find in the typical Manchurian what is perhaps the nearest among modern people to the original race. Spreading northward and westward from the middle Asiatic plains, this great wave has produced the nomadic tribes of Siberia, like the Chukchi, the Buryats, and the Yukaghir. The present inhabitants of Turkestan connect those forms which have remained near the original home with the races of Mongolian origin that live farther to the westward, like the Turks of Asia. But the Mongolian tide originally swept much farther to the west, although it was driven back later by conquering Caucasian peoples; and it has left behind such remnants as the Finlander and the Laplander, the Bulgar, and the Magyar. It is evident that these western branches of the Mongol stock are not at all pure in their racial characteristics, for they clearly show the effects of a mixture with alien European peoples. To assign them to the Northern Mongol division means only that their dominant characteristics are mainly those of Mongolian nature. We have referred the Russians to the middle Caucasian division even though the Slav or Tartar infusion is very great, but it does not dominate over the Caucasian peculiarities as it does in the case of the peoples we have mentioned. As regards the remaining types we must add to this brief list the Koreans and the Japanese, the former being far purer in Mongolian nature than the latter people, which has apparently been affected by a Malay influence from the south.

Turning now to the southern Mongol, we find that from their cradle in the Tibetan plateau they too have spread widely, and their descendants have also come to differ in certain respects as they have established themselves in other lands. Most of the present people of Tibet belong to this section; the Gurkhas of Hindustan, the people of Burma proper, of Annam, and Cochin China are close relatives of one another and of the more characteristic Mongolians of China proper who make up the vast bulk of the population. From this stock we may also derive the Malays of Sumatra and Java, of Borneo and Celebes, and the Tagals and Bisayans of the Philippine Islands.

Even the Hovars and other tribes of Madagascar may be referred to this division, for although in them the skin has become somewhat darker, we may still discern the characteristics which indicate their common ancestry with the Oceanic Mongols.

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The American Indians taken collectively constitute a group that is well set off from the rest of mankind by such characters as taller stature, small, straight, and black eyes, a large nose that is usually bridged or aquiline, a skull of medium roundness, and the yellow copper color of the skin. The common origin with the Mongols is demonstrated by the straight and long, coarse, black hair and by the absence of a beard; the mustache also is almost always absent.

All of us have seen Indians belonging to the tribes of the plains, which serve as excellent examples of this grand division. Many have also visited the homes of the Pueblo Indians, and have learned how uniform is the physical appearance of the tribes living in various parts of the United States. Indeed throughout all of North America the basic characteristics of Indians prove to be strikingly conservative, although in the Eskimo there are some departures which seem to indicate a closer connection of these peoples with the Mongols, probably as the result of some more recent influx from the neighboring and not very distant region of northeastern Siberia. Extending our survey southward through Central America, the Aztecs and Mayas are found to possess many of the same characters, though in some respects they are transitional to the Caribs of the northern edge of South America and to the Indians of South America. Traveling still farther southward, we meet the very tall Patagonian, still an Indian in essential respects, and finally, the Yahgan and Alacaluf of the Fuegian region, the most degenerate members of the race. The last-mentioned people are dull and brutish and most degraded in all respects, and stand at the lowest end of the red Indian series as regards intellectual ability and cultural attainment.

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We now come to the last of the four great divisions of the human species which includes the races usually spoken of as Africans or Ethiopians. But these races are by no means restricted to the continent of Africa, for quite as typical black types are found in far-distant lands such as Australia and many islands of the Pacific Ocean. The races assigned to this division group themselves about two subordinate types,—the tall negro proper and the shorter or dwarf negrito,—and each of these has representatives both in Africa and in the oceanic territory.

The black slaves of America were all descended from typical negros brought from the western part of Africa, and they provide us with adequate illustrations of Ethiopians as a group. In them the stature is above the average of men in general, specifically about five feet ten inches. The short jet-black hair is strikingly different from the head covering of the other great groups of human races; each individual hair is so flat in cross-section that it curls into a very tight close spiral, and this brings about a frizzly appearance of the whole head covering. There is little or no beard, the skin is soft and velvety and of various shades approaching black in color. The skull is long, the cheek bones are small, but the most distinctive characteristics of the head are found in the apelike ridges over the eyes and in the very broad flat nose which projects only slightly and turns up so that the nostrils open forward to a marked degree, while in the jaws there is an astonishing divergence from the Caucasian condition in the great protrusion which causes the angle at the chin to be about sixty degrees.

The warlike Zulus and other peoples of Southern and Central Africa are perhaps the most characteristic races in this division. Their relatives are found to the northward as far as the Sahara desert, along the southern borders of which they have spread out to the eastward and westward. Fusion with other races has taken place along this border so that many of these northern tribes are much lighter than the Zulus in the color of the skin. But many relatives of the taller African negro are found in other parts of the world, namely in Australia, and in New Hebrides and New Caledonia—islands to the north and east of this continent. The Papuan of New Guinea is a typical negro in all true respects, with strongly marked Ethiopian characteristics, though there are some differences which are transitional to the more aberrant natives of Melanesia, which includes many archipelagos like the Fiji, Bismarck, Marshall, and Solomon islands. Undoubtedly the most degenerate member of the tall negro division is the Australian native, the so-called "blackfellow." The bulbous nose and the well-grown beard mark him off from the typical stock, but his obvious relationship to this is indicated by the low brain capacity, the prominent ridges over the eyes, and the heavy projecting jaws.

Taking up the other division of the so-called Ethiopian race, constituting the Negrito section, we may begin with its Oceanic members. The natives of the Andaman Islands, the Kalangs and the Sakais of Java and neighboring regions, and the Aetas of the Philippine Islands agree in a dwarfed stature of four feet or a little over, in their yellowish brown skin color, a round head, and woolly reddish-brown hair. They, too, possess large ridges over the eyes and extremely prominent jaws, and in these latter characteristics particularly we see evidences of their relationship to the negro. But perhaps the most characteristic pygmies are found in Africa. The little Bushmen and Hottentots are low types of the Negrito stock, and they lead us to the lowest men of all, the Akkas of the West Congo region. It is difficult for us to realize how utterly degenerate and apelike these pygmies are. The jaws are disproportionately large as compared with the cranium or brain-case, and project to a degree which brings the skull very close to that of the higher apes; while in mental respects, in the absence of dwellings, and in many other ways they prove to be the lowest of all mankind,—veritable brutes in form and mode of life.

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Without a full series of photographs before us the foregoing sketch of the various races of men cannot make us fully acquainted with all the strange varieties of the human body, but it will suffice to establish two fundamental results. While all men agree in the possession of certain features which set them apart from other members of the primate order, they differ among themselves in such a way as to fall into four well-marked subdivisions branching out from a common starting-point. Furthermore, in each of these primary groups the subordinate types arrange themselves also in the manner of branches arising from a common limb. This is the relation that we have earlier found to be a universal one throughout the animal kingdom, and science believes that it indicates everywhere an evolutionary history—an actual development along different lines of descent of forms which have a common starting-point and ancestry.

The second principle is perhaps even more significant: when we review the many races from the Caucasian to the dwarf Negrito, we traverse a downward path which will bring us inevitably to the higher apes. In our survey of human races, we have passed from the Caucasian, with the largest brain and cranium and with straight jaws well underneath the brain-case, to the pygmy with a relatively small brain, with huge projecting jaws and with prominent ridges over the eyes; one step more along that path would bring us to the gorilla or the chimpanzee. The array of lower primates, from the lemur to the gorilla, gives a series of forms exhibiting a progressive advance in respect to the size of the brain and cranium, and a gradual retreat of the jaws to a position underneath the cranium; and one step further brings us to man. In a word, these two lines join—in fact, they are directly continuous. There is a far smaller difference between the lowest man and the highest ape than we have been accustomed to suppose.

Thus in general terms, it can justly be said that process of evolution which developed the first man from its ape-man progenitor seems to have continued during subsequent ages. Spreading out in diverging lines of evolutionary descent no less clearly than they have in geographical respects, certain races have far surpassed their fellows of a lower order, which, like the brute pygmy, remain nearer the common structural form from which all men have sprung.

# VI

#### THE MENTAL EVOLUTION OF MAN

The problems dealing with the make-up of the human mind and with the evidences of mental evolution bring the student to matters of more vivid human interest. Mental phenomena are so complex and intricate that it is well-nigh impossible to analyze their history without a knowledge of the principles derived from the broad study of evolution as a general doctrine, where human prejudice is not so large a factor and where his perspective is less affected by the proximity of the observer to his facts. For these and other reasons the foregoing treatment of human evolution has been confined to the purely structural characteristics of man as a species and of human races as so many varieties of this type. When the broad comparative methods of biological science are employed for the elucidation of human anatomical facts, the result in this special case, like that established through the study of the characteristics of living things in general, is the proof that evolution gives the most rational and natural explanation of the observed data. This being true, the naturalist who turns from purely structural matters to human intellect and its history, finds well-tried methods of inquiry already available, and he approaches his further studies with a conviction that evolution, having proved to be universal so far, in all probability will be found equally true in the case of psychological phenomena. This expectation is indeed realized, and the scope of the doctrine is extended over a new field, when the facts of human psychology are treated as materials for impersonal comparative study; and this result is not only useful and valuable in and by itself, but it also provides in the principles of mental evolution the transition to the field of social relations and ethical ideas and ideals which are apparently the unique possessions of men as individuals and as associated groups.

The field of comparative psychology might seem at first sight to be a foreign territory to the average well-informed layman in science, but the contrary is really the case. Every one has thought at one time or another about his own mental make-up, and about the minds of others. No one can watch a child at play with his toys or at work with his schoolbooks without being struck by many evidences of marked differences between the immature and the experienced types of mind. Every one knows also that the mental "scheme of things" is by no means the same for all nations or races of mankind existing to-day, while furthermore the fact is entirely familiar that the intellectual heritage of a present race has changed in the course of previous ages. Therefore in this field as before we need only to amplify our knowledge of such representative psychological facts as these by drawing upon the full stores of the special investigator, in order to learn that human thought, like the human frame, has undergone a natural history of transformation to become what it is and what it was not.

Many who would be ready to accept the evolution of physical characteristics find it impossible to treat the history of human mentality as a subject for dispassionate consideration, because above all else the intellectual powers of mankind seem to be truly distinctive. It is only after constant use of the methods of science that we can bring ourselves to see how closely we resemble lower forms in physical make-up; still greater reluctance must be overcome before we can view our mental processes as counterparts of those of inferior animals, so essential to our very humanity do they seem. But our duty to undertake the task is plain, and its discharge will be greatly facilitated by a clear realization that mental evolution is but a part of human transformation in times past, as the latter is only a small fraction of the universal process of organic evolution in general. While our own nature and inquisitiveness give us so intense an interest in the teachings of science that relate to the constitution and history of human faculty, wherefore these matters gain an undue prominence in perspective, it must never be forgotten that these teachings do not stand by themselves, for they are built upon the sure foundations already laid in physical evolution; and these foundations cannot be disturbed by our failure to use them as a basis when we construct our own conceptions of human intellect and its history.

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Before passing to the systematic review of the facts and principles of comparative psychology which demonstrate evolution, there are certain general aspects of the subject to be considered so as to clear the ground, as it were, for further progress. When the several organic systems of the human body were compared with those of the apes and of lower animals, their evolution was proved as far as the purely physical and material characteristics were concerned. But we know that there is no part of any one of these systems which has not its own particular function, even though this may be a relatively passive one; while furthermore, science does not know of any physiological activity without some organ or tissue or cell as its material basis. Therefore the evolution of an organic system in material respects involves its functional or dynamic evolution as an inseparable correlate; the two proceed in unity, and they cannot be regarded as entirely distinct without violating common-sense.

The fin of a fish is used as an organ of locomotion in water; from some such organ have evolved the walking limbs of amphibia and reptiles, constructed for progression upon land. Among the mammalia the fore limbs have become structurally adapted so as to be such diverse organs of locomotion as the stilt-like leg of a horse, the flipper of a seal, the whale's paddle, and the bat's wing, while among the birds the wing may change into a flipper like that of the penguin, or become reduced to a vestige as in *Apteryx*. We may focus our attention upon the material likenesses and differences in such a series of locomotory organs, but an inevitable accompaniment of their physical changes in the transformation of species has been an evolution in the functional matter of locomotion. The most complex and differentiated tracts of even the highest animals have evolved from a simple sac like that of a polyp or jellyfish, as we know from the independent testimony of comparative anatomy and embryology; in this case also the evolution of alimentary functions is no less inseparable from the transformations in structural respects. And again, we cannot understand the historical development of vision without taking into account the eyes of various types belonging to lower and higher animals.

So it is with the nervous systems of man and other animals, and with their functions. The nervous system of the human organism comprises identical organs with the same arrangements that are found in other primates and in lower vertebrates as well; the differences in structure are differences in the degree of the complexity of certain parts, notably of the cerebrum. Therefore the evolution of human mentality, which depends upon a human type of brain as a physical basis, is already demonstrated with the proof that the human brain and nervous system have evolved. It is true that an invariable and necessary connection between mind and matter is implied in the foregoing statement, and this is something which demands further consideration at a later point. But just *how* the human mind is produced by or depends upon the brain, is of far less importance for us at this time than the obvious fact that mental performance requires active nervous tissues. So far investigation has been unable to discover a valid reason for a belief in the existence of mental phenomena, as such, apart from some kind of material basis. And while we may prefer to restrict the use of the word *mind* to the series of nervous processes going on in the human organ of thought, in so far as these processes are carried on by the peculiar tissues of the nervous system they cannot be finally distinguished from the functional products or accompaniments of the same kind of active tissues and organs in lower creatures. Thus the subject of mental evolution becomes much clarified at the outset by understanding that nervous processes and nervous systems evolve together.

In the direct treatment of the facts and principles of mental evolution we can use exactly the same classification and subdivisions of the materials of study as heretofore, because psychological data are the correlates of material organic systems, and also because the former, being natural phenomena, are subject to the methods of analysis which can be employed for any series of objects that have undergone evolution. Separating the matter of fact from the question as to the method, and recalling the main bodies of evidence as to the reality of evolution, we may establish four sections of the subject before us: these are (1) the anatomy, (2) the embryology, and (3) "palæontology" of mind, and (4) an inquiry into the way nature deals with the psychical characteristics of organisms in accomplishing their evolution. To specify more particularly, it is possible in the first place to compare the activities belonging to the category of mental and nervous operations, displayed by man and other organisms, and the results form the subject of comparative descriptive psychology; the second division, namely, developmental or genetic psychology, deals with the sequence of events in the life of a single individual by which the infantile and adolescent types of mind become adult intellectuality; in the third place, in speaking of the palæontology of mind, the phrase is used to refer to the varied and changing mental abilities of human races in historic and prehistoric times as they may be demonstrated and determined by the evidences of the culture of such earlier epochs. In considering the matter of method, the questions are whether variation, inheritance, and selection are as real in the world of mental phenomena as they are in the material world, and whether the laws are the same or similar in the two cases. We shall learn how the results of such studies prove with convincing clearness, first, that the contents of the individual mind and of the minds of various human races are truly the products of natural evolution, and second, that the human mind differs only in degree from that of lower organisms, and not in kind or fundamental nature.

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When the operations of human mental life are examined, they include what are called processes of *reason* as apparently distinctive elements. The lower mammalia exhibit a simpler order of "mentality" denoted *intelligence*, while the nervous processes of still simpler forms are called *instinctive* and *reflex* activities. These are the terms of the comparative array of psychology which are to be separately examined and classified, and to be brought into an evolutionary sequence if common-sense directs us to do so.

Let us begin our comparative study with an example of the simplest animals that consist of only a single cell, such as the little protozoon *Amoeba*. We have become familiar with this organism as one that carries on all of the vital functions within the limits of a single structural unit; it is a mass of protoplasm enclosing a nucleus, and as a biological individual it must perform all of the eight tasks that are essential for life. It does not possess a digestive tract, but it does digest; it does not have breathing organs, but it does respire; and it is particularly noteworthy that it must coordinate the different activities of its parts, and maintain definite relations with the environment, even though its coordination and sensation are not accomplished by any special parts that would deserve the name of elementary nervous organs. Its many activities are simple responses to stimuli that reach it from without, and its reactions to such stimuli are called reflex processes. Should the light become too strong, it will slowly crawl to a shady place; should the water in which it lives become warmer, it responds by displaying greater activity. It exhibits, in a word, the property of *irritability*—that is, simply the power of receiving and reacting to stimuli; and being only a single cell this property is held in common by all of its parts.

We come next to a simple many-celled animal like the polyp *Hydra*, or a jellyfish. In such an animal the body is composed of numerous cells which are not all alike either in their make-up or in their functions. Some of them are concerned primarily with digestion, others with protection, while still others are exempt from these tasks and as sense-cells they devote all their energies to the reception of stimuli from without, or, beneath the outer sheet of cells of the two-layered body, they conduct impulses from one part of the animal to another, and thus serve as coordinating members of the community. For the first time, then, a nervous system as such is set apart and specialized to devote itself to the two tasks of sensation and coordination that are performed by nervous systems throughout the entire range of organisms higher in the scale. But the activities of *Hydra*, like those of *Amoeba*, are reflex and mechanical,—that is to say, *given similar stimuli and similar physiological states of the animal, the reactions will be the same*. A little water-crustacean like *Daphnia* may swim against the tentacles of *Hydra*; it is stung to death by the minute cell-batteries which the animal possesses, and then in a mechanical way the tentacles transport the food to the mouth, through which it is passed inward to the digestive cavity. There is nothing that can be called "mentality" throughout these processes, but the series of activities is much more complex than in *Amoeba* because the whole organism is constructed more elaborately, and because the special and peculiar mechanism directing the activities has advanced to a far higher condition.

Passing to the jointed animals like worms and insects, we find nervous mechanisms that are still more intricate, and with their advance in structural respects there is a corresponding and correlated progress in their functions. Because the whole organism has developed more highly differentiated groups of organs to perform the several biological tasks, such as eating and respiring and moving, it is necessary for the nervous structures concerned with the direction of these actions to become more efficient. An earthworm avoids the light of day and digs its burrow and seeks its food by wonderfully coördinated activities of its muscles and other parts, which are controlled by a double chain of ganglia along its ventral side, connected with a similar pair of grouped nerve-cells above the anterior part of the digestive tract. The ganglia of each segment exercise immediate supervision over the structures of their respective territory, while they pass on impulses to other ganglia so that movements involving many segments can be properly adjusted. Everything an earthworm does is controlled by the cells grouped in these ganglia, or scattered along the intervening connecting cords. We speak of its acts as instinctive, employing a term which seems to indicate a different kind of operation carried on by the nervous system, but a moment's thought will show that an instinctive act is simply a complex group of reflex acts. The physical basis and ultimate unit is a cell, and the functional unit is likewise a cell act; therefore the seeming difference proves to be one merely of degree and not of kind. The greater complexity of the worm's nervous system as compared with that of *Hydra* gives to the whole mechanism a plasticity that diverts the attention from the mechanical nature of the entire instinctive act and of its basic cell elements.

The instinct, like the elementary reflex, is determined by heredity. Because a certain configuration of the cells and fibers making up a nervous system is inherited as well as the characters of the constituent elements themselves, a worm or an insect is enabled to act as it does. A butterfly does not have to learn how to fly, for it flies instinctively. When it emerges from its chrysalis with its complete adult series of wings and muscles, it has also the nervous mechanism by which these parts are mechanically controlled. A ground-wasp deposits its eggs in a small burrow in which it places also a caterpillar or a grasshopper paralyzed by stinging, so that when the larva is hatched from an egg it finds an ample supply of fresh food provided by a complex series of its mother's acts that seem to be directed by conscious maternal solicitude. When the larva passes through the later stages of development and makes its way to the open air as a fully formed adult, it in its turn may go through the same course of action as its parent, but it is clear that it cannot have any remembrance of its mother's work or any personal knowledge of the value of burying its own eggs in a chamber with a living prisoner to serve as food. It was an egg when its parent did these things; as a parent itself it does not remain on watch to see how beneficial or fruitless its acts may be. A mechanism produced by nature's methods, the ground-wasp behaves as it is capable of working with its inherited structure and its inherited instinctive powers of coördination and sensation.

The complex lives of communal insects like ants and bees bring us to the level of mentality where an understanding of causes and effects seems to be the guide for conduct. Nevertheless the facts do not warrant the assumption that reason and intelligence play any part in the mental life of these creatures, as they do in the lives of man and the apes. Because we ourselves can see the utility of the definite and peculiar behavior of the queen and the worker, there is no logical necessity for assuming an identical form of knowledge as a possession of these insects. Many investigators have dealt with these fascinating subjects, and they are almost unanimous in the conclusion that the instinct of an insect is a mechanical and hereditary synthesis of combined reflex acts.

The lower orders of psychological processes play a far larger part in the lives of the higher animals than we are wont to believe. A pointer and sheep dog possess different qualifications in the way of instincts that make them useful to man in different ways. A bulldog or a game-cock does not reason out its course of action during a contest, but like a mechanism when the spring is released, it acts promptly and with effect. A ball flashing past the human eye causes the lids to close unconsciously, and it is not always possible to inhibit this instinctive mechanical act by the exercise of the will. An examination of the workings of the human body reveals manifold activities of an even lower or reflex nature, like the movements of the viscera and the adjustments in respect to the amount of supplies of blood sent to different parts of the body as local needs arise. Directed always by specific portions of the nervous system, such reflex actions play their part in human life without any effort on the part of reason and so-called will, and without coming into consciousness except indirectly and subsequently.

Passing by many interesting members of the psychological series of intergrading forms, we reach the familiar animals like the cat and dog and horse which display what is called intelligence. This is the power to learn by experience, and to improve the quality and promptitude of reactions to stimuli. In certain respects intelligence seems to differ from instinct, inasmuch as it involves a response to stimuli that may be altered and quickened by repeated experience, but in ultimate analysis the two forms of psychological processes are fundamentally alike. A single example chosen from Thorndike's extensive investigation will serve to bring out the primary characteristics of intelligence. A cat was placed in a latticed cage provided with a door that could be opened from within when a catch was pressed down, and meat was put in a dish outside the door where the cat could see it. At first, the animal escaped from the cage by freeing the door during its aimless scrambling about the catch, but as trial after trial was made, the time necessary for the cat to make its way out was shortened, until after seventy-five or one hundred trials, the animal immediately opened the door and seized the food. In mechanical terms, the connection between "scrambling about the door" and "freedom to get the meat" became established by numerous repetitions until the originally disconnected elements were physiologically associated and made inseparable. When animals like horses and seals and dogs are trained for the circus, it is by exactly the same method, for training consists merely in the establishment of a psychological sequence so that the performance of one series of acts leads mechanically to others. Thus we learn that the psychological property called intelligence is the ability to establish wide relations between numerous activities which are themselves of a more or less complex nature; and we find also that because these elements are ultimately nerve-cell and sense-cell reflexes, an intelligent response is quite as machine-like as any and all of its elements. A difference in degree of complexity and extent is the only thing that places intelligence apart from instinct and reflex action, for the units are the same in all cases,—so far as science knows.

The apes are of the greatest value in providing the transition from the grade of intelligence to the human level where reason is found. Whether or not a chimpanzee can reason at all is less important than the fact that its total "mental" powers are lower than those of man, and higher than those of inferior mammalia. Apes are far more susceptible to training than cats and dogs, because their improved nervous mechanism enables them to establish a psychological sequence with greater facility. If we are to judge by the facts at hand, these creatures possess a low order of mentality, like, but by no means equivalent to, that of man.

At the end of the comparative scale, we reach the human mind which is characterized by its ability to perceive and recognize far wider relations than those which are involved in intelligence. Human consciousness is the stream of thoughts and feelings which constitute the immediate contents of mind. In our own case, we know both the activities we perform and some of the internal phenomena with which such activities are connected. Then we are impelled to compare the objective phenomena of action with the behavior of other men and of lower organisms, and if their behavior does not coincide with our own we are justified in believing that its direction lacks some of the elements we know about in our own case. This is the method of comparative psychology, which establishes the conclusion that reason is the more complex term of a series to which reflex action, instinct, and intelligence directly lead.

Were we to study in detail the psychology of adult human beings, we would find only more truly that instinct and intelligence play a large part in our everyday mental life, and more certainly that even the highest reasoning powers we possess are only more complex in nature than the nervous processes of lower mammals and invertebrates. Just as the nervous systems advance in physical or structural respects, so must their activities become more and more complex until the result is human faculty.

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We must now briefly consider what may be called the "comparative anthropology" of mind which deals with the various degrees of mental ability displayed by different human races; this subject follows inevitably upon the comparison of the human mind viewed as a single type with the psychological processes of lower animals. When we reviewed the diverse characteristics of human races—the protrusion of the jaws, greater or lesser stature, and the like—it appeared that so-called "lower" races could be distinguished which differed from the "higher" races in the direction of the apes; the question immediately arises whether similar distinctions and relations are discoverable on the basis of mental traits. But in the present case there are not so many well-substantiated differentia at the disposal of the student, and it does not appear so clearly that the "higher" races are furthest from the lower primates and lower mammalia as regards their mental processes. What facts there are, however, prove to be highly significant, and they materially amplify our conception of human faculty as a product of evolution. The essential point is that the intellectual attainments of various races are by no means the same. The calculus is a mental product of the white race only; gunpowder and printing from movable type were independently invented by the Caucasian and Mongolian races; but the American Indian and the Negro never originated them. Human faculty, to employ the most general term for all that distinguishes man from the brutes, proves to be a very varied thing when we draw comparisons between and among races with independent lines of ancestry and heredity occupying widely separated areas. Should we analyze it, we find it to be composed of three constituents; namely, the physical elements of the brain, the degree to which the observational or perceptual and higher elements cooperate in building up the conceptions peculiar to the type, and the materials with which the physical mechanism deals, in the way of environmental, educational, and social "grist for the mental mill." Many anthropologists accord too great an importance to the third constituent of human faculty, I believe, and they are therefore led to deny that races differ in mental respects to so large a degree as the thoroughgoing evolutionist would contend. They hold that differences in such things as powers of observation are due to training: that, for example, an American Indian or a South Sea Islander sees certain things in his environment more quickly than a white man only because these are the things which the experiences of his earlier life have accustomed him to look for and to find. This may be granted, and it may also be admitted that children of so-called "lower" races can be educated side by side with the youth of white races without noticeably falling behind, up to a certain point when, at the age of adolescence, in the classic case of the Australian natives, other factors prove to be obstacles to further progress. We must also recognize that the character of the environment of a race determines to a large extent the mode of life of the people; a forest-dwelling Indian of the interior is a hunter as well as a warrior, while a South Sea Islander is a navigator and a fisherman.

But the fact remains that the inhabitants of similar countries have reached markedly different grades of intellectual and cultural life. Anglo-Saxon dominance must be referred ultimately to Anglo-Saxon heredity and not to the peculiarities of the land. Although adaptation is no less necessary for men as individuals and as social groups than it is for all other living things, I believe that it is to diversity in constitutional endowments, however these may have arisen, that we must attribute the superiority of some races over others. The question is not whether a savage race can or cannot adopt the higher conceptions of a civilized people; the fact is that they have not actually become civilized by themselves. Thus, while evolution in mental respects has not resulted in the loss of plasticity in the case of the brain and the nervous system as a whole, wherefore the activities of these organs still remain capable of individual and racial modifications that are impossible in the case of the skeleton and in the color and shape of the eye, it remains true that races do differ intellectually, and that their differences are marks of a mental evolution quite as definite as their physical natural histories of change.

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In my own view the strongest and most impressive evidence bearing upon the great problem before us is provided by the series of transformations by which the human intellect develops during an individual life. Mind has an embryology no less significant than that of the skull or of any other element of the body; and its investigation leads to the evolutionary interpretation quite as surely as the study of the various grades of adult psychology constituting the anatomical sequence, which we have reviewed previously. When in the earlier part of the book we dealt with embryology in general, we learned how the changes which take place when an organism develops from an egg demonstrate the actuality of true organic transformation without the necessity of concluding or inferring that this process might occur. It is not superfluous to insist again that the essential fact in evolution is the alteration of one organic characteristic into another type; must we not recognize at the very outset that mental transformation is as real as physical development?

In the first instance we might concern ourselves with the physical basis of mind and its history. In the earliest stages of human embryology no nervous system whatsoever is present, and it is unreasonable to suppose that there is anything going on which corresponds to human thought. A little later a cellular tube is established as a primitive nerve axis, which at first is nearly uniform throughout its entire length and displays no differentiation into brain and spinal cord. Before long an enlargement of the anterior end expands and develops into a primitive three-parted brain. It is not yet a real brain, however, and it is entirely incapable of functioning in such a way as to justify the use of the word *mental* for the results of its operations. We know that it is only in the cerebral hemisphere of the adult brain that the processes of true human consciousness go on. But it is not until long after the three-parted stage that the cerebral hemispheres make their appearance therefore we cannot speak of mind as present when the cell and tissue basis of mind is not present. When, now, the cerebral hemispheres do appear, they are small bean-shaped structures no larger relatively than those of a fish. Later they enlarge so as to attain the relative size of the cerebral hemispheres of an amphibian, and still later they are like those of a reptilian brain. Continuing to enlarge, they begin to fold so that the total surface is increased without very much addition to their bulk. At this time the cerebral hemispheres of the brain of the human embryo are like those of an adult cat or dog. The process of general enlargement and of progressive convolution are continued, and stages are reached and passed which correspond with the monkey and ape conditions.

Nothing in human development is more impressive than the origin of the cerebrum and its development by passing through successive stages which are counterparts in the main of the adult brains of other and lower animals. The alteration of a tissue-mechanism constructed in one way into a tissue-mechanism of a more complex nature, provides the most conclusive evidence of the reality of brain evolution, because the process of transformation actually takes place.

But in the present connection we are more interested in the dynamic or functional aspects of mental evolution, which it must be remembered are inseparably bound up with the physical structures and their modifications. After a human infant is born its activities are reflex and mechanical like those of the adult members of lower groups. As it grows it performs instinctive acts because its inherited nervous system operates in the purely mechanical manner of a lower mammal's nervous system. For these reasons an eminent psychologist has said that the mental ability of an infant six months old is about that of a well-bred fox terrier. The same infant at nine months displays an intelligence of a higher order equal to that of a well-trained chimpanzee; it has become what it was not, and in so far it has truly evolved in mental respects. At two years of age the child is incapable of solving problems of the calculus, for its reasoning powers are elementary and restricted, but these same powers change and intensify so as to render the older mind quite capable of grasping the highest of human conceptions and ideas. In my judgment the unbroken transformation of a child's mind that exhibits only instinct and intelligence into an adult's mind with its power of reasoning, is far more conclusive as proof of mental evolution than the inference drawn from the comparisons we have made above of the adult psychological phenomena of man, ape, cat, and fish. It is surely natural for such mental transformations to take place, for they do take place in the vast majority of human beings; when they do not, in cases where the brain fails to mature, we speak of unnatural or diseased minds.

The third division of our evidence relating to mental evolution constitutes what we have called the palæontology of mind. By this term we mean the study of human minds of the past as we may know them through the many varied relics and documents which indicate their characters. It is only too obvious to every one that human knowledge has advanced in the course of time and that every department of human thought and mental activity has participated in this progress. No one would have the temerity to assert that we know nothing more than our ancestors of 5000 or even 1000 years ago. Our common-sense teaches us even before the man of science produces the full body of evidence at his disposal that human faculties have evolved. With regard to reasoning powers, which form one of the four distinguishing characteristics of the human species as contrasted with other animals, the case has already been reviewed, and we now turn to speech and language and other departments of human mentality. When we compare the attainments of present day men with the abilities and ideas of their ancestors we will do for mental phenomena precisely what was done when we compared the skeletons of modern animals with those of creatures belonging to bygone geological ages; in this reason is found the justification for the phrase employed in the present connection.

Written history furnishes a wealth of material for interpreting the mental conditions of ancient peoples, but beside documentary evidence the anthropologist learns to use inscriptions of prehistoric times, the primitive graphic representations on tombs and monuments, and even the characteristics of crude implements like axes and arrow-heads. The layman finds it difficult at first to regard such relics as indications of the mental stature of the people who made and possessed them; but a little thought will show that a man who used a rough stone ax in the time of the ancient Celts could not possibly have had a mind which included the conception of a finished iron tool or modern mechanism. So in all departments of human culture, the evolution of material objects may be justly employed in interpreting and estimating the mental abilities of ancient peoples.

Language is undoubtedly the most important single intellectual possession of mankind, for it constitutes, as it were, the very framework of social organization. Without a ready means of communication the myriad human units who perform the varied tasks necessary for the economic well-being of a body-politic would be unable to coordinate their manifold activities with success, and the structure of civilized societies at least would collapse. It needs no legend of a Tower of Babel to make this plain. So fundamental is this truth that although we may not have recognized it explicitly, we unconsciously form the belief that speech and language are exclusive properties of the human species, and even more characteristic of man alone than the power of reason itself. While organized language is clearly something that as such we do not share with the lower animals, nevertheless we cannot regard the communication of ideas or states of feeling by sound as an exclusive property of mankind. All are familiar with the difference between the whine and the bark of a dog and with the widely different feelings that are expressed by these contrasted sounds. And we know too that dogs can understand what many of their master's words signify, as when a shepherd gives directions to his collie. We could even go further down in the scale and find in the shrill chirping of the katydid at the mating season a still more elementary combination of significant instinctive sound elements. To the comparative student the speech of man differs from these lower modes of communication only in its greater complexity, and in its employment of more numerous and varied sounds,—in a word, only in the higher degree of its evolution. And it is even more evident that the diverse forms of speech employed by various races have gradually grown to be what they now are.

At the outset it is well to distinguish between writing, as the conventional mode of symbolizing words, and spoken language itself; the two have been more independent in their evolution than we may be wont to believe. Speech came first in historical development, just as a child now learns to talk before it can understand and use printed or written letters. Furthermore, many races still exist who have a well-developed form of language without any concrete way of recording it. It is true, of course, that back of the conventions of speech and writing are the ideas themselves that find expression in the one way or the other, or even by the still more primitive use of signs and gestures. But it is not with these ultimate elements of thought that we are now concerned; our task is to learn, first, what evidences are discoverable which show that the property of human language in general has originated by evolution, and then, in the second place, to perceive how this development proves an evolution of one group of ultimate ideas, namely, human concepts of the modal value of words and symbols as expressions of ideas themselves.

A simple common-sense treatment of obvious facts will greatly facilitate our progress. We know very well that the English we speak to-day differs in many ways from the language of Elizabethan times, and that the former is a direct descendant of the other. The latter, in turn, was a product of Norman French and Anglo-Saxon,—a combination of certain elements of both, but identical with neither of its immediate parents. The Saxon tongue itself has a history that leads back to King Alfred's time and earlier. Thus we are already aware of the fact that our speech has truly evolved, like the physical structure of the men who employ it; and we know, too, how readily new words are adopted into current English, like *tabu* from Polynesia, or *garage* from the French, showing that language is even now in process of evolution.

The sounds that make up spoken words can be resolved into a single element with its modifications; this basic element is the brute-like call or shout made with the mouth and throat opened wide—a sound we may have heard uttered by men under the stress of pain or terror. All of the various vowels are simply modifications of this element by altering the shape of the mouth cavity and orifice, while the consonants are produced by interrupting the sound-waves with the palate or lips or tongue. Like the cell as a unit of structure throughout the organic world, this elemental utterance proves to be the basic unit of all human languages, which vary so widely among races of to-day no less than they have in the history of any single people.

One of the first steps in the making of spoken words was taken by human beings when they imitated the calls or other sounds produced by living things, and tacitly agreed to recognize the imitation as a symbol of the creature making it. Thus the names for the cuckoo and the crow in many languages besides our own are simply copies of the calls uttered by these birds; a Tahitian calls a cat *mimi*; the name for a snake almost invariably includes the hissing attributed to that creature. After a time words which were at first simply imitations and which referred only to the things that made these sounds came to refer to certain qualities of the things imitated, so that the naming of other than natural objects, such as qualities, began, leading ultimately to the use of words for qualities belonging to many and different objects in the way of abstractions.

Much light upon the evolution of language is obtained when we treat the speech of various races as we did the skeletal structures of cats and seals and whales. When we compare the Italian, Spanish, Portuguese, and French languages, they reveal the same general structure in thousands of their words,—a common basis which in these cases is due to their derivation from the same ancestor, the Latin tongue. The Latin word for star is *stella*, and the Italian word of to-day is an identical and unchanged descendant, like a persistent type of shark which lives now in practically the same form as did its ancestor in the coal ages. The Spanish word is *estrella*, a modified derivative, but still one that bears in its structure the marks of its Latin origin; the French word *étoile* is a still more altered product of word evolution. Even in the German *stern*, Norse *stjern*, Danish *starn*, and English *star* we may recognize mutual affinities and common ancestral structure. Choosing illustrations from a different group, the Hebrew salutation "Peace be with you," *Shalom lachem*, proves to be a blood cousin of the Arabic *Salaam alaikum*, indicating the common ancestry of these diverse languages. Among Polynesian peoples the Tahitian calls a house a *fare*, the Maori of New Zealand uses *whare*, while the Hawaiian employs the word *hale*, and the Samoan, *fale*. Whenever we classify and compare human languages, we find similar consistent anatomical evidences of their relationships and evolution. We can even discern counterparts of the vestigial structures like the rudimentary limbs of whales. In the English word *night* certain letters do not function vocally, though in the German counterpart *Nacht* their correspondents still play a part. In the word *dough* as correctly pronounced the final letters are similarly vestigial, although in the phonetic relative *tough* they are still sounded.

The evolution of the art of writing appears with equal clearness when we compare the texts of modern peoples with inscriptions found on ancient temples and monuments and tablets. Even races of the present day employ methods of communicating ideas by writing symbols that are counterparts of the earliest stages in the historic development of writing. An Eskimo describes the events of a journey by a series of little pictures representing himself in the act of doing various things. A simple outline of a man with one arm pointing to the body and the other pointing away indicates "I go." A circle denotes the island to which he goes. He sleeps there one night, and he tells this by drawing a figure with one hand over the eyes, indicating sleep, while the other hand has one finger upraised to specify a single night. The next day he goes further and he employs the first figure again. A second island is indicated, in this case with a dot in the center of the circle to show a house in which he sleeps two nights, as his figure with closed eyes and two fingers uplifted shows. He hunts the walrus, an outline of which is given alongside of his figure waving a spear in one hand; likewise he hunts with a bow and arrow, which is demonstrated by the same method. A rude drawing representing a boat with two upright lines for himself and another man with paddles in their hands gives a further account of his journey, and the final figure is the circle denoting the original island to which he returns.

Pictography, as this method of communicating ideas is called, is often highly developed among the American Indians. For example, a petition from a tribe of Chippewa Indians to the President of the United States asking for the possession of certain lakes near their reservation is a series of pictures of the sacred animals or "totems" which represent the several subtribes. Lines run from the hearts of the totem animals to the heart of the chief totem, while similar lines run from the eyes of the subsidiary totems to the eyes of the chief, and these indicate that all of the subtribes feel the same way about the matter and view it alike,—the sentiment is unanimous. From the chief totem run out two lines, one going to the picture of the desired object, while the other goes to the President, conveying the petition. Thus pictography, a method of writing that belongs to the childhood of races, may be made to communicate ideas of a strikingly complex nature.

The ancient and modern inscriptions of Asia, from the Red Sea to China, present many significant stages in the development of picture-writing. In earliest ages the men of Asia made actual drawings of particular objects, such as the sun, trees, and human figures; subsequently these became conventionalized to a certain degree, but even as late as 3000 B.C. the Akkadian script was still largely pictographic. From it originated the knife-point writing of Babylonian and Chaldean clay tablets, while among the peoples of Eastern Asia, who continued to draw their symbols, the transition to conventionalized pictures such as those made by the Chinaman was slower and less drastic.

In another line of evolution, the hieroglyphics of Egyptian tombs and monuments illustrate a most interesting intermediate condition of development. These inscriptions have been deciphered only since the discovery of the famous Rosetta stone-fragment, which bears portions of three identical texts written in hieroglyphics, in Greek, and in another series of symbols. The Egyptian used more or less formalized characters to represent certain sounds, while in addition to the group of such characters combined to make a word, the scribe drew a supplementary picture of the thing or act signified. For instance, *xeftu* means enemies, but the Egyptian graver added a picture of a kneeling bowman to avoid any possible misapprehension as to his meaning. The symbols denoting "to walk" are followed by a pair of legs; the setting sun is described not only by a word but also by its outline as it lies on the horizon. Here again one is struck by the similarity between a stage in the historic development of racial characteristics and a method employed at the present time to teach the immature minds of children that certain letters represent a particular object; in a kindergarten primer the sentence "see the rat and the cat" is accompanied by pictures of the animals specified, in true hieroglyphic simplicity.

Just as the child's mind develops so that the aid of the picture can be dispensed with, and the symbolic characters can be used in increasingly complex ways, in like manner the minds of men living in successive centuries have evolved. While an evolution of human conceptual processes in general is not necessarily implied by the evolution of the forms of written language, the former process is in part demonstrated by the latter in so far as the change from the writing of pictures to the use of conventional symbols involves an advance in human ideas of the interpretation and value of the symbols in question. A man of ancient times drew a tree to represent his conception of this object; in the writing of English we now use four letters to stand for the same object, and none of these symbols is in any way a replica of the tree. It is certainly obvious that some change in the mental association of symbol and object has been brought about, and to this extent there has been mental evolution.

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Passing now to other departments of human culture, we must deal in the next place with the basic "arts of life"; that is, the modes of conducting the necessary activities of every day. All men of all times, be they civilized or savage, are impelled like the brutes by their biological nature to seek food and to repel their foes. The rough stone club and ax were fashioned by the first savage men, when diminishing physical prowess placed them at a disadvantage in the competition with stronger animals. Smoother and more efficient weapons were made by the hordes of their more advanced descendants, some of whom remained in the mental and cultural condition of the stone age like the Fuegian, until the white travelers of recent centuries brought them newer ideas and implements. In Europe and elsewhere the period of stone gave place to the bronze and iron ages, and throughout the changing years human inventiveness improved the missile and weapon to become the bow and arrow of medieval civilization and recent African savagery. The artillery and shells of modern warfare are their still more highly evolved descendants.

So it is with the dwellings of men, and the significance of the changes displayed by such things. The cave was a natural shelter for primitive man as well as for the wolf, and it is still used by men to-day. Where it did not exist, a leafy screen of branches served in its stead; even now there are human beings, like the African pygmy and the Indian of Brazil, who are little beyond the orang-outang as regards the character of the shelter they construct out of vegetation. From such crude beginnings, on a par with the lairs and nests of lower animals, have evolved the grass huts of the Zulu, the bamboo dwelling of the Malay, the igloo of the Arctic tribes, and the mud house of the desert Indians. The modern palace and apartment are merely more complex and more elaborate in material and architectural plan, when compared with their primitive antecedents.

Baskets, clay vessels, and other household articles testify in the same way to an evolution of the mental views of the people making them. The means of transportation are even more demonstrative. The wagon of the early Briton was like a rough ox-cart of the present day, evolved from the simple sledge as a beginning. In its turn it has served as a prototype for all the conveyances on wheels such as the stage-coach and the modern Pullman. The history of locomotives, employed in the first chapter to develop a clear conception of what evolution means, takes its place here as a demonstration of the way human ideas about traction have themselves evolved so as to render the construction of such mechanisms possible.

The primitive savage swimming in the sea found that a floating log supported his weight as he rested from his efforts. By the strokes of his arms or of a club in his hand, he could propel this log in a desired direction; thus the dugout canoe arose, to be steadied by the outrigger as the savage enlarged his experience. A cloth held aloft aided his progress down or across the wind, and it became an integral element of the sailing craft, which evolved through the stages of the galley and caravel to the schooner and frigate of modern times. When the steam-engine was invented and incorporated in the boat, a new line of evolution was initiated, leading from the "Clermont" to the "Lusitania" and the battleship.

The history of clothing begins with the employment of an animal's hide or a branch of leaves to protect the body from the sun's heat or the cold winds. Other early beginnings of the more elaborate decorative clothing are discerned by anthropologists in the scars made upon the arms and breast as in the case of the Australian black man, and in the figured patterns of tattooing, so remarkably developed by the natives in the islands of the South Pacific Ocean. A visit to a gallery of ancient and medieval paintings clearly shows that the conventional modes of clothing the human body have changed from century to century, while it is equally plain that they alter even from year to year of the present time, according to the vagaries of fashion.

A brief review of the "arts of pleasure," including music and sculpture and painting, demonstrates their evolution also. The earliest cavemen of Europe left crude drawings of reindeer and bears and wild oxen scratched upon bits of ivory or upon the stone walls of their shelters; the painting and sculpture of early historic Europe were more advanced, but they were far from being what Greece and Rome produced in later centuries. Indeed, the evolution of Greek sculpture carried this higher art to a point that is generally conceded to be far beyond that attained by even our modern sculptors, just as flying reptiles of the Chalk Age developed wings and learned to fly long before birds and bats came into existence.

In the field of music, the earliest stages can be surmised only by a study of the actual songs and instruments of primitive peoples now living in wild places. No doubt the song began as a recitation by a savage of the events of a battle or a journey in which he had participated. In giving such a description he lives his battles again, and his simulated moods and passions alter his voice so that the spoken history becomes a chant. From this to the choral and oratorio is not very far.

Musical instruments seem to have had a multiple origin. The ram's horn of the early Briton and the perforated conch-shell of the South Sea Islander are natural trumpets; when they were copied in brass and other metals they evolved rapidly to become the varied wind instruments typified to-day by the cornet and the tuba. In the same way the reed of the Greek shepherd is the ancestor of the flute and clarionet. Stringed instruments like the guitar, zither, and violin form another class which begins with the bow and its twanging string. The power of the note was intensified by holding a gourd against the bow to serve as a resonance-chamber. When the musician of early times enlarged this chamber, moved it to the end of the bow, and multiplied the strings, he constructed the cithara of antiquity,—the ancestor of a host of modern types, from the harp to the bass-viol and mandolin.

The dance and the drama find their beginnings in the simple reënactment of an actual series of events. Among Polynesians of to-day the dances still retain the rhythmic beat of the war-tread measure, and many of the motions of the arms are more or less conventionalized imitations of the act of striking with a club, or hurling a spear, and other acts. To such elements many other things have been added, but the fact remains that our own formal dances, as well as the sun-dance of the Indian and the mad whirl of the Dervish, are modern products which have truly evolved.

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When we turn to science and philosophy and other intellectual attainments of modern civilized peoples, it is easier to see how evolution has been accomplished, because we possess a wealth of written literature which explains the way that human ideas have changed from century to century. In these cases there can be no question that such evidences provide accurate instruments for estimating the mental abilities of the writers who produced them. We shall take up the higher conceptions of mankind at a later juncture, so at this point we need only to note that even these mental possessions, like household culture and even the physical structures of a human body, have changed and differentiated to become the widely different interpretations of the world and supernature that are held by the civilized, barbarous, and savage races of to-day.

As we look back over the facts that have been cited, and as we contemplate the large departments of knowledge about human psychology, mental development, and racial culture which these few details illustrate, we come to realize how securely founded is the doctrine that even the human mind with all its varied powers has grown to be what it is. Indeed, it is solely due to his mental prowess that man has attained a position above that of any lower animal. And yet every human organ and its function can be traced to something in the lower world; it is a difference only in degree and not in category that science discovers. The line connecting civilized man with the savage leads inevitably through the ape to the lower mammalia possessing intelligence, and on down to the reflex organic mechanisms which end with the *Amoeba*. It is a long distance from the mechanical activities of the protozoön to the processes of human thought; yet the physical basis of the latter is a cellular mechanism and nothing more, developed during a single human life in company with all other organs from a one-celled starting-point—the human egg.

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The method by which mental evolution has been accomplished is likewise demonstrable, because the factors are identical with those which bring about specific transformation in physical respects. This is to be expected, for the contention that the structures and the functions of the several organs constituting any system are inseparable has never been gainsaid.

Mental variation is real. It needs no scientist to tell us that human beings differ in intellectual qualifications and attainments, and that no two people are exactly similar even though they may be brothers or sisters. The struggle for existence or competition on the basis of mental ability is equally real, and every day we see the prize awarded to the more fit, while those who lose are crowded ever closer to the wall. As in all other fields of endeavor, the goal of success can be attained only by adaptation, which involves an adjustment to all of the conditions of existence—to social and ethical as well as to the more expressly material biological circumstances.

Heredity of mental qualities has also been demonstrated notably by Galton, Pearson, Woods, and Thorndike, who have also shown that the strength of inheritance in the case of mental traits is approximately the same as for physical characteristics like stature and eye-color. Just as a worker-bee inherits a specific form of nervous system which coöperates with the other equally determined organic systems, wherefore the animal is forced to perform "instinctively" its peculiar specialized tasks, so the mental capacity of a human being is largely determined by congenital factors. Upon these primarily depends his success or failure. It is quite true that environment has a high degree of influence, so great indeed that some speak of a "social heredity"; they mean by this phrase that the mental equipment of an individual is determined by the things he finds about him, or learns from others without having to invent or originate them himself. Thus a Zulu boy acquires the habits of a warrior and a huntsman when he grows up in his native village, although he would undoubtedly develop quite different aptitudes if he should be taken as an infant to a city of white men. Nevertheless his mental machinery itself would be no less surely determined by heredity, even though the things with which it dealt would be provided by an alien environment.

Our present knowledge of the nature and history of human mentality enables us to learn many lessons that have a direct practical value, although it is impossible under the present limitations to give them the full discussion they deserve. Starting from the dictum that physical inheritance provides the mechanism of intellect, education and training of any kind prove to be effective as agents for developing hereditary qualities or for suppressing undesirable tendencies. Just as wind-strewn grains of wheat may fall upon rock and stony soil and loam, to grow well or poorly or not at all according to their environmental situations, so children with similar intellectual possibilities would have their growth fostered or hampered or prevented by the educational systems to which they were subjected. But the common-sense of science demonstrates that the mental qualities themselves could not be altered *in nature* by the circumstances controlling their development any more than the hereditary capability of the wheat grains to produce wheat would be altered by the character of the ground upon which they fell. Education and training thus find their sphere of usefulness is developing what it is worth while to bring out, and inhibiting the growth of what is harmful. That heredity in mental as well as in physical aspects provides the varying materials with which education must deal is a fundamental biological fact which is too often disregarded. It would be as futile for an instructor to attempt the task of forcing the children in a single schoolroom into the same mental mold, as it would be for a gymnasium master to expect that by a similar course of exercise he could make all of his students conform to the same identical stature, the same shape of the skull, or the same color of the eye and hair.

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Before leaving the subject of mental evolution we must return to the conception of inseparable mind and matter with which the present discussion began. The whole problem of human mental evolution is solved when we accept the conclusion that the nervous mechanism and the total series of its functional operations have evolved together in the production of the human brain and human faculty. The case regarding the physical organs rests solidly on the basis of the evidences outlined in a previous chapter; the special examination of purely mental phenomena has likewise been made in the foregoing sections. Just here we must pause to give further attention to the invariable relation between the human mind and the human brain.

The personality of human consciousness consists of the current of thoughts and feelings flowing continuously as one of them rises for a time to dominance only to fade when it leads to and is replaced by another dominant element of thought. This current is affected by the messages brought to the brain by nerves from the outer parts of the body where lie the eye and ear and other sense-organs. In like manner the various non-nervous parts of the body exert their influences upon consciousness, but the affective processes, as they are called, are not as well understood as the impressions passed inwards by the sense-organs along their nervous roadways to the central organ, the brain. But the brain is the place where the thinking individual resides; and this is one of the most important teachings of psychology, for not only does it help us to understand the evidence that human faculty has evolved, but it also inevitably brings us to consider certain vital questions of metaphysics, such as the immortality of the thinking individual after the material person with its brain ceases to exist. However, the latter question is something which does not concern us here; now it is most important to realize how completely mind is connected with the brain.

Many of the facts demonstrating this connection are matters of common knowledge. In deep and dreamless sleep the essential tissues of the brain are inactive, and in correspondence with the cessation of material events the thinking individual actually ceases to exist for a time. Any one who has ever fainted is subsequently aware of the break in the current of human consciousness when the blood does not fully supply the brain and this organ ceases to function properly; a severe blow upon the head likewise interrupts the normal physical processes, and at the same time the mind is correspondingly affected. Again, a progressive alteration of the brain as the result of diseased growth causes the mind to grow dim and incapable. Sometimes infants are born which are so deficient mentally as to be idiots, and an examination of the brain in such a case reveals certain correlated defects in physical organization. These and similar facts form the basis for the dictum that the development and evolution of the brain mean the growth and evolution of human intellect.

The further question as to the nature of the connection is interesting, but it relates to matters of far less consequence to the naturalist than the central fact of the invariable relation which does exist. Throughout the centuries many philosophers and naturalists of numerous peoples have endeavored to explain the connection in question in ways that have been largely determined by the changing states of knowledge of various periods, as well as by differences in individual temperament. Three general conceptions have been developed: first, that the material and mental phenomena *interact*; second, that they are *parallel*; and third, that they are *one*.

According to the first view, the individual thoughts and feelings forming elements in the chain of consecutive consciousness are affected by the events in the material physiology of the brain as a physical structure; the latter in turn react upon the psychical or mental elements. Thus there would be two complete series of phenomena, which are interdependent and interacting at all times, although each would be in itself a complete chain of elements.

The second interpretation is that the two series of events—namely, the physical processes of the brain and the elements of consciousness—are completely *independent* but entirely parallel. As one writer has put the case, it is as though we had two clocks whose machinery worked at the same rate and whose relationships were such that "one clock would give the proper number of strokes when the hands of the other pointed to the hour." But in my opinion this attempted explanation of the relation of mind to matter evades the whole question, as it does not account for the dependence of the former upon the latter, but merely assumes the existence of a more ultimate and unknown group of causes for a parallelism in the rates of operation of two series of things regarded as disconnected.

The third conception recommends itself to many on account of its greater simplicity. Formulated as the doctrine of monism, it states that the mind and its material basis are merely different *aspects* of one and the same thing, and that there is only one series of connected elements which are known to us directly as the current of our thoughts and indirectly as the physiological processes going on mainly in the cerebrum. Thus mind is purely subjective, the brain is only mediately objective. It is because the mental and the material are so intimately related that the monist believes them to be connected as are the lungs and respiration, the hand and grasping, or the eye and the reception of visual impressions from without.

But whichever one of these explanations we choose to adopt as our own, the basic fact of primary importance is that there is an invariable dependence of human thought upon a brain comprising a highly developed cerebrum, whatever may be the ultimate nature of the way mental processes are determined by physical processes, or *vice versa*. This fact stands unquestioned and unassailable; human faculty and the brain cannot be considered apart, even if they may not actually be different aspects of the same basic "mind-stuff," as Clifford calls the ultimate dual thing.

Like all of the other organs of lesser importance belonging to the nervous system, the brain is a complex of tissues which in the last analysis are groups of cell-bodies with their fibrous prolongations. When these cellular elements are in operation, mental processes go on; the unit of the mental process therefore is the functioning of a brain-cell. But we know that the substance of a brain-cell is the wonderful physical basis of life called protoplasm, that demanded our attention at the outset. The chemicals that go to make up protoplasm are everywhere carbon, hydrogen, oxygen, and other substances that are exactly the same outside the body as inside. It is the combination of these substances in a peculiar way which makes protoplasm, and it is the combination of their individual properties which in a real even though unknown manner gives the powers to protoplasm, even to that of a living brain-cell. Does science teach us, then, that the ultimate elements of human faculty are carbon-*ness* and hydrogen-*ness*, and oxygen-*ness*, which in themselves are not mind, but which when they are combined, and when such chemical atoms exist in protoplasm, constitute mental powers? Plain common-sense answers in the affirmative. We need not, indeed, we must not, attribute mind as such to rock salt or to the water of a stream, but we do know that salts and water and other dead substances may enter into the composition of the material brain which is the physical basis of mind.

In my opinion the individual argument renders the monistic conception of mind and matter unassailable. The food that we may eat and the water we may drink are dead, and as such they display absolutely no evidence of nervous or mental processes. When they enter our bodies, they with other foods replenish the various tissues, and among these the parts of the brain. In a material sense they become actual living protoplasm, replacing the worn-out substances destroyed during our previous thinking; and their properties are combined to make brain and thought, to play for a time their part in life, and to pass back into the world of dead, unthinking things. Every one of us knows that hunger reduces our ability to think clearly and fully, and every one knows also that mental vigor is renewed when fresh supplies of nourishment reach the brain. What can be the source of mentality, if it is not something brought in from the outer world along with the chemical substances which taken singly are devoid of mind? Scientific monism frankly replies that it is unable to find another origin.

We are thus brought to recognize, not only the continuity taught by organic evolution, but also the uniformity of the materials constituting the entire sensible world, inasmuch as the ultimate unit of all nervous phenomena is the reflex act of a protoplasmic mass, which itself is a synthesis of properties inhering in the chemical elements making up living matter. Among inorganic things the mind-stuff units are combined in relatively simple ways, and the "stuff" does not give any outward evidences of "mind" as such. Living things are almost infinitely complex as regards their chemical organization, and even in the very lowest of them we can discern a cell-reflex element which, combined with others like it, forms the unit of the compounds we call instinct, intelligence, and reason. Hence through an analysis of mental evolution we are enabled to form the larger conception of a continuous universe whose ultimate elements are the same everywhere.

# VII

#### SOCIAL EVOLUTION AS A BIOLOGICAL PROCESS

We now reach a critical juncture in our study of the foundations of evolutionary doctrine, for we must pass at this point to an inquiry into the nature and origin of human social relations. In undertaking this task we may seem to leave the field which is properly that of organic evolution, and many perhaps will be unwilling to view such aspects of human life as materials for purely biological analysis, arrangement, and explanation. But even before the reasons for doing so may be made apparent, every one must admit that the subject of mental evolution, which comprises so large a bulk of details expressly social in their character and value, virtually compels us to scrutinize the history of the economic and other interrelationships maintained by the human constituents of civilized, barbarous, and savage communities. Language has been treated as an individual mental product, and so have the arts of life and of pleasure; but all of these things find their greatest utility in their social usage,—in their value as bonds which hold together the few or many human beings composing groups of lower or higher grade. Without discovering any other reasons we would be impelled to take up social evolution, for this process is inextricably bound up with the origin and development of all departments of human thought and action.

If now this new field is actually to be included within the scope of the laws controlling the rest of nature's evolution, two general conclusions must be established. Although no formal order need be followed, it must at some time be shown that human social relations are biological relations, to be best explained only through their comparison with the far simpler modes of association found by the biologist among lower orders of beings; and in the second place it must be demonstrated that identical biological laws, uniform in their operation everywhere in the organic world, have controlled the origin and establishment of even the most complex societies of men. So far no reason has been discovered by science for believing that evolution has been discontinuous, holding true only for the merely physical characteristics of humanity as a whole; and furthermore, the impersonal student of nature finds ample positive evidences showing that the basic laws of associations of whatever grade are exactly the same. For these laws we are to seek.

Heretofore the doctrine of organic evolution has been discussed with reference to the single individual organism viewed as a natural object whose history and vital relations require elucidation. Both in the general arguments of the first few chapters and in the fifth and sixth chapters dealing with the single case of the human species, the proof has been given that all of the structural and physiological characters of any and every organic type fall within the scope of the principles of evolution, by which alone they can be reasonably interpreted. It has been unjust in a sense to ignore completely the importance of the organic relations of a social nature to which we are now to turn, because no individual can exist without having its life directly influenced, not only by other kinds of organisms, but even more intimately by other members of its own species. In a single day's activity we who are citizens of a great metropolis are forced into contact with almost countless other lives, glancing off from one and another after influencing them to some degree, and gaining ourselves some impetus and stimulus from our longer or shorter intercourse with each of them. Our varied social relations are so many and obvious that it is quite superfluous to specify them as essential things in human life. For the very reason that they are so obvious and constitute so large a part of our daily life, we are in danger of conceiving them to be exclusively human; we unconsciously regard them as different from anything to be found elsewhere and quite independent of the biological laws controlling the human unit.

On the contrary, as we trace the development of social organization from its earliest rudiments it becomes ever clearer that evolution has been continuous, and that during later ages there has been no suspension of the natural laws which earlier produced the human type of organism. The lessons we have learned are by no means to be ignored from this point forward; all of our conceptions of human biological history must be kept in mind, for anything new that we may learn is superadded to the rest,—it cannot disturb or alter the foundations already laid. It is even more important to realize that the same scientific method is to be employed which has been so fruitful heretofore. It has given us interesting facts; it has indicated the most profitable lines of attack upon one and another scientific problem; and it has demonstrated the practical value of accurate knowledge, even of information about the evolutionary process. As familiarity with the laws of human physiology enables one to lead a more hygienic and efficient life, and as the results of analyzing the evolution of mentality make it possible to advance intellectually with greater sureness, conserving our mental energies for effort along lines established by hereditary endowment, so now we are justified in expecting that a clear insight into the origin of our social situation and social obligations will have a higher usefulness beyond the value of the mere interest inhering in our new knowledge. Every one is necessarily concerned with social questions; never before has there been so much world-wide discussion of topics in this field. And while it is true that much good may be accomplished in utter ignorance of the past history of human institutions and of the underlying principles which control the varied types of organic associations, surely enlightened efforts will be more effective for good. Therefore every member of a community who is capable of thinking straight rests under an obligation imposed by nature to learn how he is related to his fellow-men; he must act in concert with them or else he forfeits his rights as a social unit. And it is his clear duty to search among the results of science for aid in ascertaining what he ought to do, and what reasons are given by evolution for the nature of his vital duties.

Despite the growing appreciation of the fundamental relation between biology and sociology, it is still far from universal. That the latter science is in a sense a division of the former is more often recognized by the biologist than by the average well-informed student of human social phenomena. The layman in sociology too often concerns himself solely with the complexities of the human problems, and he remains unaware of the manifold products in the way of communal organisms far lower in the scale of life firmly established as primitive biological associations ages before the first human beings so advanced in mental stature that tribal unions were found good. Among insects especially the biologist finds many types of organized living things, ranging widely from the solitary individual—a counterpart of something even more primitive than the most unsocial savage now existing—up to communities that rival human civilization, as regards the concerted effect of the diversified lives of the component units. The student of the whole of living nature is favored still more in that he learns how the make-up of such a simple organism as a jellyfish displays principles underlying the structure of the whole and the interplay of the parts that are identical with principles of organization everywhere else. And all of these things can be dealt with in a purely impersonal way which is impossible when attention is restricted to the human case alone. Thus it becomes the biologist's privilege and his duty as well to place his findings before those who wish to understand the constitution of human society in order that evils may be lessened and benefits may be extended. He does this so far as he may be able in full confidence that the elements and basic principles are discoverable in lower nature, just as they are in the case of the material make-up and mental constitution of the single human individual.

A more explicit preliminary statement must now be given of the grounds for the belief that social evolution is but a part of organic evolution in general. Some of these reasons are not far to seek, but their cogency can scarcely be appreciated until we have examined the concrete facts of the whole biological series. Any human society selected for examination—be it a tribe, a village community, or a nation—is in last analysis an aggregate of human units and nothing besides. Its life consists of the combined activities of such components—and nothing else. Could we subtract the members one by one, there would be no intangible residuum after all the people and their lives had been taken away. When these simple facts are recognized, it is clear at once that the concerted activities performed by biological units cannot be anything but organic in their ultimate basis and nature; the evolution of such activities thus takes its place as a part of organic evolution.

The task of tracing out the history of social organizations of whatever grade can now be defined in precise terms: in simple words, it is to learn how the activities of the component biological units making up any association really differ from the vital performances of biological units existing by themselves. What is it that distinguishes a savage of antiquity from an American of to-day? The modern example is just as much an animal as the earlier type, and his physiology is essentially the same. It is something added to the common biological qualities of all men, some relation which does not appear as such in the life of rude tribes, that makes the distinction. And it is just this superadded relation that requires explanation, as regards its exact biological value and its historic development as well.

In undertaking this difficult task, it seems best to begin with the very simplest organisms that biology knows, working upwards through the scale to man. By this course the most basic elements of organization can be discovered without having to look for them among the intricate details of our own vital situation, where secondary and adventitious elements stand out in undue prominence, and where the impersonal view is well-nigh impossible. Step by step we will then work up the scale of social morphology, approaching in the natural evolutionary order that part of the subject which interests us most deeply.

Just as the construction of an edifice must begin with the fashioning of the individual brick and bolt and girder, so the evolution of a biological association begins with the unitary organisms consisting of single cells, like *Amoeba*. We have had occasion to discuss this animal many times in our previous studies of one or another aspect of evolution, and once again we must return to it in order to reëstablish certain points that are of fundamental importance for our present purposes. Within the limits of its simple body, *Amoeba* performs the several tasks which nature demands a living thing shall do; it feeds and respires and moves, continually utilizing matter and energy obtained from the environment for the reconstruction of its substance and replenishment of its vital powers; it coördinates the activities of its simple body, and by its reflex responses to environmental influences it maintains its adjustment to the external conditions of life. The animal does all of these things with a purely individual benefit, namely, the prolongation of its own life. While it is performing these individual tasks, it does not concern itself with anything else but its own welfare; the interests of other living things are not involved in any way, excepting in the case of other organisms that may serve the animal as food. *Amoeba*, like every other living thing, if it is to exist, must unconsciously obey the first great commandment of nature, —"*Preserve thyself*."

But its life is incomplete if it stops with the furtherance of aims that we may call purely selfish. Nature also demands that an *Amoeba*, again like every other living thing, shall perpetuate its kind. The mode by which it reproduces is ordinarily quite simple; the animal grows to a certain bulk and then it divides into two masses of protoplasm, each of which receives a portion of the mother nucleus. Sometimes by a peculiar process it breaks up into numerous small fragments called spores, which also receive portions of the parent nucleus. The most striking feature in both kinds of reproduction in *Amoeba* is the complete destruction of the individual parent that exists before the act and does not afterwards. It is quite true that every part of the mother animal passes over into one or another of its products, but it is equally true that no one of these products is by itself the original individual. So even the simplest animal we know performs a task that is not only useless to itself, but is completely destructive of itself, for nature's greater purpose of preserving the race. We can readily see why this must be so; there is no place in the world for a species whose members put individual well-being above the welfare of the race, for which the production of new generations is essential, even though the satisfaction of this demand should necessitate the sacrifice of the parent organism. We might hesitate to use the word "altruistic" in describing the self-destructive reproductive act of an *Amoeba*, because this word connotes some degree of consciousness of the existence of other than personal interests, and of the welfare of different individuals. There is no reason to believe that such conscious recognition of any natural duties is possible in the case of so low an organism. But the fact remains that the result worked out by nature is the same as though there were a definite understanding of real duties. Even this unitary organism, then, acts mechanically so as to fulfil two primal obligations, first *to itself*, through activities with individual benefit as the result, and *to the race* by the act of reproduction which closes its individual existence and inaugurates a new generation.

The life of this example, representing the whole series of one-celled organisms, is almost infinitely simpler than that of a member of a human community, yet it reveals the beginnings of certain characteristics of the latter. Here, it is true, the natural obligations in question are not like those which are ordinarily denoted social, but it is equally true that even in this most elementary instance a living thing does not live unto itself alone. It is easy to see the value to the species as a whole of obedience to the second great law—"*Preserve thy kind*." But a little further thought makes it plain that even the performance of acts in compliance with the first mandate—"*preserve thyself*"—are not purely selfish, although their immediate value is realized as individual benefit. Surely an organism that failed to live an efficient individual life would be ineffective in reproduction, so that from one point of view everything an animal does is tributary to the culminating act performed for the larger good of the life of the whole species. It is a nice balance that nature has worked out in *Amoeba*, as well as in all other cases, between the personal life of the individual, complete only when the final process of multiplication supervenes, and this process itself, which demands an efficient performance, even though this is destructive of the performer.

Before passing to the next members of the series, which reveal additional principles more truly social in the human sense, let us pause to note that already we have found certain natural criteria that belong in the department of ethics. Even in the case of the biological unit like *Amoeba*, which is entirely solitary and unrelated to other individuals of its kind excepting in so far as it is a link in the chain of successive generations, any vital activity can be called good or bad, right or wrong. Nature judges an act good and right if it tends to preserve the animal and the species; an act is wrong and evil if it is biologically destructive of the animal or if it interferes with the perpetuation of its kind. Again it must be pointed out that these terms are human words, employed for the complex conceptions that belong alone to retrospective and contemplative human consciousness to most of us they seem to imply the existence of some absolute standard or ideal by which a given act may be tested to see if it is right or the opposite.

If human ethics is truly unrelated to beginnings found in lower nature, something that has arisen by itself from supernature, then we must not use the terms in question except by way of analogy. If, however, nature has been continuous in the working out of every department of human life and human thought through evolution, then the criteria of the righteousness of the acts performed even by an *Amoeba* may be found to be basic and fundamental for ethical systems of whatever human race or time. This subject remains to be discussed in the final chapter, but it must be clear that we cannot survey the evolutionary process by which social systems have come into being without dealing at the same time with the origin and growth of ethical conduct as such.

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Without leaving the group of one-celled animals typified by *Amoeba*, we find colonies of the most elementary biological nature, where other natural obligations are added to the two of greatest importance. Some species of the bell-animalcule, *Vorticella*, provide characteristic examples of these primitive compound protozoa. Here the assemblage is made up of one-celled individuals essentially similar to one another in structure and in physiological activities; in the latter respect each one of them is like *Amoeba* as well. They may remain together for a longer or shorter period, or during their whole existence until the time of reproduction. Like the solitary protozoön, each member leads a complete life in and by itself, equivalent to that of every biological unit. It obeys the two great laws already laid down, but in addition it seems to be required to remain with the others for some mutual good. The biological value of the association which imposes this additional obligation may be found perhaps in the fact that a large group is not so readily eaten by an enemy as an individual cell; but it is clearer that the process of reproduction, which consists of the fusion of small "gametes," or nucleated fragments produced by diverse or similar parents, must be greatly facilitated by the occurrence of gamete-forming individuals in one and the same colony. "*To remain together*" is the new duty imposed by nature for the good of all and for the welfare of each member of the group. Some biological advantage accrues to the several components, just as the banding of wolves enables the pack to accomplish something which the single wolf is unable to do, although in the latter case it is not so much a reproductive alliance that is formed as an offensive and defensive union.

One step higher in the scale stands the plant-form called *Volvox*, near the border-line between the one-celled and the many-celled organisms. This aquatic type, about the size of the head of an ordinary pin, is a hollow spherical colony, with a wall composed of closely set cellular components. These elements are not all alike, as in the case of colonial protozoa like *Vorticella*, for they fall into two classes which are distinguished by certain structural and functional characteristics. Most of them are simple feeding individuals which absorb nourishment for themselves primarily, but they pass on their surplus supplies to less favored neighbors if occasion demands. The other members begin life like the first-named, but later they become specialized to serve as reproductive individuals solely. Every member of the colony must obey the first precept of nature, otherwise it would be unable to play its part in the life of the whole community. But the discharge of the second natural obligation, namely to preserve the race, is here assigned to some, and to some only, of the whole group of cell individuals. It follows therefore that the division of the tasks necessary for the maintenance of a complete biological individual, and the differentiation of the members of the group into two kinds, leads to the establishment of an individuality of a higher order than the cell. Neither the purely nutritive nor the reproducing member is complete in itself; the two kinds must be combined to make a perfect organism. The life of any member can be selfish no longer, for if it is to exist itself, it must help others for the mutual advantage of all. A clear social relation is thus established; and the reflex conduct of the units of a *Volvox* colony can be justly denoted altruistic, even though in this case, as before, there can be no conscious recognition of the reasons why mutual interests are best served by what is actually done.

One of the most interesting and significant aspects of the life-history of *Volvox* is the appearance for the first time of biological death. More elementary organisms are immortal potentially even if not actually, for every portion of the body is capable of passing over into an animal of a succeeding generation. But in *Volvox* a division of labor has been effected of such a nature that most of the components discharge the tasks of individual value, and with the performance of these they die. Only the reproductive members are immortal in the sense that *Amoeba* is, for they only have a place in the chain of consecutive generations of *Volvox* colonies. From the standpoint of the nutritive individual it is better to be relieved of the reproductive task in order that there may be no interruption of its specialized activities for the good of all, but the entailed mortality is certainly disadvantageous to it. It is the higher interest of the colony as a whole that supersedes the welfare of the parts taken singly, and this larger welfare is safeguarded by a differentiation worked out by natural evolution which results in the assignment of personal and racial duties to different individuals, at the cost ultimately of the lives of the former.

We now reach the realm of the true many-celled animals, or Metazoa, where the biological units are combined to form an organic association displaying many more resemblances to a human society. The freshwater polyp *Hydra*, like the foregoing illustrations, is one whose structure has already been discussed in the earlier chapters, but now we may use it for an analysis of another series of biological phenomena. Its sac-like body consists of two cell-layers; the outer one is concerned primarily with offense and defense, while the inner layer is made up of digesting or nutritive elements. The essential cells concerned solely with reproduction lie below the outer sheet. Comparing this animal with an association like *Volvox*, we discover the same differentiation into immortal germ-elements and mortal cells, concerned respectively with the *Hydra's* racial existence and with its individual life; but far-reaching changes have come about in the biological relationships of the second class of cells. In describing the new phenomena it is absolutely necessary to employ the terms of human social organization, because the *Hydra's* body is a true colony of diverse cells in exactly the same sense that a nation is a body of human beings with more or less dissimilar social functions.

To begin with the differentiation into ectoderm and endoderm, the organism is comparable to a human community made up of military and agricultural classes. The cells of the former group protect themselves and the feeding elements also, while the units of the second defenseless type devote themselves to the task of provisioning the whole community, giving supplies of food to the defenders in exchange for the protection they afford; each kind needs the other, and each performs some distinctive task for the other as well as for itself. But the parallel thus drawn need not stop here. In the case of the outer layer, the cells are mostly flat covering elements that are the first to be torn off and injured when the animal is attacked. Scattered about among them are sense-cells standing like sentinels with delicate upright processes which receive stimuli from without the sense-cells transmit impulses to the network of nerve-cells below, which is a counterpart of the signal corps of an army, keeping all parts of the whole organization in communication with one another. Most wonderful of all are the stinging-cells of the outer layer; these produce a flask-shaped, poisoned bomb which is discharged by the convulsive contraction of the cell itself so as to stun and injure the enemy or prey. The bomb-throwing cells die immediately after they have ejected their missiles; like soldiers participating in a forlorn hope, they sacrifice their lives in one supreme effort of service to the cell-community of which they are members.

These and similar facts prove conclusively that *Hydra* is a true community even in the human sense, and that the laws of biological association are established at a point far below the level of the insects. The individuality of the unit is still maintained, and each cell must guard its own interests to a certain degree, but the original independence of the unit has become so altered by differentiation and division of labor that a close interdependent relation has come about. The complete individual is now the *whole* aggregate; it is the entire *Hydra* itself which must obey the primary commands of nature to live efficiently and to perpetuate its kind. True it is that the life of the higher individual is the sum total of the activities performed by its constituent cells, but no one of the varied specialized elements is biologically perfect by itself or equivalent to the whole. And, as we have seen, the welfare of the complete animal takes precedence over that of any one of its parts, just as the existence of a nation may be preserved only by the death of soldiers warring for its honor and life.

If, now, we should pass on to the more complex organisms like worms and insects and vertebrates, and should disregard the communal relations of some of these animals, each individual proves to be like *Hydra* as regards the principles underlying its make-up and workings. A single bee, like a man, is a definitely constituted aggregate of cells, differing as a whole from *Hydra* only in the *degree of differentiation* exhibited by its constituent elements. Instead of a loose network of nerve-cells there is the far more complex nervous system whose evolution has been outlined in the sixth chapter. The blood-vascular and respiratory and excretory systems have become well organized, in response, so to speak, to the demands on the part of the nervous and alimentary organs that they may be relieved of the tasks of circulation and respiration and the discharge of ash-wastes. Therefore the cells which make up an insect and a man are more diverse, they have more varied interrelationships, and they are far more interdependent then in the case of the components of *Hydra*. Yet all the many-celled organisms that we are so accustomed to regard as individuals are really communities, demonstrating the existence and partial antithesis of the great laws of egoism and altruism, which are traceable even down to *Amoeba* and its like.

So much has been made of the lower kinds of cell-associations because the mind of the layman is unconsciously imbued with the idea that human society is a new thing,—an idea which we now see it is necessary to discard at the outset. Indeed, the cell-association of the *Hydra* and insect type is a more compact and a more stable kind of community than any group of human individuals worked out by nature toward the present end of the whole scheme of evolution. That is to say, the subordination of cell-interest to cell-group welfare, while it must not go so far as to render the unit incapable of doing its work, is sufficiently advanced to make uncontrolled individualism impossible. Let any class of *Hydra's* cells, such as the nerve or muscle network, assume to exercise a selfish preeminence or to conduct a "strike," the other classes, like the feeding cells, would not be properly served and they would be unable in consequence to work efficiently for the strikers. The immediate result would be suicidal, for the selfish nerve-class would inevitably suffer through the downfall of the whole social fabric. It is a nicely adjusted equilibrium that is established, where the "equal rights" of all the diverse cells consist in freedom to play a special part in the life of the group, serving other individuals in return for their service. The Golden Rule is a natural law as old as nature; for even in *Hydra's* life, unconscious discharge of duties to the race, and hence to others, is obligatory. And all these low types of organic associations evolved ages before the rules of human social order were vaguely recognized by the reflective self-consciousness of man, to be formulated as the science of ethics.

The evolution of the wonderfully varied societies found among insects begins with the solitary insect itself, just as this, viewed as a cell-community, originates from one-celled beginnings like *Amoeba* through progressive evolution in time. The similarity between social insects and human associations is clearer than in the case of a comparison between an example from either group and a cell-community, because the higher forms lack the organic contact of the components which is so prominent a feature in the lower instance. The social bonds are looser and they allow a freer play of the constituents; but nevertheless the same laws that control the activities of the cells making up what we now take as the individual element, command obedience on the part of the interrelated members of an insect community with equal strictness.

A butterfly or a moth is primarily egoistic and unsocial in the ordinary sense during its entire life-history, until the final reproductive act which has a value to the species. The caterpillar larva devotes all of its energies to feeding and growing, unconcerned with the final duties of the moth with which it is connected just as the indifferent unit of a young *Volvox* colony is related to a reproducing member of the full-grown organism. Now and then, it is true, species like the so-called tent caterpillar are met with where numerous larvæ spin silken communal nests to which they retire at night and in which they remain to molt. The pupa, like the larva, is individualistic and employs its time in producing the final adult form. The mature individual, however, is constructed almost solely for the greater purpose of perpetuating the species. Indeed the larger silkworm moths do not and cannot feed, and their value is only that of a device for keeping the race established. Adult may-flies live only a few minutes, just long enough to provide for the fertilization and deposition of the eggs, although to prepare for these acts the young individuals must have toiled for months; the preparatory time may amount to many years in such a case as the seventeen-year locust. But nature is satisfied, as long as the organic mechanisms obey her double commandment, "Live and grow so as to multiply." Like an *Amoeba*, the solitary insect must be egoistic at first, in order to be altruistic in a racial sense in its last days.

Wasps, bees, and ants provide many familiar examples of colonial organizations that become all the more marvelous on closer acquaintance, on account of their resemblances to human associations on the one hand, and to cell-associations on the other. Their illustrative beauty is enhanced by their wide variety, for they grade from counterparts of highly civilized men down to a savage among insects, such as the strictly solitary digger-wasp, whose instincts served to exemplify the insect type of "mentality" in the discussions of the preceding chapter.

The true communities founded by wasps and hornets must be assigned to a low grade in the scale because they originate during a single season and break up at its end; for this very reason the wasp community is intensely interesting to the student of comparative social evolution. In the spring a solitary female emerges from the crevice where she has hibernated and resumes active life; she feeds for a time to renew her strength and then she constructs a simple nest of mud or masticated wood-pulp. In the first few cells of this nest she deposits her eggs, and when they hatch she herself provides the larvæ with food, but still continues to enlarge the house and to produce more eggs. Thus during the first few weeks of the colony's existence this single individual performs a variety of tasks of racial as well as of purely egoistic value; but as time goes on, a profound change comes about in her activities and in the life of the whole community. The members of the first brood do not grow into counterparts of their mother; they are all sexless "workers" who progressively relieve their parent of the tasks of nest-building and foraging and nursing, so that their mother becomes a "queen" who devotes her entire time to the special reproductive task which she only can perform. We may justly compare the queen to the reproductive organ of *Hydra*, for the values to the life of the species are identical in the two cases, while the various classes of workers are counterparts of such units as the muscle and nerve and nutritive components of the *Hydra* or any other cell-community individual. Another resemblance between the two is found in the death of all the sexless individuals at the end of the season, when reproducing males and females are finally formed, of whom the fertile queens only survive in their winter hiding places; and again we can discover the cause for biological death in that division of labor which calls upon certain members of the whole community to perform tasks that have no value when once provision has been made for perpetuating the species. Finally the mode by which the colony grows and amplifies is in all respects like the embryonic development of an egg into a *Hydra*, so that we may add the phrase "social embryology" to our vocabulary. The original female is an undifferentiated master of all trades; the small tribe she first establishes is little better off than a horde of savages; but during its seasonal existence the community increases in numbers and complexity until it advances well toward the civilized condition, when each class performs its special task for the good of all.

The bees take us higher in the scale, although many solitary species occur, as well as social forms like the bumblebees where colonies are formed in a single season only to break up with the advent of cold weather. The honeybees, however, establish permanent communities from which swarms may set out during the warm months to become new colonies elsewhere. Many hundreds of bees make up a hive, and they belong to three classes or castes, which differ in structure and social function. The queen is a fertile female, the drones are males, and the workers are stunted and infertile females which take no part in reproduction. In this case the queen never discharges any menial duties, for these are attended to by the workers; she devotes her entire time to laying eggs, which are cared for by her subjects, who act as nurses and guards for the monarch as well. The young workers serve at first as doorkeepers, and only later do they take the field in the search for nectar and pollen, and work as house-builders. Each individual performs its special task for its own benefit and for the weal of all; each possesses an equal right to share in the prosperity of the whole community so long as it acts altruistically as well as egoistically. And just as the welfare of *Hydra* is superior to that of any one of its constituent cells, so the well-being of a hive of bees may be safeguarded only by the actual sacrifice of some of its members. Should food supplies be inadequate, the superfluous drones are stung to death,—the victims of legalized murder. But more marvelous still is the provision that is said to be made by certain individuals for their own destruction should this become desirable. As every one knows, a reigning queen may leave the hive with many of her subjects and "swarm" in a new locality. When she does this, during the warm months, the workers of the original hive feed some of the female larvæ with richer food, and place these potential queens or princesses in special roomy cells apart from the ordinary brood chambers; one of them soon emerges to become a new sovereign. Let us note in passing how similar this is to the production of new egg-cells in a *Hydra*, when the mature germs of an earlier generation are prepared and discharged. When, now, the colder weather sets in, and the possibility of subsequent swarming is set aside, the reigning queen is allowed by her attendant guards to visit the royal cells, whose occupants she stings to death, thus destroying any possible claimant to her place. And when the royal princess constructs her part of the pupal case, she leaves an aperture so that if and when it should become necessary for the queen to kill her, the sovereign would not injure her sting and be unable to kill the other individuals who might become aspirants for the throne and so precipitate a civil war! As in the case of the self-destructive act on the part of a stinging cell in *Hydra*, altruistic subservience to the interests of the colony can go no farther.

The ants form stable colonies of still higher grades, where the workers are not all alike in general structure, but become more rigidly specialized for the performance of restricted tasks. As before, there is the fundamental differentiation into the sexual "queens" and males, and the sterile workers concerned with the immediate material life of the community. In some species the workers serve as herdsmen, caring for the ant-cattle or aphids, from which they receive minute drops of a sweet juice for food. The aphids are tended on the leaves of various plants during the summer, and are carefully reared and stabled and fed below ground during the winter months. In other species seeds are procured and stored in underground granaries. The leaf-cutters are forms which grow food supplies of fungi in subterranean mushroom gardens; the compost consists of cuttings brought from the leaves of bushes by myriads of workers, whose processions are guarded by larger-headed soldiers of several ranks. In the honey-ants of Colorado and tropical America certain individuals pass their time suspended from the roof of a large nest-chamber, where they receive the sweet juice brought in by the workers. They serve as animated preserve jars, distended sometimes to the size of a grape with the communal stores of food, which they return to the workers when external sources of food may fail. Finally there are the slaveholding species which conduct forays upon the nests of other forms, to procure the young of the latter, which grow up in their captors' nests and serve them as nurses and masons and foragers. So long has this custom been established that some slaveholders are entirely unable to feed themselves, and would die out if their slaves failed to support them.

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Let us pause at this point to summarize the results of the foregoing analysis, in order that we may approach the biological study of human associations with definite and clear conceptions of the fundamental laws controlling living communities of all grades.

We have dealt mainly with *Amoeba*, *Hydra*, and the ant-community which exemplify three somewhat distinct types of organic individuality. Some of the transitional forms have been specified to show how the second kind originates from the first, and how in its turn this grows in time into the third and most complex association; thus *Vorticella* and *Volvox* connect *Amoeba* with the cell-community individual like *Hydra* and a solitary wasp, while the annually established colonies of social wasps and of bumblebees lead to the permanent colony-individual. Restricting attention to the three primary examples, and remembering that the criterion of completeness is the ability to discharge satisfactorily all of the eight biological tasks, it is clear that the entire *Hydra* and the whole ant-community correspond *physiologically* with *Amoeba*, although the first-named is *structurally* a cell-community equivalent to many protozoa, and the insect colony is composed of many such cell-communities as elements. In the third type, neither a single queen nor a single worker is able to carry on all of the biological tasks any more than a muscle-cell or an unformed egg of *Hydra* can maintain itself capably in isolation. Therefore the ant-society as a whole and the *Hydra* in its entirety are organic individuals on the same physiological plane with *Amoeba*, and they are equally subject to the same great laws of nature demanding selfish maintenance and racial perpetuation.

But we must not lose sight of the fundamental value of the unit during the evolution of a higher from a lower type. The tissue-cell of *Hydra* must still obey the mandate to live an efficient personal life, because this is necessary for the welfare of other cells and of the whole complex. The original egoistic tasks are not abolished, but new duties are added to them in ways we have learned to distinguish. In *Vorticella* the products of fission do not separate, and certain advantages accrue from the organic continuity thus maintained. The success of *Hydra* in its ceaseless struggle to live depends wholly upon the cooperation of its differentiated cell-units, now no longer equivalent in function to the all-powerful *Amoeba*, although each one must be kept alive until its task is done, or the whole association would have no place in nature. Similarly in the higher insect community, the superadded duties to fellow-components are even clearer, for in the competition of colony with colony, involving terrific battles whose casualties may be numbered by thousands, the stronger wins; and strength depends upon the concerted efforts of all the members of the kingdom, that only collectively constitute a complete biological whole. Mere self-protection demands altruistic conduct: if the worker ceased to bring in food when its own hunger was satisfied, there would be no tribal stores for the stay-at-home queens and nurses; and if the soldier fled from the field of battle to save its own life, its act would be suicidal ultimately, for to the degree of one unit the defense of its non-military supporters would be weakened and they would be so much the less unprotected during their service for the soldiers and all others. Furthermore, we must admit the reality of natural criteria of ethical values, established far below mankind in the scale of life. In an ant-republic, laws are instinctively obeyed quite as implicitly as though they were intelligibly proclaimed to all of the emmet citizens. Right is might when community battles with community, for right is that which is biologically favorable. And what may be correct conduct on the part of the members of one species may be naturally wrong and evil in another case. To kill the princesses in order to obviate the possibility of civil war seems advantageous and therefore right when the queen remains in the persistent colony of honeybees, ready to do her part the following spring; but it might result in disaster and evil in the case of the social wasps, where the community dies as such in the fall, and the continuity of the species from one year to another requires the production of many queens lest the severe conditions of the winter's hibernation should kill all fertile females if only one or two were available. The standards of conduct are simple indeed; and whether or not it may seem best to separate the processes of social and ethical evolution culminating in human phenomena, the fact remains that these processes begin with elements discovered by the biologist among organisms of the lower levels in the scale.

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We come at length to the biological interpretation of human social evolution, in so far as this may be expounded in a simple and concise form. The comparative method must be employed in order to discover the fundamental attributes of savage, barbarous, and civilized communities which seem to differ so considerably in their complexity of social structure, and in order also to show that such basic elements are like those of communities formed by lower animals, and are equally the products of natural evolution. This whole subject seems to be exceedingly complex, because in our daily contact with others of our kind and in our occasional views of foreign races like our own, the smaller details occupy our attention, diverting it from the great basic principles according to which every society is organized and operates. But when once the major elements have been discovered in civilized and more primitive nations, the secondary and less essential phenomena fall into their proper relations, and a statement of the whole process of development becomes relatively simple. So much space has been devoted to lower types of communal organisms in order to learn what the fundamentals are, and not merely to provide analogies that may be useful hereafter. It now remains to arrange the evidences of social progress during the history of mankind itself, and to bring such human facts into relation with what has been discovered in lower nature. It is helpful to begin this part of the subject by asking ourselves what is already part of common knowledge about human history. Do we know of any civilized nation that is absolutely stable and unvarying in social structure, or one that has remained unchanged throughout historic time? The answer must be negative, for in no case does the past disclose an example of permanence in social or in any other respect; monarchies and republics are plastic like the human frame itself. The American Commonwealth is a relatively young social organism, and it is an easy task to trace its growth from beginnings in the diffuse and uncorrelated colonies of pre-Revolutionary years. Those colonies that were formed by English settlers were transplanted outgrowths from a civilized social parent which in its turn had clearly evolved from the state of King John's time and the still cruder form it had under King Alfred.

Should we follow back the recorded history of any people now civilized, we would always find evidence of ceaseless change; and the writings of ancient historians like Herodotus and Cæsar and Tacitus give a great deal of information about the barbarous conditions from which civilization evolved.

But much more is known that materially amplifies the account of human progress based upon documents alone. The student of existing human races early learns that social structure is a very varied thing. The natives of northern Africa now live in a semi-civilized state which is very like that of medieval England. In Siberia and the American Southwest are tribes that correspond socially with the barbarians of Europe described by Greek and Roman writers. The American Indians discovered by the earliest colonists, the Polynesians of a century ago, and the Fuegians of recent decades provide counterparts of the ancient stone-wielding people who were the savage ancestors of European barbarians. Hence the comparative study and classification of modern races establishes a scale of social grades which corresponds with the order of their historic succession, just as in a larger way the complete series of comparative anatomy from *Amoeba* to man displays the order of evolution from unicellular beginnings to the present culminating types. Savagery, barbarism, and civilization are the three major terms of this social scale, but by no means are they discontinuous, for many intermediate forms of organization occur which are transitional from one major type to a higher one.

In human social evolution the starting point is not so simple as the solitary unit from which insect societies evolved,—that is, an organism which lives alone and is associated with another of its species only at the time of mating. The lowest human beings now existing have some form of family organization, traceable to the more or less continuous unions formed among certain of the apes and even among many lower animals, and not a characteristic that belongs to mankind alone. The savage and his mate constitute the social unit out of which all else is built up; the man and the woman must perform all of the vital tasks demanded by nature. Fruits and vegetables must be secured from the wild forest or by cultivation; the flesh of game animals or of a human victim is no less essential for food. The savage is his own weapon maker and warrior; he himself builds the rude shelter for his family and fashions the canoe if such is required. He is also his own judge, recognizing no control save the dictates of his wishes and needs, for he does not consciously realize that he must obey the primal commands of nature to preserve himself and his family so that the species shall persist. In brief, the elementary family unit carries on all of the individual biological tasks of foraging, righting, home-building, and the like, and it also discharges the racial task of multiplying, quite as instinctively as it provides for its own maintenance.

By the union of several families, a primitive association arises, like that of the Veddahs in Ceylon. The primal duties of each family are unchanged, and their biological activities are identical, as in the protozoön colony of *Vorticella* or in a pack of wolves; but certain new relations are established. A member of such an inchoate tribe must not treat his confrères as he might a man of another group; robbery and murder within the limits of the small association are detrimental to communal interests, though they may remain unchecked if the victims are strangers. Coöperation for mutual offense and defense makes the group stronger than its constituent family units taken singly, and every man of such a tribe gains something by looking out for others as well as for himself. By natural selection alone the bonds of union would be strengthened in direct proportion to the subordination of individual interest to group welfare, and to the amount of altruistic action that in a true sense grows out of purely selfish conduct.

But when such a primitive biological association forms and grows, an opportunity arises for increasing the effectiveness of the whole group by differentiation. Some of the men are stronger in battle and they soon become the chief warriors; others prove to be more skilful in the hunt or in the construction of canoes and weapons. Just as among the insects, the hunter seeks food not only for himself but for the warriors, who in their turn defend themselves, but do not cease fighting when they have disposed of their own enemies if foes of their comrades still survive. The barbarous state of society thus arises, and the division of labor brought about during its origin makes it possible and indeed essential for many family units to remain together for mutual good. The union is stable and efficient, however, only if the individual suppresses his own selfish inclinations, suspending private quarrels when public wars are toward, and acting at all times in concert with his fellows. Self-control increases necessarily, and lines of conduct deemed right by a solitary savage unit come more and more under the sway of social inhibition, for although the primitive savages must inhibit individualistic action to some degree, the barbarian must suppress much more of his purely personal wishes for the purpose of social solidarity. Thus it comes about that a barbarous community can number thousands, while a tribe of savages with a higher degree of individualism and less altruism cannot cohere if it comprises more than hundreds or scores.

Civilization is a product of evolution by precisely the same natural mode of development, that is, through further subordination of individual to communal interests and through progressive dividing up of the tasks necessary for the life of the group. The final result is so obvious and familiar that we take it for granted, accepting it as self-sufficient without realizing how it has come about and how modern is the present state of affairs. Let us compare the life of an Indian savage living on Manhattan Island four centuries ago with that of a New Yorker to-day, as regards so simple a matter as the procuring of fish food. The Indian emerged from his tepee, built by himself, and walking to the shore, stepped into a canoe which also he had made with his own hands. Paddling to the fishing ground, he patiently cast his line until the desired fish were caught. Does any one of us do all of these things for himself? We live in houses constructed for us by others who devote their lives to building; we are very apt to go about the city in conveyances that demand special and peculiar skill for their invention, manufacture, and operation. Arriving at a market-place, we obtain such an article of food as a fish without having to go out upon the water ourselves, for many other workers have built vessels that we do not know how to make and may not know how to handle, and hundreds of fishermen devote their lives to their special task, not for themselves, but for us and all others, such as the builder, the subway operator, the boat maker, and the manufacturers who supply their clothing and apparatus.

What has come about then is a higher degree of specialization in the performance of the fundamental biological tasks, resulting in the formation of coherent and efficient groups comprising millions as compared with the thousands of barbarism and the hundreds of savagery. Just so the communities of insects with the greatest degree of altruism and division of labor far exceed in numbers the small colonies of the social wasps with lower social differentiation.

But the great biological functions of an entire complex civilized society remain the same as those of a primitive savage family unit, of an insect community, of *Hydra*, and of *Amoeba*. Let any nation fail to maintain itself in material individual respects, it must inevitably die out; in the islands of the South Seas many a tragic death-struggle of a people can be witnessed. If in the second place a nation should concern itself too greatly with the material benefits of human life without obeying the natural mandate to propagate itself, its place in the scheme of things becomes insecure, as in the case of the French Republic. Natural social laws that go back to *Amoeba* must be observed, consciously or unconsciously, or else even the civilized community must fall, like scores and hundreds of others that lie along the road of historic progress—a road strewn with the remains of the unfit thrown out by natural selection.

What now are the lessons of social evolution and what guidance does science give for human endeavor? Although it may seem that the biologist leaves his field when he considers these questions, his duty would be unfulfilled if he neglected an opportunity to give his results their highest utility through their use for the betterment of human life.

The first lesson is that the history of human social organization is far from unique, and that it is identical with the process by which insect communities and cell-aggregates have evolved; in a word, the laws of biological association are uniform throughout the entire organic scale. In some respects evolution in mankind has yet to equal the heights attained by some insects, inasmuch as no human society has accomplished so rigid a specialization of its members that a given individual is foreordained by its inherited structure to be a particular kind of worker and nothing else. Furthermore, evolution in human society is still far short of a state where some and some only are reproductive members of the group while the others are necessarily sterile; social insects with stable colonies are so organized that the queens and drones are solely reproductive while the workers are destined to care for the material wants of the colony. It is true that the birth-rate is by no means the same in all classes of society, but the social and other adventitious restrictions that bring this about are not on the same plane with the hereditary determining factors which operate among insects. Therefore the scale of human communities proves to be only a part of the wider range of organic associations in general—a part which can be definitely placed in such a wider scheme and so become more intelligible in itself.

In all departments of social evolution, progress is made by the twofold process of combination and differentiation. We have dealt with detailed instances, and now it is profitable to treat the process in a larger way, with a view toward the possibilities of the future. The Thirteen Colonies, somewhat similar in their earlier economic activities, united for mutual support much as wolves combine to form a pack. Later, as circumstances directed, they differentiated into farming or manufacturing or commercial organs of the body politic, each to some degree freeing itself of the functions undertaken by others, and becoming thereby more dependent than before upon those that specialized in different ways. As in the history of the insects in a growing wasp community and of savages evolving into barbarians, the original condition of relative independence passed into a state of interdependence and cooperation. In like manner, if nature remains the same, as there is every reason to believe it will, nations now separate will unite to make more complex combinations that will be veritable empires of world-wide scope. Countries on opposite sides of an ocean are now more closely connected by lines of communication and means of travel than were the Carolinas and New England a century ago. Diplomatic activities give many signs of a growing appreciation of the value of reciprocal agreements for mutual advantage, and the Hague Conference is a concrete manifestation of a continuing process of social evolution that finds its beginnings and its interpretation far below human history in lower organic nature.

But perhaps the most important result of this whole discussion is the lesson of social service that it teaches. We are members of a vast community whose complex total life seems far removed from anything going on in an ant-colony, and our daily tasks vary greatly in specific character and degree when compared with those of lower communal organisms. It seems scarcely credible that any principles of social relationship, however general, can hold true for us and for them. But when the rock-bottom foundations are reached, they are simple and instructive indeed. Being here, we cannot escape our personal obligations as living things or our equally clear duties as members of our community. These facts being as they are, what must we do? Self-interest is rightly to be served, otherwise we would be incapable of discharging our secondary tasks, namely, those of service to others in ways that are determined by hereditary endowment and conditional circumstances. The difficulty is to find the right compromise between the two sets of obligations; but the right balance must be found, or else the health of the community is impaired. Should any class demand more than its just dues, others must suffer through the diversion of what they require, and the well-being of the selfish class is jeopardized to some degree, so closely interwoven are the interests of all. Freedom of opportunity within the limits of ability and efficiency is the right of every one, but freedom of conduct must never result in trespass upon the equal rights of others to make the most of their abilities and opportunities.

To summarize, then, social evolution is a continuous process accomplished through differentiation and division of labor among the components of biological associations. Although the total form remains the same everywhere, progress has been made in content through the further subordination of selfish to altruistic conduct; only by this means does an individual gain liberty to pursue the social task for which he is best fitted by nature.

# VIII

#### EVOLUTION AND THE HIGHER HUMAN LIFE

We have now reached the last division of the large subject that has occupied our thoughts for so long. The present title has been chosen because the questions now before us relate to the highest human ideas belonging to the departments of ethics, religion, theology, science, and philosophy. These matters may seem at first sight to be far removed from the territory of the naturalist as such, and quite exempt from the control of laws which determine the nature and history of the human individual in physical, mental, and social respects. Yet one reason alone would impel us onward: we cannot close the present examination into the basic facts of evolution and into the scope of the doctrine without asking to what extent a belief in its truth may affect our earlier formed conceptions of nature and supernature. Heretofore these possible effects upon what may be dearly cherished intellectual possessions have received no attention, so that we might learn how evolution works in the lower fields of organic life in general and human life in particular without being disturbed by them. No doubt, however, the conviction has grown with each step in our progress that the principles we have learned must cause us to readjust our views of the highest elements in human thought to a degree that must be inversely proportional to our previous acquaintance with the laws and processes of nature. But the seeker after truth is fearless of consequences. He knows that truth cannot contradict itself; and if those to whom he looks for authority give him conflicting accounts of nature's history, he knows that one of these must be less surely grounded than the other. The investigator soon learns to withhold final judgment, realizing that the primary conditions for intellectual development are the plasticity and openness of mind that dogmatism and finality destroy. He knows that while his researches may be, and indeed must be, iconoclastic, they provide him with better icons in place of the old.

Let us recall the steps in our progress through one and another field of knowledge, from which representative facts have been chosen for classification and summary. We began with the basic principles of organic structure and workings, and then we examined serially the larger categories of the evidences relating to evolution as a fact, and to the mode of its accomplishment by natural factors. Proceeding to the special case of our own species, we learned that human beings are inevitably a part of nature and not outside it; in structure, development, and palæontological history, mankind is subject to the control of the uniform laws which operate throughout the entire range of living things. Finally, the mental characters and the social relations of human organisms were derived from beginnings lower down in the scale, and were proved to be no more exceptional than the physical constitution of a single human being.

Are we to forget all of these things when we try to put in order our ideas belonging to the categories of higher thought? Can we hope to find the truth if we fail to employ the methods of scientific common-sense which only yield sure results? It is no more justifiable to discard our hard-earned knowledge than it would be for an advocate to undertake the conduct of a case in deliberate disregard of what he had learned of the law, or for a surgeon to leave his knowledge at the door when he entered the operating room. Too often we are bidden to view the larger conceptions of nature and supernature as something outside the realm of ordered knowledge too frequently we are given statements upon authority that takes no account of reason, and we are asked to accept these views whether or not they accord with the demonstrated facts of common-sense. But those who have followed the present description of evolution can readily recognize their obligation to use for the further analysis of higher human life the means which have given in that doctrine the most reasonable explanation of the natural phenomena already investigated.

I need hardly say that we now enter upon the most difficult stage of our progress. The regions we have traversed were more readily explored because they were remote from the matters now before us; even in the case of man's mental and social evolution it was possible to take a partially impersonal view of certain of the essential elements in human life, which we cannot do now. For ethics and religion and philosophy are groups of ideas that are familiar to us as the property of mankind alone. Countless obstacles are in the way. Much mental inertia must be overcome, for it is far easier to accept the average and traditional judgments of other men—to let well enough alone—than it is to win our own way to the heights from which we may survey knowledge more fully. Human prejudices confront us as a veritable jungle, hemming us in and obstructing our vision on all sides; and perhaps much underbrush must be cut away if we are to see widely and wisely. Nevertheless, to those imbued with a desire to learn truth, anything and everything gained must surely repay a thousand times all efforts to obtain clearness of vision and breadth of view. With our perspective thus rectified by our backward glance, we turn to the three divisions of human thought now to be examined. The conceptions of ethics come first for reasons that must be apparent from the classification of the facts of social evolution; just as mental attributes and communal organization are inseparable, so rules of conduct arise *pari passu* with the origin of a biological association. Religion and theology form the second division, which takes its origin in part from the first, for these two groups of ideas are largely concerned with the authority for right conduct and with human responsibility for taking the right attitude toward the entire visible and unseen universe. Finally, science and philosophy are briefly treated as evolved products which include within their scope all that there is in human knowledge; for this reason they take the highest place, instead of the position below religion usually assigned to them. At the last, having reached our final standing ground, we must look back in order that we may clearly define the lessons and ultimate values of the whole doctrine of evolution.

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Ethics is the science of duty. It is usually restricted to an examination of purely human obligations, and to a search for the reasons why men should do certain things and refrain from committing other acts. Like psychology and sociology, ethics began as a strictly formal and *a priori* system of dogmas which related to the life of cultured human beings alone. Again, like the sciences specified, it gradually broadened its scope so as to include the conventions of races lower in the scale than the civilized peoples who only were sufficiently advanced intellectually to conceive it. Thus the comparative method came to be employed, and in direct proportion to its use, more liberal views have developed regarding the diverse methods of thought and standards of social life and of conduct among differently conditioned peoples. Still more important is the demonstration that human ethics as a whole, like human faculty and civilization, takes its place at the end of a scale whose beginnings can be found in lower organic nature.

Those who have followed the account of social evolution given in the preceding chapter must realize that the basic general principles of natural ethics, as contrasted with "formal" ethics, have already been discovered and formulated. A biological association of whatever grade and degree of complexity is impossible unless biological duties are discharged. Human ethical conduct differs from insect and protozoön ethical conduct only in the element of a participation in the process by the explicit consciousness of man that he has definite obligations to others; and this distinguishing characteristic is the direct outcome of an evolution which adds reflection and conceptual thought to a mental framework derived from prehuman ancestors. The insect hurries about in its daily life as an animated machine, whose activities are defined by heredity; its special mode of conduct is just what nature has produced by selection from among countless other forms of living which have not had the same degree of biological utility. But man alone recognizes vaguely or clearly the "why and wherefore" of his acts that are far more instinctive than he supposes; he only is consciously aware of the bonds of kinship and economic interdependence. He looks about for the authority which imposes his duties and fashions his bonds, and conceives this authority as something superhuman, until the comparative studies of evolutionary phenomena reveal the true causes in uniform nature itself.

According to biological ethics, the fundamental obligations of all living things are the same, even though the modes of discharging them may be various. Every individual must lead an efficient personal life by procuring food, but animals differ very much in their alimentary apparatus; among other things they must respire, but some are so simply organized that they do not need elaborate organs like the tufted gills of a crustacean or the lungs of higher vertebrates. Every individual of whatever grade must also provide in some way for the maintenance of the species, but some, like a conger eel, produce enormous numbers of eggs which are left uncared for, while others, like birds, bring forth only a few young, which receive constant attention and protection until they are able to shift for themselves. Nature has no place for even a human community unless individual and racial interests are conserved, so that the greatest duties are definitely formulated—all else is secondary and less essential. Selfish action on the part of every unit is obligatory, but it must always be antecedent to endeavor in the wider interests of the race if the unit is a solitary individual; if it is a member of an association of any grade, then it must serve its fellows in some way. Egoism and altruism are natural essential guides to conduct; neither can safely exclude the other, and their antithesis sets a problem for every organism, which is to work out the proper compromise that will be most satisfactory to nature. The Golden Rule is taught by biology because it is demonstrated empirically, and not because it has any *a priori* value as an ideal ethical principle.

But utilitarian or natural ethics need not stop with the statement of vague generalities like the foregoing. In human society, as in the life of low animals, the worth and value of any form of conduct and of every single act can be estimated by definite biological criteria. The institution of marriage and the conventions of common morality have their biological value in their provision for the care of children; the safeguards of property rights enable the industrious—the biologically efficient—to keep the fruits of their labors; the establishment of formal civil and criminal laws is biologically valuable in a social way, in so far as such laws diminish the unsettling effects of personal animosity and the desire to wreak personal vengeance; the establishment and differentiation of legislative, executive, and judicial organs of government lead to greater social solidarity and higher biological efficiency. Thus unchecked individualism is just as wrong ethically and biologically among men as it would be in the case of insect communities, as pointed out in the preceding chapter; no one has a right to expect service or deference to personal interest from others if he fails to work for them and for the good of all. It is true that the social structure will stand a great amount of tension, but if this becomes too great, either a readjustment is effected, as when King John was forced by the barons to concede their rights, or else the whole nation suffers, owing to the selfishness of a few. In the war between Russia and Japan, the latter won because the individual soldier merged his individuality in the larger mechanism of the regiment and brigade and army corps, gladly sacrificing his life for the nation represented by the person of its Emperor. The single Russian soldier may have been far superior to a Japanese in muscular strength, and perhaps in arms also, but selfishness and greed on the part of many who were responsible for the organization and equipment of the Russian armies rendered the whole fighting machine less coherent and therefore less efficient than that of the Japanese.

In the evolution of ethics the recognition of ideals of conduct has followed long after the institution of a particular precept by nature, which is obeyed instinctively and mechanically by force of inheritance. In the case of the communities of insects, the results are the same as though the individual animal fully recognized the value of concerted endeavor. So among primitive savages of to-day there is only a vague conception of abstract duty as such, or it may be practically lacking, as in the case of the Fuegians. So also a growing child is substantially egoistic, and it must be taught by precept and example that the rights of others can be safeguarded only by the altruistic correction of personal action, long before the child can grasp the higher conceptions of ethics. If a human being never learns to do so, and becomes a criminal through force of heredity or circumstances, the machinery of the law automatically comes into operation to conserve the welfare of the community. Such a criminal may be unable to control his destiny, and may not be responsible for being what he is, but nevertheless he must pay the penalty for his unsocial heritage by suffering elimination.

Ethical systems are built around man's vague recognition of certain natural obligations, and they have thus become more or less complex, and more or less varied as worked out by different peoples. They must necessarily be much concerned with social questions, with morals in the usual sense and the more rigid principles enacted into the spoken and printed law, but they have also become closely connected with religion and theological elements. Especially is this true in the ethics of barbarous and savage peoples, who accredit the "categorical imperative" to some supernatural power, as we are to see in a later section. The one point that comes out clearly is that the systems of conduct and duties have evolved so as to be very different among various races, and that in the history of any one people, ethics has passed through many varied conditions. What may be deemed right at one period becomes wrong at another when conditions may be changed; in medieval England the penalty of death was prescribed for one who killed a king's deer, as well as for a highway murderer. The Fijian of a quarter century ago killed his parents when they became too old to be effective members of their tribe. And so deeply ingrained was this principle of duty that elderly people would voluntarily go to a living grave surrounded by their friends; while in other authentic cases, parents have first killed their sons who failed to obey the tribal law, and have then committed suicide. We can see how nature and necessity would institute a law requiring such conduct where a tribe must carry on almost incessant warfare and where the available food supplies would be enough for only the most efficient individuals. Infanticide also has been practised for reasons of biological utility, as among the Romans, who at first maintained their racial vigor by deliberately ordering the death of weak babes. But times have changed, and ethics has become very different with passing decades. Our civilization has resulted in a development of human sympathy as an emotional outgrowth of necessary altruism; this motive directs us through charitable institutions and hospitals to prolong countless lives which are more or less inefficient, but which do not render the whole body politic incompetent in its struggle for existence.

Nature then has itself attended to the development and institution of ethics. As we look back over the long series of stages leading to our own system of conduct the most striking feature of the history is the increasing power of self-control or inhibition. As a natural instinct this tends to prevent the committing of acts which for one reason or another are naturally harmful to society as a whole. What we call conscience is an instinct implanted by purely natural factors, and it unconsciously turns the course of human action in the directions of selfish and altruistic interests. Conscience, then, without ceasing to have validity and efficiency, appears on the same plane with all of the other products of evolution which owe their existence to individual or social utility.

Theology and religion involve intimately related conceptions of the world, its make-up, and its causes. Strictly speaking, religion is a system of piety and worship, while theology deals more particularly with the ultimate and supernatural powers conceived in one way or another as the God and the gods who have constructed the universe and have subsequently ordered its happenings. A religion is a group of ideas having the effect of motives; it is dynamic and directs human conduct. Theology, on the other hand, is more theoretical and descriptive, and its conceptions, together with those of other departments of human thought, give the materials for the formulation of the religious beliefs which determine the attitudes of men toward all of the great universe in which they play their part and whose mysteries they attempt to solve.

Defined and distinguished in these ways, these two departments of higher human life present themselves for comparative study and historic explanation. They differ much among the varied races of mankind, so much, indeed, that an investigator who approaches their study with a knowledge only of Christian religion and theology finds it difficult at first to recognize that the same fundamental ideas, although of far cruder nature, enter into the conceptions of an idol-worshiping fanatic living in the heart of Africa. But, nevertheless, beliefs that fall within the scope of the definitions adopted above are to be found among all men, and they must be examined so that their agreements and differences may be demonstrated, and their common elements may be explained as the natural products of a process of evolution.

Such a broad comparative study, like that of physical, mental, and social phenomena discussed heretofore, must be conducted objectively; that is, each and every particular belief of a religious or theological nature which can be discovered in any race is entitled to a place in the array of materials which demand scientific treatment. They must be verified, classified, and summarized, in order that their total meaning and value can be discovered. It must be strongly emphasized that for such purposes the inherent validity and truth or falsity of diverse religions are not called into question when they are so considered as objects of study; many still entertain the view that the mere task of conducting an analysis of a group of religious beliefs of whatever nature must tend to destroy or alter that system of religion in some way and degree. But whatever the comparative student may himself believe, the conception of Jehovah in the Hebrew religion is quite as legitimate an object of study as the Buddhistic concept of Brahma as the Ultimate Being, or the Polynesian idea of Tangaroa as the god of the waves. We would naturally be inclined to exclude the last from our own personal system of piety and worship as the childish concept of an imaginative, adolescent race; but whatever the truth may be, the fact of a belief in Tangaroa is as real as the fact of Christian belief in God. We can no more destroy any one of these ideas by investigating its nature and origin than we destroy the efficacy of the human arm when we study its muscles and bones and sinews. The former, like the latter, take their places among natural phenomena whose history must be inquired into if there are any reasons for supposing that they fall within the scope of evolution. I would be the last to lead or to take part in an attack upon any system of religion, but as a student who is interested in the universality of organic evolution, I am forced to scrutinize each and every authentic account of a religion to see if such systems present objective evidence of the fact of their evolution through the operation of purely natural causes.

But before passing to a detailed treatment of the analysis, synthesis, and genesis of religious systems, let us employ our common-sense for a brief backward glance over the known history of familiar facts. Every one is aware that the Christian religions of our time and community have not existed forever; this, indeed, is indicated by the way the passing years are denominated. We call the present year 1907 Anno Domini, and this whole expression explicitly refers to the fact that less than two thousand years ago the Christian systems of piety and worship collectively took their origin from their Hebrew ancestor. The same parent has produced the relatively unchanged Judaism of the present day. Judaism itself evolved under the influence of the Prophets, of Moses, and of Abraham. Turning to Asia, we learn how Buddhism evolved from Brahmanism. The teachings of Mohammed at a later time developed into the formulated precepts of the Koran. Would any one venture to assert that all or any of these systems of thought have stood firm and immutable from the finite or infinite beginnings of time? Would any one contend that the creeds of Protestantism have remained unchanged even during the past twenty years? Like all departments of human belief and knowledge, religious concepts have obviously altered in natural adjustment to changing times and to advancing conditions of human intellect; and the question turns to the mode by which they have been modified, to see whether natural causes of evolution have changed them, and have originated their earliest beginnings at the very outset of human history. It has been stated above that every race of mankind, however primitive or advanced it may be, holds some form of religious belief based upon some conception of the supernatural powers back of the world; and what the universe is conceived to be must largely determine the particular characteristics of a theology, and through this the special form of its attendant religion. We have before us a wide array of types to study and to compare, which vary so greatly, partly for the reason specified, that an inclusive definition of religion must be couched in very general terms. If we define it as the attitude and reaction of a human being conditioned by his knowledge of the immediate materials and his conception of the ultimate powers of the universe, its scope is so extended as to include the ideas of the atheists and agnostics as well as the crude conceptions of lower races and those systems of piety and worship conventionally regarded as religions by civilized peoples. More than this: we cannot regard the total reaction of a thinking being as essentially different in ultimate value from the attitudes toward their worlds of animals lower than man. The situation of a well-trained sheep dog is one of pastures and fences and gates, of rain and sunshine, of sheep, and of a master whose voice is to be obeyed. What the dog may do is partly determined by what it finds in its world of animate and inanimate things. Although the animal's "conception" of such things must be far simpler than a human being's, nevertheless its life is lived in reaction to all of its surroundings as they are presented to its cerebral apparatus by the proper organs. So in the human case, conduct is directly affected by the living and lifeless objects of a total human situation, the only difference being that reflective consciousness and reasoned interpretation have their share in determining the assumed attitude in ways that seem to have no counterparts as such in the mental lives of lower animals. But whether or not the similarity between human religion and lower organic reaction be admitted,—and the admission is one that greatly facilitates an understanding of evolution in this field,—the general resemblance of all religions in fundamental character at least must be accepted.

Another general feature of religious systems is their complexity. The essential elements of all of them are few indeed, as we shall see at a later point; they are beliefs regarding ultimate powers, human responsibility to such powers, and future existence. These have taken one specific form or another in various lines of racial evolution, but aside from their own changes they have gathered about them many other articles of creed relating to other departments of thought and life. Ethical rules of conduct are so added, as in the Hebrew religion where the idea of Jehovah involves God the Ruler and Judge who imposes and administers the laws of right living. Social customs are almost invariably intertwined with religious views, among savages as well as among the more advanced Mohammedans whose rules relating to family organization form an integral part of the whole cult. The emotional elements play a large part in some cases, in the fanatical creeds of the Dervish and Mahdist and in the "revivals" under nearer observation. In Greek cosmology and worship, aesthetics figured to a large degree. Temperamental and other psychological characteristics have profound effects upon religions, which we may illustrate by such extreme examples as the austerities of New England and Scotch Presbyterianism and the contrasted liberties of the natural religions of tropical races. But all of these accessory elements belong to other well-defined departments, some of which have already been considered, and among the materials of their proper divisions they find their interpretation and historical explanation in evolution. It is with the basic elements themselves that we are now concerned.

Only within recent years have systematic attempts been made to classify religions on the basis of impersonal objective study. Throughout all times men have instinctively set up their own religion as the only true one, besides which all others are designated simply as false—a very natural distinction, but one which is too naïve for science, as well as one that takes into account subjective or personal values which are not to be considered in an objective comparison and analysis. The linguistic basis was first employed by Müller, with the result that religions were placed in the category of evolutionary accompaniments of the other mental possessions and of the physical qualities of genetically connected peoples. Thus the nations of Europe that branched out in all directions from very nearly the same sources possessed common linguistic characters and somewhat similar creeds. The Sanskrit-speaking races were the original Brahmins and Buddhists. Ancestor worship is an accompaniment of the peculiar languages spoken by eastern Mongolian peoples. And although the correlation specified is by no means invariable, because a race of one stock can readily accept the religion of a neighbor or of a conqueror, yet much is gained through the introduction of the idea of evolutionary relationships.

A more logical classification frankly adopts the genetic method and clearly recognizes the direct effects of cultural and intellectual attainments upon the way a religious system becomes formulated. In such an arrangement, similar to that of Jastrow, religions can be classed as those of savagery, of barbarism, of advanced culture, and of civilization. Among the first named, notably those of Polynesian and African tribes, beliefs in diversified ghosts and spirits bulk largely, and every moving thing, be it a river or a cloud or a tree or animal, is held to be animated by an invisible conscious genius; the spirits reside in everything, as well as in the great unknown beyond. Above these in the scale are the religions of so-called primitive cults, more elaborate and formalized in the ancient beliefs of Egypt and Assyria, but still below those of advanced culture, which make up a third group. The fourth class includes the religions which tend to be coextensive with life, and which enjoin the higher harmony of practical and theoretical conceptions. Taking Christianity as an example, the contrast with the beliefs of savagery brings out clearly the nature of progressive development. Here religious thought is no longer esoteric, confined to a chosen sect like the Levites among the Hebrews or the shaman and medicine-man among the American Indians; nor is religious observance restricted to the innermost shrine of the tabernacle or sacred dwelling, accessible to few or only one. It comes to be regarded as something in which each and every individual can participate, and a personal possession that has a direct part in determining all forms of human life and action. This is another way of saying that the more highly evolved religions owe their character to the greatly varied and abundant intellectual elements which are built into them. And this is why religion in the highest form, more clearly than in the lowest forms, is to be spoken of as an outlook upon the world which is determined by the total intellectual equipment of the individual man who thinks about the universe and directs his course of action by what he finds.

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We come now to a closer concrete study of the basic elements of religion; that is, of those beliefs that are invariably present, in one form or another, in every system of piety and worship, and that constitute the innermost framework beneath the secondary creeds added to them. Following Mallock and others, we may distinguish three such elemental conceptions. These are, first, the belief in the existence of a supernatural being or beings, endowed with intelligence like, but superior to, our own; second, the idea of human responsibility to this or these powers; and, third, the belief in immortality as an attribute of the supreme powers and of human individuals also. Let us see how these beliefs appear in characteristic systems of religion.

In all forms of Christianity the central idea is the conception of a triple unity personified as God. He is regarded as the Creator who has made all things and who demands reverence from his subjects. He is the Author and Finisher of the faith as well as the sole Cause of the universe itself. Much of this element is directly derived from Judaism, the progenitor of Christianity; but a difference consists in the triple nature of the supreme being according to the newer creed. As the original and supreme being, God is not only the Creator, but the watchful Judge as well, demanding reverent obedience to the laws of the world in which he has placed man, and imposing sacrifices and penitential observances when his mandates have been disobeyed. As the God of Mercy he is incarnated in the person of Jesus of Nazareth, and offered as a vicarious sacrifice for sinners who are thus enabled to escape the penalties they would otherwise have suffered. As the Holy Ghost, God is the vaguely personified ultimate source of the higher and nobler elements of human thought, aspiration, and life in general. The second basic tenet of Christianity is that of human responsibility to God, to whom man is related as the created to a creator, as a subject to a ruler, and as one saved to his redeemer. The institutions of sacrifice and ritual are outward signs of human subjection to God himself and to his laws, according to which the universe is conceived to operate. Finally, Christianity teaches that just as God in his single and triune form is eternal, so the soul of man is immortal, with or without its earthly temple of flesh and blood. The essential thinking individual is believed to pass to heaven, where rewards for right living are bestowed, or to hell, in order to suffer punishment for sin during all eternity, or some part of it, according to different views regarding the efficacy of Christ's vicarious atonement.

It is true that the manifold sects of Christianity differ somewhat in the detailed forms of these three essential beliefs, but not to the same degree as in the case of the secondary additions. God's laws, Christ's teachings, and the inspiration of the Holy Ghost are the recognized guides to conduct; but human frailty has been such that the history of Europe presents a panorama of warring sects in almost unceasing strife about details of ritual and interpretation, while the great fundamental truths have been too frequently ignored. The conflicts of Catholics and Protestants, Puritan and Cavalier, and Northern and Southern Presbyterianism, have not been waged on account of basic beliefs like the three outlined above, or about the Golden Rule, but on account of comparatively trivial details which to the impersonal student have scarcely more than the value of individual preference.

Judaism, the next great religion, has already been mentioned as the parent of Christianity, to which it gave the concept of a Supreme Being, as well as that of a Messiah. It is a purer monotheism than its outgrowth, whose trinity is more like certain elements of Greek theology. Jehovah is the one supernatural power, the creator and lawgiver and immediate cause of all the workings of nature. It is he who shapes the world out of nothingness and who separates the waters from the dry land; he parts the waters of the Red Sea to save the Israelites, and brings them together again to overwhelm the pursuing hosts of Pharaoh. It is his voice that thunders from Mt. Sinai, and his finger that traces the commandments to rule the lives of his chosen people upon the tablets of stone intrusted to Moses the Seer. At the behest of Joshua he holds the sun and the moon in their courses above the vale of Ajalon so that there will be more time for the destruction of the Philistines. In brief, Jehovah is the eternal god of law and power, demanding sacrifice and priestly atonement, and promising happiness eternal upon the bosom of Abraham to those who recognize their responsibility to him and obey his precepts. Again, there are three fundamental beliefs, that differ from those of Christianity as the Talmud diverges from the New Testament scriptures.

Mohammedanism is another outgrowth from this group of religions. The teachings of the Koran give the institutional and ritual forms to the same three elements distinguished above. God is the identical single God; and Mohammed is His Prophet, as Jesus is the New Prophet of Christendom. The true believer's responsibility entails active warfare upon the heretics, that is, those who do not accept the Koran. The immortal state of Mohammedanism is a very different thing from the heavenly bliss of Christianity, for the promised rewards are such as would appeal to the warm-blooded Southern temperament.

Turning now to Asia, we find in Brahmanism and Buddhism two systems of religion that are related to one another exactly as are Judaism and Christianity. The analogue of the Old Testament is a group of priestly hymnal writings known as the Vedas, which date back to about the fourteenth century before Christ lived. Their objects of worship at first are numerous invisible beings that actuate the things of the world, as in Greek theology, but later one of them assumes preëminence as the all-pervading essence of things,—Brahma. The precepts of Brahmanism enjoined adoration of the unseen powers and of their works, as well as practical rules of human conduct, such as those which divided a man's life into the four periods when he should be successively a student, the head of a family, a counselor, and a religious mendicant who should renounce the world of social activities and human desires. In earlier writings, the immortal state is a kind of heaven, but later it meant simply an absorption into Brahma, the eternal impersonal being.

Buddha was an orthodox Brahman reformer of the sixth century before our present era, just as Jesus was an orthodox Hebrew reformer. The essential creed of Buddha made his religion far more ethical than earlier forms, and placed it on a plane even above Christianity of later centuries. This creed relates to the element of human responsibility particularly, the other two remaining much as they were found by Buddha. According to his teachings, a man rested under an obligation to live nobly in the truest sense, and he acquired merit—*karma*—or lost it, in proportion to his deserts. At death a human soul is reincarnated, in a lower form of animal or even in a being residing in one of a series of unseen hells, if punishment is due; if a higher state is merited, progress is made through thousands of existences until perfection is rewarded by an eternal fusion with the essence of Brahma. It is because there is no escape from just punishment that Buddhism in its original form is properly denoted more ethical than a religion which teaches that sacrifice of any kind will exempt the sinner from deserved penalties and bring about the bestowal of unearned rewards.

Polytheism is the name given to a religion such as that of the Greeks or Romans, who believed in many gods and spirits of greater and lesser power. These supernatural beings, each in its own sphere, immediately directed the processes of nature and controlled the lives of men. One of them, Zeus, was regarded as the supreme "father of gods and men," who delegated specific duties to others; Ares was the god of battles, Hermes was the messenger, Athena implanted wisdom in the minds of men, and Poseidon ruled the sea. The gods were very human to the Greek mind, living in Olympus as men do upon earth, and even visiting the mortals. Their worship involved propitiatory sacrifices and rites as well as thanksgiving offerings when favors were bestowed. But although they were immortal, they did not allow the immortal souls of human beings to join them in their elysium, but compelled the disembodied shades to wander unhappily among the tombs and about their earthly abodes.

Roman theology and religion comprise almost identical forms of the three fundamental elements. The names are changed, and Zeus becomes Jove, his wife Hera is Juno, Ares is Mars, and Hermes is called Mercury. In all other respects, however, the two systems are as much alike as the Greek and Roman languages and Greek and Roman physique.

The religions of savagery are far less analytical, and much more naïve in their reference of natural happenings to the direct interposition of malevolent and benevolent spirits. Their gods are numerous as in Greek religion, and likewise one of them is usually set up as the superior deity, to be the Tirawa of the Indian, the greater Atua of Polynesia, and the Mumbo Jumbo of a West African negro. There is no centralization of the supernatural powers, as in the Jehovah of Judaism and the still subtler Brahma of the Asian. Then, too, the gods must be concretely materialized for purposes of worship and sacrifice; consequently idols are made, to be regarded as the actual spirits themselves permanently or for the time being, and not viewed as representations of an ideal, like the statues of more advanced peoples. The immortal state is described in low religions in various ways that seem to be determined by what the believer himself most desires. The spirit of an American Indian goes to the happy hunting-grounds, where it mounts a spirit pony and forever pursues the ghosts of bison which it kills with spirit bow and arrows; to provide these necessaries his earthly possessions are laid beside his dead body. The Norseman was conducted to Valhalla and, attended by the Valkyrie as handmaidens, he eternally drank mead from the skull of an enemy and gloried over his mundane prowess in battle. It is unnecessary to expand the foregoing list, because the examples sufficiently represent the various grades of human religions. Regarding them as typical, we can see how universal are the three fundamental ideas with which we are concerned. Every race has its own conception of future bliss, as well as its conception of responsibility to the immortal and supernatural powers of the universe. Whatever may be the actual reality, and however closely the conceptions of one or another religion may approximate to the truth, such reality and approximation are not the subjects of the present discussion. Nor is it our purpose to bring out more explicitly the genetic relationship of one religion to another; the evolution of Buddhism from Brahmanism, the origin of Christianity from Judaism, and the divergent development of the several creeds of Christendom amply illustrate the nature of religious history. It is evolution here as elsewhere and everywhere.

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Having distinguished the three general elements of all religions, beyond which everything else is of minor importance, we now turn to the question as to the *natural* origin of these elements. Clearly they cannot arise independently, for the belief in supernatural and eternal spirits is closely connected with the conception of an immortal soul.

The first is the conception of infinite personalities that later become more or less merged into one supreme being. This begins with the idea of the soul as the human ego, conventionally regarded as something independent of the material body during life and immortal after death. The savage goes to sleep, and in his dreams he goes upon journeys and battles strenuously with other men and with beasts, only to find when he awakes that his body is not fatigued, and that it has not really taken part in the activities of his dream life. His companions about the fire also tell him that this is so, while he is equally sure that his essential self has been doing many things during the interval of sleep. In his dream life he finds himself joined by others whom he knows are dead. He sees again even those whose bodies he may have assisted in eating. His total world very soon comes to have an unseen region which is the abode of ordinarily invisible beings having the forms of men, with whom his own dream person can associate; this unseen sphere is furnished also with ghostly counterparts of the trees and rocks and waters with which he is familiar when he is awake. Before long his soul or ghost or spirit is conceived as something which possesses two qualities: it can be disassociated from his body and enter the spirit-world where it seems to defy all the laws of waking life, for with the quickness of thought it visits neighboring islands as readily as it passes to the next hut; and it possesses immortality, for it is exactly like the persistent spirit-individualities of those who have died before him. The other cause for the development of the conception of gods and God in the mind of the savage is the fact that things have been made which neither he nor any other man can make. He can dig a ditch, and make a house, and fashion a canoe, and build ramparts of earth; but human power has obviously been insufficient to construct rivers and mountains and forests and their denizens. Mankind itself has certainly been made in some way, for it exists. Because the savage cannot conceive of things being made excepting as they are made by the human hand, and because so much confronts him that is beyond the power of human construction, he comes to postulate the existence of man-like, but greater than human, personalities, and as he cannot see them in the light of day, they belong to the spirit-world to which souls go. Imagination sometimes gives human outlines to shadows among the moon-lit trees, so that elves and pixies, nymphs and fairies, become established in the world as the primitive man conceives it. Larger tasks are discharged by more important spirits, and everything natural thus becomes animated by supernatural beings. Thor was the god of thunder; Freia the goddess of spring and vernal awakening; Athena inspired the minds of men. Venus and Aphrodite played their special parts, also. But such powers as these, established by the untutored mind, needed to be accounted for, and so in the more advanced religions Jove and Jupiter were created as the more ultimate causes, in response to intellectual demands. By combining all powers into one, God and Brahma are the results.

Thus in merest outline the conception of the infinite personality works out its evolution. At all times, among primitive and higher religions, the powers are clothed with human forms, and gods are pictured as men endowed with intellects and passions, and motives of vengeance and benignity. Man cannot shape his postulated deities save in such forms, with the possible exception of the most philosophical concept of all, Brahma.

The second fundamental belief, namely, in immortality, owes its origin in greatest measure to the psychological processes described above. Another potent factor, however, has been the natural desire to continue existence hereafter, usually in order to reap rewards not bestowed here. This desire is implanted by nature through the operation of purely biological factors, and it has the value of an organic instinct. To specify more particularly, nature has placed every organic individual under the necessity of doing its utmost to prolong its own life in the interests of itself, of others of its tribe, and of its species. Extinction is not faced willingly by a human being endowed with full consciousness any more than it is passively tolerated by a lower animal which instinctively struggles with its foes until death. So the desire to continue alive—the "will to live"—is a natural instinct, which combines with the belief in persistent disembodied spirits and, no doubt, with many other elements, to develop the basic conception of some kind of an immortal existence.

The third element, human responsibility to the infinite personality, is variously recorded in lower and higher religions. Its conception grows partly out of the feelings of awe and terror inspired by great works of nature such as the thunder-storm, the cyclone, and the volcano, while the orderly and regular workings of even everyday nature seem to demonstrate the direct control of the powers who rule man as well. The savage sees his crops destroyed by a tempest or drought; he attributes the disaster to the particular powers concerned with such things whom he must have angered unwittingly, and whom he must propitiate by sacrifice or penitence. His individual and tribal acts do not always accomplish the desired ends, and again the laws of infinite and ultimate powers must have been contravened, as he interprets the situation. Therefore his whole religious consciousness was exerted in the direction of finding out what was the ultimate constitution of nature, with which human activities must harmonize if they are to be successful. Bound by custom and convention and biological law, he looks about wonderingly to find the external authority for his bonds. To his mind this authority must be the host of spirits and gods who had made him and the things of his world. It is in this way that so many ethical elements have found places in religious doctrines, to be viewed as absolute rules of conduct coming from outside of nature, and not from nature itself, in the way the earlier sections of this chapter have shown.

Let us now summarize the results of the foregoing brief survey, conducted by the identical methods employed for the analysis of other bodies of fact. We have sought for those characteristics which are common to all religions of whatever time and place and race. Combined with many secondary and adventitious elements of other fields of thought and action, such as social, political, ethical, and psychological factors, they have proved to be the three essential beliefs in God or gods, human responsibility, and immortality. As a veritable backbone, they underlie and support the whole body of religious doctrine and organs of thought formed about them. We have seen, furthermore, that a natural explanation of the way these elements have originated can be discovered by the comparative student of religion, who describes also how they have variously evolved among different peoples. In all of this we have not questioned at any time the validity or reality of any one of these concepts; to ask whether or not they correspond actually to the truth is beyond our purpose, which is simply and solely to inquire whether even these mental conceptions furnish evidence of their evolution in the course of time. I believe that such evidence is found, and I believe also that this discovery must be of the greatest importance to everyone in formulating a system of religious belief, but the construction of this is not the task of science as such. Every individual must work out his own relation to the world on the basis of knowledge as complete as he can make it, but every individual must accomplish this end for himself. Because no two men can be exactly alike in temperament, intellect, and social situation, it is impossible for entire agreement in religious faith to exist. One's outlook upon the whole universe is and must be an individual matter; science and evolution are of overwhelming value, not by directing the mind to adopt this or that attitude toward the unseen, but by providing the seeker after the truth with definite knowledge about the things of the world, so that his position may be taken on the sound basis of reasonable and common-sensible principles.

* * * * *

When we take up science and philosophy, or knowledge as a whole, after religion, it may seem that we have reversed the proper sequence. There are many reasons for following this course, inasmuch as "knowledge" is the all-inclusive category of thought; our world is after all a world of individual consciousness and ideas. In dealing with religion, ethics, social organization, and human culture, we have been concerned with the evolution of so many departments of thought and action; and now we are to develop a final conception of evolution as a universal process in the progress of all knowledge.

Let us look back over the history of mathematics. The primitive human individual did not need to count. He dealt with things as he met them, and he disposed of them singly and individually. A squirrel does not count the nuts it gathers; it simply accumulates a store, and it perishes or survives according to its instinctive ability to do this. Just so was primitive man. The savage, when he organized the first formed tribes, learned to count the days of a journey and the numbers engaged on opposite sides in battle. He employed the "score" of his fingers and toes, and our use of this very word is a survival of such a primitive method of counting. The abacus of the

Roman and Chinese extended the scope of simple mathematical operations as it employed more symbolic elements. With the development of Arabic notation capable of indefinite expansion, the science progressed rapidly, and in the course of long time it has become the higher calculus of to-day. The conceptions of geometry have likewise evolved until to-day mathematicians speak of configurated bodies in fourth and higher dimensions of space, which are beyond the powers of perception, even though in a sense they exist conceptually. The behavior of geometrical examples in one dimension leads to the characteristics of bodies in two dimensions. Upon these facts are constructed the laws of three-dimensional space which serve to carry mathematical thought to the remoter conceptual spaces of which we have spoken. It may seem that we are recording only one phase of mental evolution, but in fact we are dealing with a larger matter, namely, with the progressive evolution of knowledge in the Kantian category of number.

Natural science began with the savage's rough classification of the things with which he dealt in everyday life. As facts accumulated, lifeless objects were grouped apart from living organisms, and in time two great divisions of natural science took form. Physics, chemistry, astronomy, geology, and the like describe the concrete world of matter and energy, while the biological sciences deal with the structure, development, interrelationships, and vital activities of animals and plants. Surely knowledge has evolved with the advance in all of these subjects from decade to decade and from year to year. And just as surely must evolution continue, for the world has not stopped developing, and therefore the great principles of science must undergo further changes, even though they are the best summaries that can be formulated at the present time.

Philosophy deals with general conceptions of the universe. When we look back through the ages we find men picturing the world as an aggregate of diverse and uncorrelated elements—earth, air, fire, and water. The synthesis of facts and the construction of general principles down through Bacon, Newton, and Schopenhauer to modern world conceptions results in the unification of all—"the choir of heaven and furniture of earth." The lineal descendant of the long line of ancestral philosophies is the monism which sees no difference between the living and lifeless worlds save that of varying combinations of ultimate elements which are conceived as uniform "mind-stuff" everywhere. Whether or not this universal conception of totality is true, remains for the future to show. For us the important truth is that here, as in all other departments of knowledge, evolution proves to be real.

* * * * *

In closing the present description of the basis, nature, and scope of the doctrine of evolution, I find great difficulty in choosing the right words for a concise statement of the larger values and results of this department of science. So much might be said, and yet it is not fitting for the investigator to preach unduly. The lessons of the doctrine must be brought home to each individual through personal conviction. But because I firmly believe in the truth of the statement made in the opening pages, namely, that science and its results are of practical human value, it is in a sense my duty as an advocate of evolution to make this plain.

The method of science is justified of its fruits. At the very beginning we learned how, and how only, sure knowledge can be obtained and how it differs from a belief which may or may not correspond with the truth. Based upon facts of smaller or larger groups, scientific laws are so many summaries of past experience, and they describe in concise conceptual shorthand the manifold happenings of nature. Their difference from belief inheres in their ability to serve as guides for everyday and future experience. This entire volume is a plea for the employment of common-sense as we look upon and interpret the world in which we have our places and in which we must play our rôles. Our search for truth will be rewarded in so far as we organize our common-sense observations into clear conceptions of the laws of nature's order.

The doctrine of evolution enjoins us to learn the rules of the great game of life which we must play, as science reveals them to us. It is well to remember that a little knowledge is a dangerous thing, but because evolution is true always and everywhere, an understanding of its workings in any department of thought and life clears the vision of other realms of knowledge and action. Perhaps the greatest lesson is at the same time the most practical one. It is that, however much we may concern ourselves with ultimate matters, our immediate duties are here and now, and we cannot escape them without giving up our right to a place in nature. We are taught by science that we live under the control of certain fundamental biological, social, and ethical laws; we might well wish that they were otherwise, but having recognized them we have no recourse save to obey them. Evolution as a complete doctrine commands every one to live a life of service as full as hereditary endowments and surrounding circumstances will permit. Thus we are taught that the immediate problems of life ought to concern us more than questions as to the ultimate nature of the universe and of existence.

Every one can find something worth while in the lessons of evolution, summarized in the foregoing statements. The atheist, who declines to personify the ultimate powers of the universe, may, nevertheless, find direction for his life in the principles brought to light by science. The agnostic, who doubts the validity of many conventional dicta that may not seem well grounded, can also find something to believe and to obey. Finally, the orthodox theist of whatever creed may discover cogent reasons for many of his beliefs like the Golden Rule previously accepted through convention; and he must surely welcome the fuller knowledge of their sound basis in the materials and results of comparative analytical study. To every one, then, science and evolution offer valuable principles of life, but great as their service has been, their tasks are not yet completed, and cannot be completed until the end of all knowledge and of time.

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"Zoönomia," 135.

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