HUMAN BIOLOGY
AND
RACIAL WELFARE

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PREFACE

Each one of us feels in his own experience an insistent urge to specialize in order that he may do, not a variety of things, but a few things better and more quickly. He must swim with the stream or he will not survive. It is true in business as in science. In one way this concentration is good, and in another it is bad. It is good since it is the essence of progress which makes the world a better place to live in, but the individual suffers. The more successful he is as a specialist, the more difficult it is for him to avoid becoming narrow-minded. Because he does not understand the hopes and aspirations of others he may also become intolerant. He may adopt a condescending attitude toward his fellows whom he regards as less favored.

The situation has not been helped by the action of educators in permitting specialization very early in the curriculum before the students can secure a broad grasp of the problems of human life and of the methods of attacking them. Indeed it grows worse because through specialization, advances in the sciences dealing with man have been so phenomenal that each has come almost to speak in a language of its own which is difficult to understand without much preliminary study. Thus, barriers are erected which prevent breadth of view and which breed intolerance. It is really a vicious cycle which hands out great benefits with one hand and iron-bound restrictions with the other.

The purpose of this book is to play a small part in breaking down these barriers in respect to the group of sciences which have a definite bearing on human welfare and are referred to collectively as "human biology." This will also make for progress because many of the real problems lie between the sciences and are not perceived without broad knowledge. To do so involves team work by many specialists with the idea of describing in simple language the goal which they are striving for. It is also a kind of return to the public for value received for research in the pure sciences is never self-supporting. There must be "give" as well as "take."

The book is written for two groups of readers. First, for students who are about to specialize and can do so more intelligently after they have seen in perspective what lies ahead. This applies particularly to medical students who in order to be good physicians must above all be good biologists. A knowledge of what is known of human life past, present and possible future, is for them essential. In the second place it is hoped that the book will be of interest to readers of mature years occupied both in science and in business who have an inquiring turn of mind and wish to look a little below the surface. In this way it may assist in the movement in favor of "adult education" which is gaining momentum within the United States and is destined to spread.

Valuable suggestions have been received from many quarters not only by the Editor, but by the individual contributors who have one and all entered enthusiastically into the spirit of the enterprise writing on their own responsibility and making acknowledgment when necessary. The editor, however, is particularly grateful to Dr. Conklin, Mr. Embree, Dr. Gregory and Mr. Hoeber for their continued interest and advice.

E. V. Cowdry.

Washington University,
St. Louis,
January 2, 1930.

INTRODUCTION

Edwin R. Embree

IN an essay entitled "This Simian World" Clarence Day has considered what kind of planet this might be if some other species than the great apes had evolved into mastery. He plays with the idea of the dignity and wisdom that might have been displayed if children of elephants had developed into leadership instead of monkey-like animals; what cleanness and cunning would have marked a world ruled by super-cats; what poise and vision might have come with glorified descendants of eagles. But as a matter of fact animals akin to monkeys were the ones who did evolve; it is the children of that race who rule the earth today. The biology derived from this ancestry governs our potential development and marks its ultimate borders.

We inherit some very great liabilities from these animal forebears. Our bodies are weak and puny as compared with the magnificence of elephants. The grace and beauty of the great cats is lacking in our Simian civilization. We have little sense of personal dignity and no real regard for privacy. We congregate in hordes, live together crowded into tenements and hovels. We are unstable, constantly running after new toys and new ideas, rushing, often aimlessly, up and down the earth as our ancestors used to scuttle chattering among the trees.

But we inherited in common with our monkey cousins, one great talent, namely curiosity. And that single quality, probably more than all other things taken together, is responsible for the phenomenal progress of our race. We have an insatiable hunger to know all about everything. This appetite drives us to avid gossip about our fellows; to handling and tinkering with—"monkeying with"—every object or idea that crosses our path; to rushing hither and yon to glimpse a dog fight or view an aeroplane; and also to deep and profound study of intricate problems of medicine and physics.

Two other characteristics have helped us humans in our special type of progress. Our chattering forefathers have given us a love of talk. We are forever gabbling; we have invented great systems of language; we even pay men to talk to us in groups. We store up words in scrolls and books, and build huge temples called libraries in which to hoard this preserved chatter. We compel children to devote years to the study of talk of previous generations. We have invented devices whereby we can speak to our friends thousands of miles away, and machines which record our babble and reproduce it from black metal discs. This ability to talk and our devotion to it is a biological character of our species. It enables us to communicate ideas as well as gossip and to pass on to the whole race our accumulated research and experience.

We have also inherited a compulsion to action. We must always be busy; we rush about, we build and tear down and build again. We are not content simply to inquire and find out everything; but we are driven to *do* something about it all. And this again while it means a lot of aimless motion also results in turning our knowledge of physics, for example, into bridges and steam trains and aeroplanes, and our knowledge of chemistry and medicine into protection of health; into prolonging and making more robust our lives.

These are simply rather picturesque aspects of our biological make-up. Papers in the present volume discuss in fundamental terms various phases of the biology of man and his environment. Such presentation gives an approach to intelligent understanding of ourselves in our present state of development and in our present world.

Our inquiries about our bodies and habits have for many years been taking new directions. From passing curiosity we have turned to deep study of ourselves: our diseases and how these may be cured and prevented, our intellects and how from childhood they can be trained into ever more masterful tools, our emotions and how they may offer increasing pleasure and satisfaction and produce less distress and conflict and distraction. Being members of a group living together in a common world, we are also beginning to study

our group activities and relations. Students of the social sciences are attempting to discover and explain the causes of herd action and that of individuals with respect to the group and also to formulate suggestions of ways by which, if we wish, we may change or modify such conduct for the well-being and happiness both of the individual and of society.

A new factor is transforming world relations. Recent inventions are in effect causing the planet to shrink rapidly. Curtiss, Wright and Lindberg, and Marconi, Edison and Bell have between them practically murdered space. We have crossed the Atlantic in a day and may soon be flying from New York to Tokyo in less time than, a century ago, our fathers moved in ships from Boston to New Haven or in covered wagons from Kansas City to Topeka. Individuals are talking between Philadelphia and London and Berlin as readily as our forebears conversed about the village store. Each of us is using every day houses and clothes and machines and toys some part of which comes from Germany, France, England and Japan. Our whole world of 1929 in many ways is more closely packed together than a single province of France or county of England two or three centuries ago.

We have brilliantly (although not yet with consistent thoroughness) searched out the secrets of the world about us and we have turned this knowledge to very great practical service to ourselves. We have learned much about our own bodies and are now able to protect them against many insidious enemies: germs, harmful foods, improper balance in the action of glands, unwholesome emotions, unsocial acts. With these tentative findings in our possession in physics, medicine, biology, psychology and the social sciences and with more accurate knowledge increasing steadily (although in a spotty manner and along an irregular front), the question arises as to whether it may not now be possible to make another great push forward in human evolution.

It is beside the point to dispute as to the relative importance of inheritance and education, of nature vs. nurture; for any great advance must include attention to both the biological and the social. We must, for instance, find some way to avoid wars if the race is not to destroy itself with its

ever-increasing knowledge of physics and chemistry which may be used for mutual benefit or equally for world destruction. We must improve beyond recognition by present standards both the significance and the extent of our educational system; we must continue to protect our health and lives if we are not to lose irreparably in individual and group progress. But since after all we may assume that we have developed from a definite species and since the limits of our progress are involved in this ancestry and in the degree to which we have evolved from it, a fundamental question of the future is: Can we to some extent control the direction of the evolution of the race?

THE CONTROL OF NATURE

Human progress has been a series of triumphs over natural forces. But when anything new is proposed, certain people cry out that this is a perversion of nature. Of course it is. Man rules by bending the world to his will and to the service of his ends.

Man has progressed by mastery over other forces. He rules, insofar as he does, because he has turned nature to his service. Natural science is a series of victories over other animals and over inanimate forces. Coal, which in the normal "state of nature" lies in deep pockets underground, he has mined and burned to keep him warm and to run his engines; electricity, which naturally is jumping haphazard about the universe, he has harnessed into means for communication and power. He has exploited the tendency of bees to store up honey and has lured these busy little insects into building up great piles of this sweet food, not for themselves, but for man. Cows, that by nature furnish milk for their young, he has perverted into continuing their supply of milk long past the need of their calves so that it may be poured out for his nourishment. He has exploited the seed-bearing nature of fruits and grains and has used this super-abundance of seed for his food; he has crossed one species with another and produced such hybrid foods as the loganberry and the tangelo grapefruit to please his palate, and new varieties of flowers for his enjoyment. He has developed to a state of perversion the normal

tendencies of many vegetables so that larger, richer roots grow on Burbank potatoes, more profuse grain on many varieties of wheat and oats, larger and more succulent stalks on sugar cane. He has interfered with the natural reproduction of animals in order to breed cattle with greater quantities of muscle for him to eat, pigs with nutritious fat for his table, and hens with a penchant for laying eggs. He has produced abnormalities such as oxen and mules where these better serve some special purpose of his.

Man also interferes with nature when he kills parasites which might otherwise cause his illness or death, when he eradicates mosquitoes and so avoids malaria and yellow fever, or when he sets one virus to fight another as in vaccination against smallpox. He changes natural processes when he gives anesthetics to deaden pain and when he aids childbirth by mechanical means or by caesarian operation. The whole story of medicine is a history of triumphs over natural forces. Here again, man is beginning to take an interest in even more vital elements of control. He practices birth control; he makes it impossible for certain of the insane and feeble-minded to reproduce their kind. He is beginning to inquire about the possibility of breeding not only better horses and dogs, but even a finer race of men. Against such proposals many cry: "It is a perversion of nature." Certainly: but no more so than flying in aeroplanes, using milch cows, growing grapefruit or wiping out the cause of yellow fever.

What has been done is nothing compared to that which may be just ahead. It is highly important that in such fundamental matters we proceed wisely, cautiously and on the basis of well established facts. Any constructive activity in human biology must rest upon the carefully assembled findings of wise research and must be supported by intelligent public opinion.

THE CONTENTS OF THIS BOOK

The papers presented in this volume report the results of investigations in a great group of sciences vitally affecting man. They are intended not only to give a general background and perspective to students of special sciences, but also to give to the average intelligent layman some

knowledge of the present state of learning in these several branches of knowledge and to give him some idea of the bearing of the various specialties upon man and the possibilities of his further development. This book is one answer to the lament of H. G. Wells when he says "If only the scientists would tell us *less mumblingly* what it is all about!"

We live in a particular world. Our life and activities are hedged in and controlled by the nature of the earth and the universe of which it is a part. We have throughout the ages speculated about the form and composition of our world and have looked wonderingly at other spheres which seem to our unaided eyes but tiny specks sailing through the firmament of space. Great telescopes have been invented to enlarge the reach of our weak eyes. Through these we explore the heavens and in other ways we are getting slight tentative knowledge of our neighbor worlds. The story of these explorations into the far reaches of the universe is told in Part I, with special attention to conditions of possible life, somewhat similar to ours, upon the other spheres. The magnitude of space and the far stretch of time give perspective to any consideration of man and his world today and in the future.

The stream of life upon our planet leading up to the races of man, or the subdivisions of the human race, is discussed in Part II. By such a critical examination of how changes and new departures in organic life have come about we can look to the future with at least scraps of knowledge of nature's precedents.

In addition to glimpses of the past, for the whole record doubtless will never be unfolded, we need an understanding of the materials nature has to work with in man: the structure of the human body and the ways in which it performs its functions. This subject is presented in Part III.

As biological units we depend upon the world we live in for food, for air and water and light and warmth. We are on a planet teeming with multitudinous life in the form of animals both large and microscopic and of almost infinite varieties of plants, as well as of hundreds of millions of other human beings. We must snatch the means of living from this world; we are constantly influenced by heat and

cold, light and darkness. We are aided by certain animals and plants, which we have domesticated, that is, trained to tolerate and even enjoy being exploited for our food and service. Other species have not been tamed: lions and tigers are still fierce enemies; plants of the jungle and undomesticated herbs which we call weeds fight constantly with us for possession of the land. A notable enemy plant is the prickly pear which is conquering thousands of acres of previously fruitful land every month in Australia. The microscopic forms of life, bacteria and protozoa, threaten us today more than the fierce giants of old. Part IV is devoted to this large subject of environment.

Much of the exact knowledge in medicine and other sciences, reported in Parts III and IV of this book, has been obtained through dissection of human bodies after death and by cautious experiments on living beings—scientists often experimenting on themselves as in yellow fever and typhus—and equally cautious work on animals. The information obtained from the latter source is usually applicable to human beings, since we have many similarities to other animals. Misguided people called "anti-vivisectionists" have attempted to tie the hands of investigators in the use of animals. Women, wearing furs taken from animals trapped and killed with great cruelty, have often expressed the most sentimental sympathy for animals used under merciful conditions for experimental work. Such people, even when consistent and actuated by the best of motives, are often unaware of the use of anesthetics in animal experiments and of the care with which the research is carried out, and also of the intensity of human suffering which such experiments tend to relieve or prevent. Dr. W. W. Keen has suggested that agitators against animal experimentation should be compelled to watch preventable death with all its grimness in hospitals and homes or be confronted with a dead guinea pig and the dead body of one of their friend's children and be asked to choose between them.

In the final division, Part V, the future is discussed on the basis of facts presented earlier and of studies of the tendencies of evolution in man and other animals. In this section is included a tentative report on the inheritance of disease

and a consideration of population growth, the mingling of races, and the question of the purposeful improvement of the human species.

THE PROPER STUDY OF MANKIND IS MAN

Studies in human biology are now for the first time coming into their own. With a basis of exact science in mathematics and physics and chemistry, all biology begins to have a firm foundation. It will always be difficult to make exact observations and to formulate theories which govern living organisms as compared to the accuracy of studies in pure mathematics or of inanimate matter. It is more difficult still to arrive at exactness when research concerns human beings as contrasted with simpler forms of life. But progress is being made. The recent advances in preventive medicine are among the great triumphs of science of all time. Knowledge applicable to man's welfare is now coming in other phases of biology. Studies in physiology and chemistry are giving information concerning glands and diet that have direct influence upon life and health. Biologists with a background of statistics are bringing in information concerning wide tendencies in disease and death, in population growth and potential evolution. Men called anthropologists are searching out the history of past races and the life and habits and customs of living peoples in diverse parts of the earth, and by putting together all this information they give us some idea of the directions in which we are developing and of ways in which we may shape the course of our own progress. Sociologists and political scientists and economists are beginning to glean objective evidence of the ways we live together and act in group life. Psychologists and psychiatrists are delving into our minds—even our subconscious thoughts and emotions.

Each science depends upon the others. It is largely because of the progress in such fundamental disciplines as physics and chemistry that advance is now possible in general biology and in the biological aspects of man. The present volume is a compendium of present knowledge in the several subjects that comprise the study of Man as an Animal. It should serve as a record against which to measure the rapid and significant advance that may be just ahead.

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PART I. PERSPECTIVE

HUMAN BIOLOGY

Chapter I

LIFE IN SPACE AND TIME

Henry Norris Russell

FEW problems arouse more widespread interest than those of the extent of life in time and space. "Are there other inhabited worlds than ours?" "How long has life existed in this world?" "How long may it continue to exist?" These are far from easy questions; but, by patient accumulation of all the available data, a more definite approach to an answer may now be given than seemed possible a decade or two ago.

We must first, of course, define our terms. "World" may be used in its widest sense, to denote any body whose existence can be observed, or rationally conjectured, within the known universe. "Life," if we are to remain in the realm of science, must be restricted to connote organisms whose chemistry and metabolism are of the same general nature as those which are common to all terrestrial life, animal and vegetable. Organisms of radically different composition and structure may conceivably exist; but our present knowledge of nature does not justify any extended speculation concerning them.

Thus specified, our problem falls naturally into successive parts: First, we may enumerate those physical and chemical conditions which appear to be necessary for the existence and permanent maintenance of life of the kind that we know. Second, we may review the bodies known to astronomy, considering which of them pass the tests just laid down, and so may be the abodes of life, and what evidence there is to believe that any of them actually are so. Third, we may consider the evidence which bears on the past duration of life where it now exists, and the probable interval during which it may continue to flourish. Lastly, we have to assess the probability that other habitable and inhabited

worlds, not accessible to present means of observation, may exist within the known universe.

THE CONDITIONS NECESSARY FOR LIFE

These may be summarized as follows:

(a) *The Presence of Those Chemical Elements which are Essential Constituents of Living Matter.* It was once uncertain to what extent this condition might be fulfilled, and, indeed whether elements unknown on earth might not exist, or even predominate, in other worlds. The evidence of the spectroscope has settled the matter. Lines which reveal the presence of familiar terrestrial elements are found in the spectra of the remotest observable nebulae, millions of light-years distant. As science advances, one after another of the groups of "unknown" lines which were supposed to indicate the existence of strange elements have been identified as due to known elements under new conditions, until hardly anything remains. The same elements, therefore, are found everywhere in the universe. What is more, there is good evidence that they are everywhere present in much the same proportions, and that the well-known differences between the spectra of the hotter and cooler stars arise not from differences of composition, but from differences in the physical conditions, which put sometimes certain elements, and sometimes others, into a condition to absorb lines in the rather limited spectral region which can be observed.

Most of the important constituents of living organisms: hydrogen, carbon, nitrogen, oxygen, magnesium, calcium, iron, are shown by direct evidence to be widespread, if not ubiquitous. For a few, such as phosphorus and chlorine, evidence is lacking, on account of the absence of suitable lines of these elements in the observable part of the spectrum; but the general evidence for the uniformity of nature is so impressive that there can be no doubt that these, too, are to be found wherever extensive aggregations of matter exist.

(b) *The presence of certain compounds* which are of especial importance to life; and, most of all, of *water* and *carbon dioxide.* The relation of these substances and their properties to life has been so ably discussed by Professor Henderson

as to make repetition superfluous. But, though the raw materials for these: carbon, oxygen, hydrogen, are widespread, it cannot be expected that the compounds themselves will be found everywhere. It is well known that a celestial body of small mass, such as the Moon, cannot permanently retain an atmosphere. The molecules of a gaseous atmosphere are in rapid motion, and flying about in all directions, and only the gravitational attraction of the body keeps them from diffusing away into the practically perfect vacuum of interplanetary or interstellar space. For a body no larger than the Moon (and at ordinary temperatures), gravity is not strong enough to keep them back, and an atmosphere, even if one were artificially supplied, would escape into space. Carbon dioxide, being gaseous, would escape (though more slowly than the lighter gases) and water-vapor would be readily lost, so that liquid water, too, would gradually evaporate away.

The Earth's attraction is abundantly sufficient to retain an atmosphere, and as we shall see later, Mars is also able to do so. For bodies roughly similar to the inner planets of our system, the limiting size, below which an atmosphere and ocean cannot be retained, appears to correspond to a diameter of about 3000 miles. We may expect smaller bodies to be airless, waterless, and lifeless, while on those considerably larger, water and carbon dioxide are likely to be ubiquitous.

(c) *A Surface Temperature Below the Boiling Point of Water at All Times, and Above the Freezing Point at Least at Regular Intervals.* It is a commonplace that *liquid* water is a necessity for the growth and reproduction of life, though not for its mere existence in a dormant state. Terrestrial experience shows that life, however, may persist under alternations of temperature with a very low minimum, provided that the maximum temperature is above freezing and lasts long enough. If this condition is met, the lower limit of the fluctuation could probably descend far below any observed terrestrial temperatures without making life impossible. The upper limit appears at first to be more sharply defined, for even temporary boiling appears to be fatal, and most terrestrial forms succumb at temperatures

far below 100°C. It is noteworthy, however, that some organisms, such as the algae of the Yellowstone hot springs, maintain themselves at temperatures but a few degrees below the boiling point. How far life could follow the rise of boiling point with higher pressure, we do not know. It might even be that some resistant spores, or their equivalent, might survive evaporation to dryness; but the upper limit, as stated above, may serve as a basis for our further discussion.

(d) *A Supply of Light Sufficient for Photosynthesis.* Whether this, again, is an absolute requirement is hard to determine, for it is conceivable that organisms might derive their supplies of energy from chemical reactions, starting with inorganic materials; but the presence of light is certainly highly favorable to the maintenance of life, and probably to its origin as well. Indeed, it has recently been shown that light alone, in the presence of inorganic catalysts, suffices for the photosynthesis of fairly complex compounds.

Ultraviolet light needs special consideration. The shortest waves transmitted through the Earth's atmosphere (from 3500 to 3000 Ångstrom units) are very potent physiologically, and on the whole, highly beneficial. The shorter wave lengths are very injurious, indeed lethal, which is doubtless a consequence of the fact that terrestrial organisms are never naturally exposed to them. That different limits of tolerance could be developed under different conditions is probable.

The last two conditions demand that the abode of life shall be a *planet*, revolving at an appropriate distance about a self-luminous star, from which it derives its light and heat.

The conditions already stated appear to be either rigorously necessary, or at the least, probably so, for the very existence of life upon a planet. Those which follow, though perhaps not unconditionally requisite for the development and maintenance of life, are so much in its favor that they should be added to the list.

(e) *The Existence of Land Areas.* On a planet meeting the other conditions of habitability, but bathed in a shoreless ocean, life of suitable terrestrial forms might maintain

itself indefinitely if transplanted under favorable conditions. But how life could have originated on such a planet is a hard question. Without trespassing on the field of the biologist, reference may be made to the belief that the appearance of such complex systems as the simplest of living things is far more likely to occur if there exists a large number of more or less isolated local environments, such as would be provided by tide-pools or fresh-water ponds, than in the uniform conditions of the open sea. Indeed, in a sea so deep that no light reached the bottom, it is very hard to see how life could get any start. The presence of land, that is the absence of excess of water, appears therefore to be almost a necessary condition.

(f) *Rotation of the Planet.* This again is hardly a *sine qua non*, but, nevertheless, important. The regular alternation of day and night, and the seasonal changes which accompany it if the equator is inclined to the plane of the orbit, greatly increase the area of the planet's surface over which favorable temperature conditions are attained, and the rhythmic alternation of the environment is pretty well recognized as a favorable factor in evolution. The effective alternative to rotation is of course a state in which the planet keeps the same face always toward its primary—as the Moon does toward the Earth, or Mercury toward the Sun. Under these conditions, the range of temperature from one side of the planet to the other will be very great, and the atmospheric circulation probably very violent, and the conditions, though not necessarily fatal to life, will be clearly unfavorable.

(g) *Atmospheric Oxygen.* Free oxygen is a prime necessity for animal life, and a waste product of most vegetable forms. One cannot exist without consuming, nor the other without producing it. Yet, though it is so intimately associated with the higher forms of life, this is not the case with the lower. Many bacteria, for instance, can grow only in its absence. There appears, therefore, to be no sufficient reason for laying down the presence of free oxygen as a prerequisite for the origin of life upon a planet. Other chemical reactions than those involving direct oxidation might have provided the primordial forms of life with the required energy.

We are so used to the existence of free oxygen in the atmosphere, so abjectly dependent on it in fact, that it is hard for us to realize how remarkable it is that a gas so chemically active should be present in large proportions. Free chlorine would be only a little more surprising. There are many purely inorganic reactions that take oxygen out of the atmosphere, and that on a very large scale, and no known inorganic processes which put any in. Should all earthly life perish, while geological processes went on, we might expect a steady depletion of the atmospheric oxygen. Practically all volcanic rocks contain considerable quantities of the ferrous compounds of iron, which are incompletely oxidized, and on weathering pass into the ferric state, with absorption of oxygen. Volcanic gases, moreover, have never been found to contain free oxygen, but often contain élements avid for combination with oxygen, so that they are sometimes actually combustible. The evidence indicates, indeed, that the materials of the Earth's crust as a whole, down to a depth of say twenty or thirty miles, are definitely unsaturated with respect to oxygen. If the whole crust should be fused and thoroughly mixed, it appears very probable that all the oxygen of the atmosphere would be absorbed by the ferrous iron of the molten lava, and might not nearly suffice to oxidize it.

There is little reason to suppose that the Earth is of an exceptionally unoxidized composition (especially as compared with bodies of similar density, which alone can be planets with land and water areas), and it does not therefore seem probable that free oxygen should be an initial constituent of a planetary atmosphere. It might indeed be liberated by inorganic means, for example, as has been suggested, by the dissociation of water-vapor at a high temperature, and the escape of the fast-moving hydrogen atoms from the atmosphere, leaving oxygen in excess. But as the molten mass cooled, it is hard to see how this oxygen could escape chemical combinations with the vast mass of incompletely oxidized lavas, rendered more active chemically by the presence of water at high pressure and temperature.

Vegetation, on the other hand, is continually breaking up carbon dioxide, and pouring oxygen into the atmosphere,

and under terrestrial conditions a certain proportion of the carbonaceous and other reduced compounds, which represent the other side of the equation, are buried in sediments, and so withdrawn from the cycle of change.

If conditions on our own planet can be taken as a guide, it would appear, therefore, that an oxygenated atmosphere may be regarded, not as a prerequisite for life, but as its result, and as strong evidence that life exists upon the planet, or, at least, has existed in the past, within an interval comparable with geological time.

The oxygen of the Earth's atmosphere is of importance to life in another fashion, less widely known. High in the upper air, more than twenty miles from the surface, a small proportion of it is transformed into ozone, probably by the influence of short-wave radiation from the Sun. Though transparent to visible light, ozone has a remarkable power of absorption for the ultraviolet rays; and, owing to its presence, no radiations of wave-length shorter than 2900 Ångstrom units reach the surface, though the Sun doubtless emits them powerfully. This limitation is a great tribulation to the spectroscopist; but, were the ozone removed, the short waves, whose injurious effects are well known, would have a most disastrous effect upon life at the surface. A very small quantity of oxygen in the atmosphere would however probably suffice to produce enough ozone to afford effective protection.

One or two other factors may perhaps be mentioned. The *superficial gravity* of the planet, though it would have a great deal to do with the limiting size which could be attained by land animals, appears to interpose no fatal obstacle to the existence of life, even were it far greater than on earth. But too small a force of gravity would permit the escape of atmosphere, and make a world uninhabitable.

Again a certain minimum *atmospheric pressure* is necessary if liquid water is to exist at all, for if the pressure is less than $\frac{1}{170}$ that which prevails at the Earth's surface, ice would evaporate directly, at a temperature below its melting point. A high atmospheric pressure and density would presumably greatly influence the modes of respiration and locomotion of animals; but the only limit which can be set

corresponds to a thickness of atmosphere so great that, even in the absence of haze, little or no light from without could reach the planet's surface. An atmosphere many hundreds of times as thick as the Earth's would be required to approach this limit.

THE HABITABILITY OF KNOWN ASTRONOMICAL BODIES

We may now pass briefly in review the bodies known to present-day astronomy, examining whether, and to what degree, the conditions for the existence of life upon them are met.

When it is realized that the number of these extra-terrestrial bodies is about a billion,* this sounds like a formidable project. But the overwhelming majority of this vast multitude may be dismissed at once. Almost all of them are *stars*, self-luminous masses of incandescent gas with temperatures which rise to millions of degrees in the interior, and, even at the surface, range from more than 20,000°C. down to 2000°C. for a few exceptionally cool stars. There can be no thought of life here, unless in poetic fancy, such as that which makes the angel in Moody's "Masque of Judgment" retire to ponder on deep problems of theology: "Where in the Sun's core light and thought are one."

The *nebulae*, too (the only other bodies which are visible at interstellar distances) fade from our list at once. Some, like that in Andromeda, are vast clouds of stars, so remote that their very light takes a million years or more to reach us. Others, like that in Orion, are clouds of gas and dust, so rarefied that there is no more matter in a cubic mile of their substance than in a cubic inch of common air.

Comets, too, such as we know in our own system, are mere "airy nothings" of very low density, and incapable of supporting life.

Planets alone, as has already been said, can be habitable, and here the limits of our observing powers begin to be felt. The stars, even the nearest of them, are so remote that planets like ours, if revolving about them, would be

* The common American usage, according to which a billion = 10^9 = 1,000,000,000, requires explicit statement, but hardly an apology.

utterly invisible with the greatest telescopes yet built, or even dreamed of; nor is there any other way at present known to science by which their existence could be certainly detected.*

We are thus confined perforce to the consideration of the planets of our own solar system, and the number of cases which we have to deal with is cut down from a billion to a little over a thousand. Most of these, again, drop out, when we consider that the *asteroids*, which number more than a thousand, are without exception less than 500 miles in diameter, and far too small to retain a trace of atmosphere. The same can be said of the 26 *satellites* of the various planets. Two or three of the largest may be a little better able to hold an atmosphere than the Moon, but none of them can actually retain one, unless they are too cold to be habitable.

Only the eight principal planets now remain. One of these is our own home, and out of the contest. Of the rest, the four major planets: Jupiter, Saturn, Uranus and Neptune, appear to be hopeless. All four are of low mean density, and their solid or liquid cores, if they have such, must be surrounded by atmospheres thousands of miles in depth. Their visible surfaces are composed of clouds, but not of clouds such as those with which we are familiar, for these surfaces are exceedingly cold.

It is only within recent years that the determination of planetary temperatures by observation has become practicable. To attempt it, we must be able to measure the heat which reaches us from the planet; and this is excessively small in amount. With a thermopile composed of wires of brittle alloy, fine as hairs, mounted in a vacuum, with a great reflecting telescope to concentrate the radiation of the planet on such an instrument, and an exceedingly sensitive galvanometer to record the minute currents which are produced in it, the problem has been solved, and extensive radiometric observations have been made by Coblentz and Lampland at the Lowell Observatory, and by Pettit and

* The partial eclipse of a small star by a very large planet might perhaps produce an observable diminution of light; but this test would not distinguish between a cool planet and a faint companion star, still far too hot to be habitable.

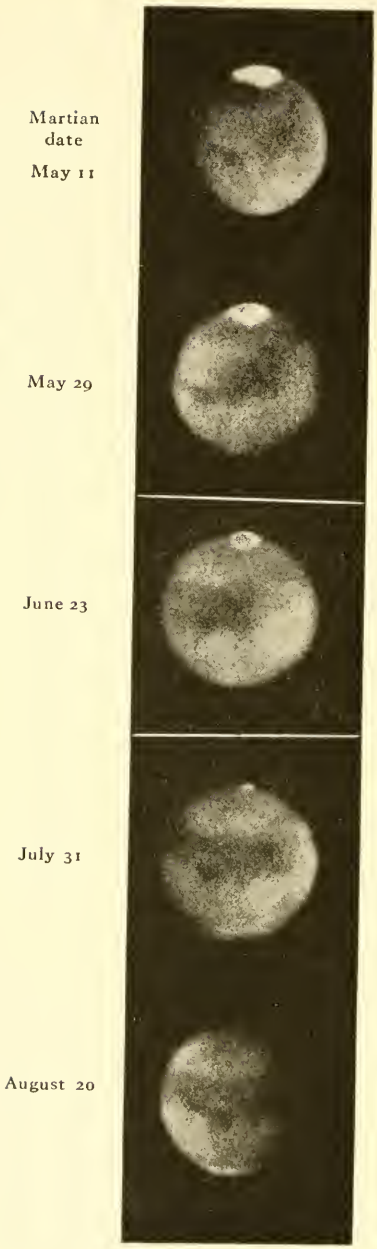

Fig. 1.

Nicholson at Mt. Wilson. The heat which reaches us from a planet is, however, of two kinds. One is carried by the solar rays which have been reflected from its surface or atmosphere, along with the light by which we see it. The other comes from the solar energy which has been absorbed by the planet's surface, has heated it up, and is then re-emitted in virtue of the temperature of the surface. To distinguish between the two is practicable, because the reflected radiation (speaking broadly) is carried by short waves, and the "proper" radiation of the planet by waves ten or twenty times as long. A suitable screen, such as a plate of glass, or a cell containing water, is transparent to waves of the first sort, and stops those of the second, so that the effects of the two can be separated. From the observed percentage of transmission it is possible to calculate the temperature of the planet's surface (with some reservations).

When this process is applied to Jupiter or Saturn, it is found that practically all the heat which we receive from them is carried by the reflected sunlight. Unless the surface temperature is more than 100° below zero, a readily measurable amount of planetary radiation would be superposed upon this; where we find hardly any; and the detailed computations lead to a temperature of about −130°C. for Jupiter, and −150° for Saturn. These are but little above the temperatures at which the radiation of the Sun, enfeebled by distance, would suffice to keep the surface. It is therefore clear that, whether or not the interior of the planet is hot, very little heat must leak out to the surface. Uranus and Neptune, being farther from the Sun, are doubtless still colder, and direct observations of the former indicate that this is so.

Higher temperatures may prevail in the sunless interior, but the low density shows that this interior is either so hot

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FIG. 1. Mars. Actual photographs of planet Mars taken through large telescope showing successive stages of development during Martian summer. Dates given with photographs are seasonal dates on Mars which correspond to our calendar dates. Note gradual decrease of snow at pole and darkening of planet's tropics with advance of Martian summer. This gradual darkening of certain regions of planet in his summer season and their subsequent fading in winter are best explained by assuming that darkening is due to growth of vegetation. (By E. C. Slipher, Lowell Observatory.)

as to be gaseous, or else the core of the planet is surrounded by an ocean thousands of miles deep.

These four planets, therefore, are in all probability lifeless.

The case of Mercury is still worse. All the tests show it to be devoid of atmosphere and water. One face, turned continually towards the Sun, reaches a temperature of 400°C. (as shown by the radiometric measurements). The other, in permanent darkness, must be exceedingly cold. No more inhospitable world could be imagined, it is a real Inferno.

Two worlds only, out of a billion, remain, Venus and Mars, and in these cases the conditions are more favorable. Both are large enough to retain an atmosphere, and both actually possess one; one is hotter than the Earth, and the other colder, but neither is outside the limits of tolerance. They and they alone, need discussion in detail.

Venus, until a few years ago, appeared the most favorable known habitat for life outside the Earth. Though she receives twice the intensity of solar radiation that we do, the reflecting power of her surface is high, and less heat in proportion remains upon the planet. The radiometric measures indicate a temperature of about 60°C. for the sunlit side (which, though rather high, is not out of the question), and −20°C. for the dark side (not impossibly low). The existence of an atmosphere is proved conclusively by the appearance of twilight when we see the planet as a thin crescent. Above the visible surface, this atmosphere appears to be less extensive than the Earth's; but this surface may well be composed of clouds. The uniform whiteness of the surface, and the absence of definite markings have long been recognized as favorable to this view; and the remarkable photographs of Ross in 1927, which show darkish spots visible by ultraviolet light only, and changing from night to night, go far to settle the matter.

After three hundred years of observation, the planet's rotation period is still unknown. There is no doubt that it is much longer than the Earth's, and it was at one time supposed that, like Mercury, Venus kept one face always toward the Sun; but this is hardly reconcilable with the

relatively high temperature of the dark side, and it is probable that the rotation period is a few weeks in length.

All these indications are favorable; but the crucial test remains, i.e. the composition of the atmosphere. Fortunately oxygen and water vapor show numerous absorption lines in the observable region, mainly in the red, and can be detected by spectroscopic means. The application of this test to the planets is hindered by the fact that we have to observe through the Earth's atmosphere, which is rich in both substances. But, if the planet is observed when it is rapidly approaching the Earth, or receding from it, the "Doppler shift" due to this motion sets the lines produced in the planet's atmosphere a little to one side of the stronger ones arising in that of the Earth. Even if the two are not clearly resolved, measures of the position of the resulting blend will show what the relative intensities of the two absorptions are.

This ingenious method, devised independently by Lowell, Campbell, and St. John at the three great observatories of the Western United States, has been applied to Venus by the last-named astronomer. Not the slightest effect due to the presence of oxygen on the planet could be detected, though the lines should have been clearly separated. By comparison with laboratory measures, he concludes that the quantity of oxygen above the visible surface of Venus must be less than $1/1000$ of that in the Earth's atmosphere. This test is apparently decisive. The spectroscopic test for water vapor also gave a negative result; but it is much less delicate, and a small quantity might escape detection.

It would seem decidedly improbable, on general principles, that Venus, which is quite as much like the Earth in size and mass as one of a pair of twins is usually like the other, should have been initially entirely devoid of water while the earth had so much. Escape of water vapor against the planet's gravitation appears to be out of the question. The cloud-like forms observed with ultraviolet light suggest condensations of vapor of some sort, and nothing else than water appears to be at all plausible in the connection. But how so little vapor can exist above the clouds, if they are really composed of water, at a relatively high tem-

perature, is hard to see. The stratosphere, or isothermal layer, in the upper part of the Earth's atmosphere, is almost free from water vapor, though the troposphere, or lower atmosphere, is full of it. If a similar demarcation exists on Venus, and if the lower atmosphere is full of clouds to its very top, the observed phenomena may perhaps be explicable.

The absence of oxygen cannot be similarly explained, for, not being subject to condensation, it would diffuse freely into the upper atmosphere. It must apparently be accepted that Venus is devoid of oxygen, and this points strongly to the conclusion that neither animal nor vegetable life is present upon the planet. Why this should be the case is a matter of conjecture. The suggestion has recently been made by Webster that, if the planet's rotation is slow, and the difference of day and night temperatures as great as is observed, winds of great violence will blow from the warmer to the colder regions, and it may well be that marine erosion has more than overtaken the forces of elevation, so that the planet has been, for the most of its history, covered by a shoreless sea, in which life had no chance to arise; nor would its opportunity have been much better on incessantly storm-swept coasts. It may be, on the other hand, that there is no water on Venus, in spite of the *a priori* probability, and in this case the absence of life follows necessarily.

Though much remains to be known about the conditions which prevail upon this, the nearest of the planets, the conclusion that life, as we know it, is not to be found on Venus appears to rest on firm foundations.

So we come finally to Mars, and to a situation singularly contrasting with that of Venus. Though of little more than half the Earth's diameter, Mars has a surface-gravity 38 per cent as great as the Earth's, and is fully able to retain an atmosphere. It actually possesses one, as many things prove, but one less extensive than ours. The amount of atmosphere above a square mile of the surface appears to be between one-tenth and one-half as much as on the Earth, which, under the smaller force of gravity, would give an atmospheric pressure at the surface lying between

4 and 20 per cent of that under which we find ourselves. The atmosphere is clear, and usually permits a good view of the planet's surface, especially if the observations are made with yellow or red light. Clouds, though occasionally observed, are very rare, and permanent surface markings are numerous. With the aid of these, the rotation period has been accurately determined as $24^h\ 37^m\ 22^s.\ 58$, only a little longer than the Earth's, while the equator is inclined to the orbit by 25°, which leads to a sequence of seasons very like our own. Noteworthy seasonal changes have been known ever since the planet was first observed telescopically. The most conspicuous of these is the alternate waxing and waning of the white polar caps, which shrink in summer and form again during the winter night, exactly as snow-caps might be expected to do. Unlike the Earth's polar snows, however, they become very small in late summer, the northern cap diminishing to 200 miles in diameter, and the southern (which has its summer when Mars is nearest the Sun) sometimes vanishing altogether. That these caps are formed by some substance which, like snow, is precipitated from the atmosphere in cold weather, has never been doubted; and there is no longer any question that they are actually composed of frozen water.

Radiometric measures of temperature, dealing not only with the planet as a whole, but with separate regions of the disk, were made extensively during the favorable oppositions of 1924 and 1926. The results obtained independently at Flagstaff and Mt. Wilson show that the temperature rises at noon in the tropics to 10° or 15°C. (50° to 70°F.), and gets almost as high at the poles in the latter part of the long summer day (which endures for almost a year of our time). At night, even at the equator, it falls below the freezing point, and the polar nights must be cold indeed.

This is exactly the right temperature range for the appearance and disappearance of snow or frost; and the conclusion that water exists on the planet's surface is put beyond doubt by spectroscopic observations, which show that there is water-vapor in the atmosphere, though only to about 5 per cent of the amount present in the Earth's.

The amount of snow in the polar caps can be roughly estimated from the fact that the heat which is received from the Sun during the season is sufficient to melt and evaporate it, and it is found that when melted they would form a layer of water averaging only a few inches deep. All the water resulting from the melting would be too little to fill Lake Erie, and it is evident that Mars, as a whole, must be a very dry planet, and that desert conditions must prevail over most of its surface.

The spectroscopic test reveals oxygen, too, in the atmosphere of Mars. The Mt. Wilson observations indicate that the quantity of this gas, above a square mile of the planet's surface, is about 15 per cent as great as for the Earth. The corresponding partial pressure of oxygen at the surface is 6 per cent of the terrestrial value, too little to support human respiration but probably within the limit to which life could adapt itself. The presence of oxygen appears to be intimately connected with a characteristic of the planet, which has been known longer than any other, namely its red color. The greater part of the planet's area is rather uniformly of this hue and all students agree in the belief that in these portions we see the bare surface in its natural color. Now unweathered igneous rocks are not usually red, though they are so occasionally. The incompletely oxidized ferrous compounds give them a grayish or blackish tone, sometimes of a bluish cast. But the fully oxidized products of weathering of such rocks are usually colored yellow or red by ferric oxide. Mars shows just such a color, while among all the other bodies of our system whose bare surfaces we can see (Mercury, the Moon, and the asteroids and satellites) not one has an atmosphere, nor is one red. The absence of red, even in patches, upon the airless surface of the Moon is especially noteworthy.

The most interesting of the Martian markings remain to be discussed. The dark areas, which cover about 35 per cent of the surface, are of a greenish or bluish-gray hue, in contrast to the reddish-yellow of the rest. They were once supposed to be seas, but this cannot be true, for, if they were, the reflection of the Sun from the water surface would be by far the most conspicuous feature upon the

planet. They show, too, conspicuous differences of intensity, and depth of color, within their own areas, which could hardly occur in water unless it was very shallow. Most noteworthy of all, they exhibit marked seasonal changes. Even the principal markings, though of fairly permanent form and position, vary greatly in intensity, being at times conspicuous, and again almost invisible.

Speaking broadly, they are most prominent in the spring of the hemisphere in which they lie, and tend to fade out in the autumn and winter, at which season the color sometimes changes from greenish to yellow or brown. These changes, though repeating themselves roughly in successive seasons, show considerable irregularity.

Crossing the lighter regions between the dark areas, and in some cases the latter themselves, are the finer markings known as the *canals*, discovered by Schiaparelli in 1877. No doubt remains of the reality of such markings, for many of them have been photographed time and again. The photographs show, too, that the canals are of the same general color as the dark areas, for, like the latter, they come out strongly on photographs taken with red light, and are inconspicuous with blue or violet. It is well established, too, that they show seasonal changes in visibility which run parallel to those of the dark areas.

On one further point all observers of the canals are agreed; they are difficult and elusive, and can be well seen only at those favorable times when the incessant turbulence of the Earth's atmosphere, which produces the confusion of the telescopic image known as "bad seeing," quiets down for a few moments and permits a relatively clear view of the planet. Concerning their appearance, when best seen, experienced observers are in extraordinary disagreement. Some, like the late Percival Lowell, drew them as fine sharp lines, following great circles on the sphere for hundreds of miles, meeting by threes, fours, or more, at sharply defined points, and covering the whole planet with a geometrical network. Others, such as Barnard, described instead a complex mass of fine detail, appearing as if it "had been painted with a very poor brush, producing a shredded or streaky and wispy effect," but failed altogether

to see the sharp geometrical network; and many intermediate drawings and descriptions exist.

There is no room here for a full discussion of this problem; but it may be said in brief that the only reasonable explanation of these discrepancies appears to lie in what astronomers call "personal equation." The process of recording, by sketch or verbal description, details which can be seen only by glimpses of a few seconds' duration when the air is steady, is one of extreme complexity; and psychological elements in the report which the eye makes to consciousness are apparently important. The most skilled and scrupulous observers cannot discriminate between the objective and subjective elements in such a report of his senses, and so the discrepancies arise.

There is little reason to hope that keener eyes, or better atmospheric conditions, will be available for work on Mars in the future than there have been in the past, and it appears necessary to leave the question of the exact appearance and arrangement of the finer Martian markings *sub judice*, as a matter not at present determinable; while admitting their reality. The photographs, unfortunately, cannot settle the question, for the details in question are so fine that the grain of the plates would conceal them, even if no other difficulties existed.

All the necessary and important conditions favorable to life appear to be present on the surface of Mars: an adequate temperature, sunlight, water, atmospheric oxygen, a land surface, days and seasons. The force of gravity at the surface, and the atmospheric density, though less than those to which terrestrial life is adapted, appear to be well within the limits of possible adaptation.

Two independent lines of evidence point toward the actual existence of vegetable life upon the planet. The first is the character of the seasonal changes in the dark areas and canals. The brief description already given shows that these are just what might be expected from the growth of vegetation, as the temperature rises in spring, and the water locked up in the polar cap is released, and its dying down in the cold and dryness of late autumn and winter. The fact that the changes, in successive Martian years,

though similar, by no means follow exactly the same routine, is in full accord with this view, as is also the nature of the observed variations in color.

Though the hypothesis of vegetation offers a sufficient explanation of the observations, it is by no means a necessary one. Arrhenius, for example, has suggested that similar variations in appearance would be presented by saline deserts, playas as they are called in the Southwest, which, in the rainy season, are seas of dark mud, while in the dry season the efflorescent salts come to the surface and the color-tone is much lighter. Even in the absence of actual rain, the absorption of moisture by hygroscopic salts might produce a similar effect. That such areas should exist in a desert planet, whose surface has been extensively weathered, is highly probable, and the seasonal changes, alone, can hardly be regarded as decisive evidence in favor of vegetation.

The presence of a considerable amount of oxygen in the atmosphere, however, cannot be accounted for on the salt-desert theory, while it is an immediate consequence of the presence of vegetation. Indeed, as has already been said, it is hard to see how the oxygen could have got into the atmosphere by inorganic processes, or remained there permanently if it had. In the writer's judgment, the combined evidence makes the existence of vegetation upon the surface of Mars highly probable, though it cannot be said that it establishes it beyond all doubt.

Granting this, the canals are simply interpretable in accordance with W. H. Pickering's suggestion that they represent narrow strips of vegetation along valleys or water-courses of some sort, where there is more moisture available than in the surrounding deserts. The canals in the dark areas, whose existence appears to be well authenticated, would then be bands of richer vegetation in a country of sparse growth, and the seasonal changes in the canals are immediately explicable.

The importance of such a conclusion to a general philosophy of nature is obvious. Life, amazing as it is in the complexity and delicate adjustment of its processes, is not confined to our world alone, where we might suppose

its origin to be due to some happy, but almost infinitely improbable, combination of favorable conditions. There are but three bodies in our system upon which life as we know it could have the least chance of survival. If it is present upon two of these three, it is reasonable to suppose that, if favorable physical conditions exist elsewhere in the universe, life would stand a good chance of coming into being.

Whether animal life, and, still more, intelligent life, exists on Mars is a harder question. With oxygen to breathe, and vegetation to provide food, animal life might well exist; and we can assign no reason why intelligence should not have evolved. But to obtain evidence of the existence of such life, if it exists, upon a planet which never comes nearer than about 35,000,000 miles would be a hard matter. As is well known, Lowell believed that he had secured such evidence, and his arguments were of a thoroughly scientific character and deserve careful consideration. Briefly stated, they are as follows:

The network formed by the canals, which run in great circle courses across hundreds of miles of desert, suggests a geometrical diagram far more than a map. Accepting the belief that they are water-courses, or rather the fertile land on each side of these, it is beyond the bounds of credulity to suppose that a system such as is shown on Lowell's drawings is the product of geological forces; it appears obviously, indeed glaringly, artificial. Hence the "canals" represent strips of irrigated land flanking artificial water-courses, and were laid out by intelligent creatures of high engineering skill. As the polar snows recede, the canals darken (vegetation grows). This "quickening" of the canals progresses steadily toward the equator and even beyond, and, in some cases, half a Martian year later, it has been seen to follow the same canal in the opposite direction. Now water may flow down hill one way, but not both ways; hence it is carried along some canals, at least, by artificial means; it is *pumped;* and the inhabitants who made the canals are still there to work them. Indeed the orderly and world-wide character of the system indicates a degree of racial organization superior to the present state of mankind.

The intellectual elegance of the argument, here too briefly sketched, demands admiration; the difficulties with it lie mainly in its premises. The main point at issue is the geometrical character of the canal system, which is doubted or denied by the majority of observers. It is hardly necessary to say that no question as to the trustworthiness and integrity of any of the distinguished observers who have studied the planet can for a moment be raised; each faithfully describes what the subconscious processes of his brain report to his consciousness. But, when these reports differ so widely, with respect to details which all agree are clearly seen only by glimpses, there appears to be no way to determine which, if any, of the drawings of various observers most resembles what we would see if the planet were ten times nearer, and its details observable with certainty.

Again, the progressive "quickening" of the canals need not necessarily be due to the progress of water along them. Lau has suggested that as the polar caps melt, the atmosphere may become foggy, and later clear up, beginning in high latitudes. The growth of vegetation, which has proceeded under the fog, would then first become visible near the pole, and appear to progress toward the equator as the fog cleared. This effect might advance northward or southward in opposite seasons, without any water having to run up-hill. Indeed, one of the chief difficulties of the hypothesis of artificial irrigation is that the planet's whole surface must be assumed to be extraordinarily flat.

In view of these considerations, the verdict which must at present be rendered upon Lowell's suggestion is the Scottish one of "not proven." There is too much uncertainty about some of the more critical data, and too many alternative explanations, to justify acceptance. But to deny that intelligent life exists on Mars would be quite unwarranted. Even a direct proof that all the visible features of the planet's surface were of "natural" (as distinguished from artificial) origin would obviously be no evidence at all for the negative.

The question must, in our present state of knowledge, be left open, without prejudice. Animals, indeed, intelligent

animals, *may* exist on Mars; but we have no reliable evidence whether or not they do.

It is interesting to consider that, if Venus had intelligent inhabitants, who could observe the Earth as well as we can study Mars, and whose instrumental equipment and scientific knowledge were at the present human level, these inhabitants would probably come to just the same conclusion regarding the Earth. Seasonal changes on our planet would be conspicuous; the presence of oxygen would be spectroscopically evident; the widespread existence of vegetation might be inferred; but of the works of man, even his greatest, nothing could be seen which could definitely be distinguished from the products of unconscious forces. The realization of this is wholesome, for us the self-styled "lords of creation."

THE AGE OF THE EARTH AND OF THE STARS

Geologists have long been able to arrange the strata in order of their relative age, and to distinguish many successive periods by their characteristic fossils; but it is only in recent times that the geological time-scale has become expressible in years.

Estimates based upon such processes as the date of formation of sediments, or that of accumulation of soluble salts in the ocean suffer from the difficulty that, even though the present rate at which these proceed, and the cumulative effect of their action in past time, were accurately known, we have no security that their rate of operation in the past was of the same magnitude as at present. Calculations based on the cooling of the Earth's interior once appeared more reliable, but they have been completely upset by the discovery that heat is generated by radioactive substances in the superficial layers. Radioactivity, however, has furnished us with what is apparently a trustworthy time-scale in place of these dubious ones.

The radioactive elements are gradually and spontaneously disintegrating, an atom of one sort ejecting a part of itself and changing into an atom of another, and so on through a long sequence of transformations. The rate of these transformations appears to be quite unaffected by any external

conditions, e.g. pressure, temperature, and the like, and presumably depends upon the structure of the minute nuclei of the atoms. Radium is one of the shorter-lived products in a series which begins with uranium, the heaviest atom known, and ends with lead; but the lead which is so formed differs in atomic weight from common lead (206 instead of 207) and can therefore be identified by a careful analysis. If lead of this peculiar type is found in a uranium mineral, there is every reason to believe that it was not an original constituent, but has been formed *in situ* by radioactive change in the crystal where it is found. The rate of change is very slow, no less than 66,000,000 years being required for the transformation of 1 per cent of the uranium. Hence, if we find lead of this peculiar sort in a mineral, amounting to 15 or 20 per cent of the weight of the uranium which is present, it is evident that it must have lain undisturbed in the rock for a prodigious time before the miner and the chemist broke upon its rest. The ages of minerals in many eruptive rocks have been found in this way, that is, the time since the rocks themselves were molten. The geological period during which the intrusion of the mass occurred can often be fixed, which leads to the determination of a large number of datum points along the scale of geological time. Jeffreys (1924), reviewing the evidence, gives the following summary:

Period	Years
Eocene	60,000,000
Carboniferous	300,000,000
Upper Pre-Cambrian	550,000,000
Lower Pre-Cambrian	1,300,000,000

Life was already abundant in Cambrian times, and had developed a multitude of highly organized forms, so that its origin must be placed much farther back, and probably not less than a billion years ago. During all this time, the physical conditions on the Earth's surface, and, in particular, the temperature, must have been very similar

to what they are now. The evolution of living forms has been continuous, with no trace of a serious general set-back. There have been recurrent epochs of glaciation; but at no time is there evidence that a frigid climate prevailed over the whole world; and it is quite certain that the temperature never rose anywhere near the boiling point, even for a single year. The Sun's radiation of heat, upon which the Earth's surface temperature wholly depends, must have been remarkably constant all through this long interval.

But radioactivity tells us more than this about the history of our planet, it enables us to set an upper limit, as well as a lower, to its age. Uranium still exists in the Earth's crust, widely disseminated in the rocks, though in very small quantities, averaging about one part in 140,000 by weight.

There must have been more uranium in the past, and, in place of that which has changed, we should find an equivalent amount of lead. Now the amount of lead which is now present in the crust is approximately thrice that of the uranium. Aston's recent separation of common lead into isotopes shows that about 30 per cent of this lead has the atomic weight 206. If all the lead of this sort has arisen from disintegration of uranium, a simple calculation shows that the earth would be 4,800,000,000 years old, and to account for any considerably greater age appears to be difficult.

This seems at first sight perilously like an attempt to date the Creation. But it dates not the origin of matter, but the formation of our planet, of which we will presently speak, pausing only to note with what relatively narrow limits the age of the Earth now appears to be definable, the upper limit being less than three times the lower. Future discoveries may, of course, give reason to change these estimates; but, in the present state of knowledge, the conclusion that the Earth is more than two and less than five billions of years of age appears to be trustworthy.

The origin of the solar system next requires consideration, and the limitations of space compel an unwelcome brevity. Our system possesses an extraordinary dynamical peculiarity. More than 98 per cent of the angular momentum

(a quantity whose total amount cannot be altered by any processes occurring within the system) is at present possessed by the planets, which form but $1/700$ of the whole mass. There are arguments which approach, if they do not actually constitute, a proof that no such extreme segregation of the angular momentum could be brought about by a gradual process in an isolated system; and it is now generally admitted that here, for once, the catastrophic explanation is to be preferred to the uniformitarian.

Much the most satisfactory theory of the origin of the planetary system is that which attributes it to a close encounter between the Sun and a passing star whose track almost grazed it. Under the enormous tidal forces huge eruptions of matter would take place from both bodies. Much would fall back on the Sun, or be carried away by the star; but in the rest, set moving sidewise by the attraction of the star as it receded, we may see the raw material of planets, asteroids, satellites, meteors and comets. This hypothesis was first advocated by Chamberlin and Moulton, and has been modified by Jeans and Jeffreys. Into the details of the controversy between the "planetesimal" and "tidal" forms of the theory we need not enter. Many of the details of the origin of our system are still obscure, and some very puzzling; but the general theory of origin by an encounter holds the field.

During the earlier stages of the system, when much loose matter was still flying about, the orbits of the planets would tend to become nearly circular (as they actually are). An independent estimate of the age of the system may be made from a study of this process. Jeffreys reaches the figure of 7,000,000,000 years, which is only an indication of the order of magnitude, and therefore in satisfactory agreement with the radioactive data. Putting all this in a sentence, it appears that the solar system was probably formed by an encounter between the Sun and a passing star, sometime about four billions of years ago.

How does this compare with the age of the Sun itself, or of the other stars? This question refers, of course, to their age as *stars* (luminous bodies) and not to that of the matter of which they are composed.

The Sun has certainly been shining, with nearly its present brightness, throughout geological time. During this interval it must have dissipated into space an amount of energy vastly exceeding the whole initial store of potential energy of all kinds (gravitational, chemical, etc.) which can be attributed to it in virtue of known properties of matter.

All investigators are therefore now agreed that some otherwise unknown, and enormously great, source of energy exists in the interior of the Sun and of the stars, where it is being gradually transformed into heat and radiated from their surfaces. It is agreed, too, that this energy must come in some way from the disintegration of atoms, though the details of the process are still in debate. According to the theory of relativity, all energy possesses mass, and the Sun cannot radiate heat, i.e. energy, without diminishing in mass. To a single pound of mass corresponds heat enough to raise 20,000,000 tons of rock to a temperature of 2000°C. and convert it into incandescent lava; yet, measured in this way, the Sun's total radiation corresponds to a loss of mass of 4,600,000 tons per second. This is a truly startling figure, and might raise alarm concerning the future, were it not that calculation shows that if consumed steadily at this rate, the Sun would last for 15,000,000,000,000 years.

To what degree the Sun's actual life as a luminary approaches this figure depends upon the as yet unanswerable question how great a portion of its mass is capable of transformation into energy. It appears probable, in view of certain properties of double stars, to be discussed below, that a large part of the mass is transformable, and that the life of a star is thousands of billions of years in length. It is well established, both by Eddington's theory and by observation, that the more massive stars are the brighter. Ages ago, when the sun was more massive, it was doubtless brighter and hotter; long hence, when it has lost mass perceptibly, it will be fainter. It should, so far as can at present be estimated, continue to supply light and heat enough to maintain life on the Earth, at its present distance, for tens or even hundreds of billions of years. The past duration of terrestrial life appears therefore to be but a

small fraction of that which, barring accidents, it may in future enjoy.

Only one type of physical catastrophe appears to threaten any premature termination of this long forecast. Every now and then a star, which, so far as we can tell, has previously been normal, suddenly blazes out, and in a few days becomes ten thousand times brighter than the Sun, or more, appearing, even to the naked eye, as a conspicuous "new star," or nova. Within a few weeks the brightness fades, and in a decade or two it is back almost where it was before. Such an outburst by the Sun would unquestionably destroy all earthly life, except possibly that in the cold waters of the deep sea, and even this would probably soon perish for lack of food; and we may be sure that none has occurred since Pre-Cambrian times.

Novae, however, are by no means rare phenomena; one is seen every year or two, and many more must escape discovery. Allowing one nova per year, which is too few, and ten billions of stars, visible and invisible (which is a great many) to share the risks of catastrophe, we find that an average star is likely to blow up once in ten billion years, at the longest. An interval ten times shorter would be better in accordance with the evidence.

We do not know, however, whether such calamities happen to stars of all sorts, or only to those of certain special characteristics, nor, in the latter case, whether the Sun belongs to a susceptible species. In any case, the possibility is remote enough to be eliminated from practical human consideration.

THE POSSIBLE EXISTENCE OF LIFE IN UNKNOWN WORLDS

Whether other stars, as well as the Sun, have attendant planetary systems is not a question which can be settled by observation, unless our present powers of investigation should be increased to an extent which now appears improbable. To assess the probability that such systems may exist is not, however, beyond the sphere of legitimate inference.

If planetary systems arise from close encounters between stars, the chance of their birth is capable of calculation.

From the known distances which separate the stars, and their rates of motion, it may easily be shown that, on the average, a star should approach another within a distance equal to that which separates the Earth and Sun, only once in 60,000,000,000,000 years, and a much closer approach would probably be necessary to produce a planetary system. This indicates that such encounters can have happened to but a small fraction of the stars. Evidence that encounters at a greater distance have actually happened is furnished by the binary stars. Such a pair of stars moving together through space, and revolving about one another in orbits, must evidently have had a common origin. It is reasonable to suppose that they have been formed by the division of a single mass. In this case, the original orbit must have been nearly circular. The present orbits are highly eccentric; and the only way in which it appears to be possible to account for this is by the effects of encounters. A passing star, attracting the components in different directions and with different intensity, would disturb their motion and convert a circular orbit into an ellipse. To account for the present high eccentricity it must be assumed that on the average a binary star has met with several such encounters. Jeans, to whom this argument is due, has shown that this is possible, provided that the past lives of the stars extend over thousands of billions of years, so that they have lost considerably in mass since their formation.

Encounters close enough to produce planetary systems should be much less probable than those which have just been discussed; but, even so, they may well have happened to one star in a thousand, or more. In this case the number of planetary systems may run far into the millions. It is not in every such system that planets would be found which were even potentially habitable; but the number of such bodies should nevertheless be very large. Upon how many of them life would actually be found is not so easy to estimate. But if life exists in two out of three of the possible places in our system, it may well be abundant elsewhere.

All told, the existing evidence indicates that the number of worlds in which life is actually to be found within the

known universe is probably to be counted by thousands, and may be as great as a million. In how many of these intelligent life may exist we are hardly able to conjecture, but there is no reason for supposing that our world is unique even in this respect.

Only one characteristic remains by which our system and our world are likely to be distinguished. It is not at all improbable that a world but a few billions of years old may be the youngest of all. Indeed, encounters, under present stellar conditions, should be so rare that it appears improbable that even one should have happened, anywhere among the stars so recently. However, as Eddington puts it, these few billions of years may be "the interval between the event itself and a direct consequence of this event (*viz.* the evolution of beings capable of speculating about it.)" Compared with the inhabitants of the older worlds, our race may be primitive indeed.

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PART II. THE ORIGIN OF MAN

Chapter II

EVOLUTION TRACED BIOCHEMICALLY

A. B. Macallum

THE cell, animal or vegetable, as we know it, is a complex and highly developed chemical mechanism, capable of continuing its life, as it has done in a suitable environment through eons of time, and transmitting to its descendants the endowments of a far past. This suitable environment did not always obtain for in the earliest age of the earth the physical conditions on its surface were vastly different from what they have been since and are now. This at once suggests the question how and when did life have its beginning.

To conceive of an answer to this question, one must concede that the cell has in its history undergone an evolution the results of which have as greatly modified its structure and characters as has evolution affected the multicellular forms of animal and vegetable life. The units of primordial living matter must, therefore, as organisms, have been much simpler chemically and structurally, and smaller in volume, than existing ordinary animal and vegetable microorganisms. We can, from what we know of the latter, predicate what the primordial organism lacked as compared with the living unicellular organism of today.

First of all there was no nucleus in it. There are cellular forms of life in which no nuclei exist, e.g. the blue-green algae (Cyanophyceae), the moulds, and bacteria. Nuclei are also wanting in certain Protozoa (e.g. *Dileptus anser*), in certain others of which (Euplotes, Ceratium, Euglena, etc.) the types of mitosis they exemplify indicate that their nuclei have not yet acquired the special characters of those found in typical animal and vegetable cells, while in Calcituba mitosis in any form, rudimentary or otherwise, does not occur, the chromatin of its nuclei, when cell division begins, segregating in a peculiar fashion into a large number of spherules from which new nuclei are formed. Indeed a

comparative study of the nuclei in Protozoa shows that the nucleus is not an original organ of the primordial cell, but developed gradually in its history, and very probably long before the evolution from the primordial form of life, the protocyte, of the first animal and vegetable cells had begun. This would thus explain why mitosis is so similar in both. The non-nucleated animal and vegetable cells are very probably variant special survivals of descendants of the protocyte.

There was no superficial envelope for the protocyte such as we find enclosing protozoan and protophytan organisms of today. The superficial layer of its mass could have been but what the superficial layer of molecules formed, molecules kept in position by cohesive or molecular forces as the superficial molecules of a drop of water or of mercury are fixed in their position through the action of surface tension forces. Such an envelope is found in many protozoan forms (Amoeba, Pelomyxa, etc.) in Myxomycetes (the slime moulds) and in leucocytes, and it is through decrease at points on the surface of the tension there that ameboid movement occurs. The envelope is thus so labile, physically, that the cell can take in solid food particles and even other organisms. This type of surface may, because of its general occurrence, be considered as primordial.

It had not differentiated so far as to constitute local condensations in its interior in the form of granules, spherules or chromidia. The protocyte would then be uniformly homogeneous in a microscopic sense as it is in the plasmodia of slime moulds and in the symplasms (Löhnis) of bacteria.

The protocyte must, therefore, have been a simple undifferentiated cytoplasmic structure, but because of its constitution, with potentialities for chemical transformation and for variations in structure which explain the origin and development of the cellular organisms which have evolved from it. It must have been very minute, much smaller in volume than the cell of today which we can see with the microscope. Fragmentation of it, physically or mechanically engendered, must have been the method by which it multiplied and descendant forms arose and carried on life.

This organism must have been capable of syntheses which enabled it to live. It had to depend on the inorganic elements of its environment for these syntheses. Like a number of plancton organisms and bacteria of today, it was capable of combining free atmospheric nitrogen and carbon dioxide to form amino acids, the integral units of the protein molecules constituting it, for after a time the primeval atmospheric and surface waters of the earth contained no organic compounds which it could assimilate. It could, therefore, live and reproduce itself in an absolutely inorganic world, and its metabolism, depending wholly on its power to synthesize from inorganic elements its proteins, foreshadowed the diatoms and desmids as well as the Azotobacter of today. The capacity of these to synthesize from carbon dioxide, nitrogen, oxygen, phosphates and sulphates, their organic components is very probably inherited from the protocyte, or if not inherited, then due to a constitution of their complexes which has developed to assimilate the inorganic elements of their environment.

How minute such an organism must have been can only be inferred from what we know of the minutest organisms of today. These are invisible under the highest power of the microscope, that is, they are less in diameter than 0.1 micron (a micron being 0.001 of a millimeter) but if they were not transparent they could be revealed with the ultramicroscope. They can pass through the pores of a Berkefeld filter and are consequently termed "filtrable." One species causes the foot-and-mouth disease, another smallpox, a third rabies, and a fourth the mosaic disease of the tobacco leaf, and there are quite a number of others which are pathogenic. Indeed it is only because of their pathogenic character that we have any knowledge of their existence. Whether these have a normal habitat of their own and are pathogenic only when they infect animal or vegetable tissues, or whether there are ultramicroscopic organisms which are always non-pathogenic cannot be determined, for there are no methods for demonstrating their existence in the non-pathogenic state. Therefore, it cannot be known whether there are non-pathogenic ultramicroscopic organisms which can and do constitute proteins for their own complexes

from free nitrogen, carbon dioxide, phosphates, sulphates and iron of their environment.

The fact, however, that there are such ultramicroscopic organisms is an indication that life is possible in exceedingly minute, specially constituted, protein complexes, and we can, accordingly, conceive that organisms of this type must have been the very first to appear on the earth when its surface conditions favored the evolution of life. The fact also that such organisms multiply, indicates that they must increase in size to permit this multiplication. Such increase in size may lead to variations in volume and eventually to the evolution of organisms of microscopic size, but with more or less undifferentiated cytoplasm, from which developed the ancestor of all the cells, animal and vegetable, of today.

What was the origin of such a primal ultramicroscopic organism?

There have been advanced a number of theories and hypotheses to account for the origin of life on the globe. Only several of these are now worthy of attention, and a brief reference to the character of such may be made here.

There was first of all the theory of spontaneous generation. This theory, first definitely advanced by Aristotle, but held in a more or less inchoate form by earlier Greek philosophers from Thales onward, postulated that living organisms can arise spontaneously in media previously free from all forms of life whatever. Lucretius expressed this view, when he said that "the earth has rightfully received the name of mother since all things are begotten of it and many living creatures arise out of it, having been generated by the rains and the warm mists formed by the sun." Till the nineteenth century the belief in spontaneous generation was almost universal and it was not an unnatural result of observations made in an uncritical age. Some of these were very superficial. One, based on the fact that when a quantity of animal tissue, like beef muscle, is exposed to the free air and sunshine at summer temperature larval forms of flies and other insects appear in it in a few days, was explained as spontaneous generation of these in putrefying flesh. This explanation was everywhere accepted until Redi, in 1668, showed that when meat is placed in a wide-

mouthed jar and the mouth covered with thin gauze permitting free entrance of air and warmth but excluding flies and other insects, no larvae of any form made their appearance in the medium.

The results of similar carefully made experiments disposed of a number of instances of supposed spontaneous generation, but the theory was maintained, nevertheless, and it was generally held that the microorganisms which the microscope revealed to observers of the seventeenth and eighteenth centuries did not arise from preexisting forms, a view stoutly maintained by Needham and Buffon. Needham, when he heated infusions of animal and vegetable matter so as to destroy germs existing therein and kept them for a few days at room temperature, found these to contain swarms of animalculae which he concluded must have arisen from non-living matter. Buffon repeated Needham's experiments and confirmed his results and conclusions. Spallanzani, however, found that no organisms appeared in such infusions if they were heated for half an hour and kept in flasks hermetically sealed by fusing their necks in the flame. This result was regarded as decisive until after the discovery of oxygen by Priestley in 1774, when it was maintained that from Spallanzani's infusions oxygen of the air was excluded, and that this element was necessary there to permit of spontaneous generation of organisms in it. The discussion on the subject was continued, consequently, until in 1856 Schroeder and von Dusch, and finally, in 1859, Schroeder, found that in infusions treated as in Spallanzani's experiments, but contained in flasks closed by plugs of cotton wool which allowed free access of air, but no air-borne organisms, to the infusions, no living forms developed therein. This result has been confirmed a countless number of times in the last seventy years, and today no one believes that living forms do spontaneously originate under the conditions which now obtain on the surface of the earth.

This turned attention to other possible explanations of the origin of terrestrial life, and in 1871 Lord Kelvin, then Sir William Thomson, advanced the view that life began on the earth when fragments of shattered life-bearing

planets of other solar systems far distant in space, arriving as meteors, set free in the earth's atmosphere the organisms they carried from their original home, and that thus terrestrial life began. This theory involved difficulties which denied a general acceptance of it. Life in organisms, meteor-borne, would have to be maintained for an impossible length of time, for a meteor derived from the nearest solar system, that of which α Centauri is probably the sun, would require 62,000,000 years to reach the earth, moving at the rate of 40 miles per hour (Arrhenius), and when it plunged into the earth's atmosphere the heat thereby developed would sterilize all organisms on it, even if they survived alive after so incredibly long a time.

This theory, which failed to win acceptance, was again advanced, but with an important modification, in 1903 by Arrhenius, who used the then recently discovered fact of the pressure exercised by light and other radiations to maintain that organisms could be driven by it through space independently of meteors and with a velocity enormously greater than the latter are supposed to have. This pressure would, according to the calculations of Arrhenius, reduce the time for the transportation of organisms from α Centauri from 62,000,000 years to 9000 years. These would experience a temperature of $-220°$C., that of interstellar space, from the beginning to the end of their course, but the low temperature, which would reduce desiccation almost to an absolute minimum, would also very greatly reduce the chemical activities in the organisms and these would then survive, as it were in a latent condition, and reach the earth's atmosphere, in which, because of their enormous velocity (more than 800 miles per second) friction would develop a temperature of not less than 100°C. This, Arrhenius held, would not necessarily sterilize them for the protein in them, being in a very dry state, would not be denatured at such a temperature. He discounted the action of light on such organisms, for cultures of certain bacteria had been found unaffected by bright sunlight after a month of exposure to it.

This theory, in the present state of our knowledge bearing on the facts involved, does not appear tenable. It is

scarcely conceivable that the high temperature of 120° to 300°C. developed on contact with the atmosphere would leave unaffected the living complexes of these organisms, and that the intense ultraviolet light from the sun, a great portion of which does not penetrate the earth's atmosphere, would not sterilize the organisms before they reached the outer limit of the atmosphere.

The theory of Arrhenius, furthermore, left unexplained the origin of life. It merely postulated that life originated somewhere else in the universe than on the earth and did not attempt to explain how. If life originated elsewhere, what were the conditions that promoted this origin, and in what respect were they different from those which prevailed on the earth at some time in its history?

One must, accordingly, turn for intellectual satisfaction to another theory which does not avoid the cardinal element of the problem but predicates that life will originate anywhere in the universe where the conditions favoring its origin obtain. It postulates also that such conditions obtained on the earth during its earliest geological age, conditions which, as Huxley expressed it, "it can no more see again than a man can recall his infancy." Among those who have been expositors of this theory during the last fifty years may be named Pflüger, Moore, Allen, Sharpey-Schafer, and Osborn, and in 1910 the author gave his unreserved endorsement of it.

This theory must not be confused with that of spontaneous generation. The latter, discredited now, as already indicated, implied that life could originate *de novo* today under the conditions which ordinarily prevail on the earth's surface. To prevent this confusion the theory now to be discussed should be called the paleogenetic theory.

The conditions necessary for this generation of living forms must have prevailed on the earth's surface when the temperature of its rock crust sank below 100°C. At temperatures above 350°C. all the water later forming the oceans was then as water vapor in the atmosphere which had a pressure more than two hundred times what it exercises today. Countless condensations must have taken place on the hot rock crust, and the water condensed must as

often have boiled away until the temperature fell to about 120°C., when permanent deposits of water were formed, but the atmospheric pressure, because of the still large, though now reduced, quantity of water as vapor in the atmosphere, must have been about or more than twenty times as great as it is today. As these condensations occurred almost continuously or consecutively, there must have been, also continuously, electrical discharges of enormous voltage which ionized the constituents of the atmosphere and caused the formation of new compounds which must have played a part in later syntheses, especially in local condensations of water which, on reduction of volume through evaporation, retained them as solutes more or less concentrated.

What were these constituents? For an answer we must go to what spectroscopy has revealed regarding the constituents in the gaseous envelopes of the cooler stars. It has been found that in stars of the type K* (with temperature of not more than 4000°C.) hydrocarbons are present, and in the N stars (with a temperature of about 3000°C.) and the R stars (with a temperature of about 2300°C.) carbon monoxide, cyanogen, methane, oxygen and nitrogen are found. In the atmosphere of each of not a few of the derivations of such stars, as planets are, each with a diameter of more than 4000 miles, these gases, with water vapor, must have obtained, and thus the atmosphere of the earth in the earliest period of its history was very probably so constituted. What the proportion of each gas was cannot be known, but undoubtedly carbon dioxide was more and oxygen less abundant than in the atmosphere of today, for the carbon of the coal deposits was then combined with oxygen as carbon dioxide from which it was set free by vegetable life, and thus the oxygen content of the atmosphere was increased. Thus the earth inherited its primeval atmosphere.

In that atmosphere when condensations of the water vapor began there must have been other inorganic constituents, especially the chlorides of sodium and potassium, since rain water today carries from the sea these salts to the land surface, for M. J. Pierre found in the rain water collected

* Of the Harvard classification.

in the neighborhood of Caen (see Smith, cited by Joly) as much as 1.23 tons of potassium per square mile per year, and this indicates that other salts were present. Though chlorides were then not as concentrated as they are in the ocean today, some of what the first condensations dissolved from the hot lithosphere must have been carried into the water-laden atmosphere of the time. These chlorides, thus present, must have been to a great extent dissociated (ionized) through the electric discharges accompanying the condensations and free chlorine would thus be present to react with the other constituents of the atmosphere and promote the formation of new compounds. With the first condensations the water acting on carbides of the hot rock crust, such as those of calcium and iron, would set free methane and other hydrocarbons, which with the free chlorine would render possible other syntheses.

What all the compounds so formed were one cannot predicate with certainty, but one may reasonably assume that some of them were carbonyl chloride ($COCl_2$), carbonyl chloramide ($ClCO{\cdot}NH_2$), chlor-methane ($CH_3{\cdot}Cl$), ethane ($CH_3{\cdot}CH_3$), acetic acid ($CH_3{\cdot}COOH$), acetamide ($CH_3{\cdot}CO{\cdot}NH_2$), amino-acetic acid ($NH_2{\cdot}CH_2{\cdot}COOH$), propionic acid ($CH_3{\cdot}CH_2{\cdot}COOH$), amino-propionic acid ($CH_3{\cdot}CH{\cdot}NH_2{\cdot}COOH$) and thio-amino-propionic acid ($CH_2SH{\cdot}CH{\cdot}NH_2{\cdot}COOH$). Such would be condensed with the water vapor when the temperature fell below 100°C., and in small bodies of water, which by evaporation became reduced in volume, they would become concentrated and then further syntheses would occur.

From these, under the physicochemical conditions prevailing in their media, in which were contained chlorides, phosphates and also catalysts, traces of iron salts for example, peptides and even polypeptides, consisting of many amino acid links, would be synthesized, some of these approaching in composition the constitution of proteins.

These syntheses would take place countless millions of millions of times, resulting in many varieties of products until, eventually, there would be formed a protein complex of ultramicroscopic size, endowed with the constitution, and, accordingly, the properties of an ultramicroscopic

organism, capable of synthesizing its own complex from the carbon dioxide, nitrogen and other constituents of its habitat, thus increasing in size, which would at length entail divisional fragmentation and reproduction. So would begin the long reign of life on earth.

At what temperature of the primal surface water of the earth this synthesis occurred can only be conjectured. It must have been not above 80°c., and possibly much lower, for although certain algae live and multiply in the waters of hot springs at temperatures above 80°c., and bacteria of the thermophilic class can be cultivated in media at 80°c., with an optimum of 65° to 70°c., this accommodation to high temperatures may be a later adaptation. When, of course, a living complex is formed of proteins of a simple type it should, one may suppose, be more resistant to the action of heat, but many of the proteins which we can prepare from animal and vegetable cells are "denatured" at 60°c., and at 80°c. all are so altered that the life of the organisms yielding them or formed of them at once ceases. Indeed there are few organisms, and these nearly all bacterial, which can survive a temperature of 50°c. maintained for several days. Possibly the protocyte, because of its comparatively simple constitution, may have been able to survive, and even to thrive, at 80°c., but as the temperature of its media fell gradually it would adjust itself accordingly, and thereby finally develop an altered protein complex at 20° to 30°c., which at higher temperatures, 50° to 70°c., would be "denatured," thus ceasing to live. In this adjustment it is possible that new amino acids, those with cyclic atom complexes in them for instance, would be formed which, entering into the constitution of the protein complex, made it more sensitive and more readily affected by higher temperatures.

To summarize: the primal organism, the protocyte, was ultramicroscopic in size, was of comparatively simple constitution, and began as a product of the union in a special complex of a number of amino acids which were formed from constituents of the atmosphere when the condensations of water vapor, at or below 100°c., were continuous, and when also evaporation of small isolated

bodies of water concentrated the amino acids in them and rendered the synthesis of them to complexes, millions in number, one of which, of special constitution, had, to use Tyndall's expression, "the promise and potency of all terrestrial life."

The animal cell, so far as experimental results indicate, lacks the power of synthesizing any of the amino acids except the simplest, amino acetic, and consequently it must depend on those formed by vegetable cells. It must then have evolved later from cells which had the power of synthesizing their own amino acids, but which tended to vary and to develop ultimately a dependence for these on the hydrolysis of the proteins of vegetable organisms they invaginated. The Protozoa of today, with the exception of a number of forms, derive their amino acids from the hydrolysis of the organisms, animal and vegetable, which they ingest.

This variation could only have begun after the cell nucleus had fully developed, for mitosis in typical animal cells is so similar in its character to mitosis in typical vegetable cells as to make it difficult to suppose that it originated independently in both kingdoms. The variation could not have developed except after a long time, perhaps millions of years. There would appear to be today descendants of a very early stage in this variation, for Euglena, Peridinium, Ceratium and other flagellates, which at times contain chlorophyl and then synthesize from inorganic elements their own proteins and carbohydrates, and are consequently regarded by some as vegetable organisms, are also by zoologists generally classed as animal forms. It is also remarkable that in these forms the mitotic figure in all its stages is so different from what it is in typical animal and vegetable cells, and so rudimentary in character as to suggest that in these forms are still repeated the nuclear form and structure that obtained in an early stage of the evolution of typical mitosis.

The fact that the flagellates mentioned could alter with the conditions of their environment their metabolic activities, so as either to be photosynthetic or to depend for their nourishment wholly on ingested food material, is an indication that the primal ancestors of the animal cell

could have arisen from variants of vegetable organisms in which there was such an adjustment in their metabolism as to permit eventually the development of the animal type of nutrition.

The nucleus of the animal cell, then, harks back to that of the vegetable cell when mitosis had developed and become as characteristic as it is in the typical animal and vegetable cells of today. The transmission of mitosis, unchanged, then, through hundreds of millions of years from the time when animal organisms had not yet developed, predicates an incredibly long time for the primal vegetable cells to develop mitosis so fixed in character as to render it invariable in its characters after all that time.

The nucleus then must be an organ which in origin antedates that of the animal cell. This prompts the question why it arose. The answer is not at hand, but one may refer to some facts which point to a solution of it.

The life of the protocyte must have been at first passed wholly in the waters of the globe in which the salts dissolved from the rock crust must have been of low concentration. Into the complex of the protocyte these would diffuse, and it would adjust itself to them. If any chromatin obtained, it would have been unaffected by them, or, if affected, only to an extent that would have produced some of the variations such an originally undifferentiated organism would undergo. The concentration of the salts in its habitat was, however, slowly increasing as it has done ever since, till now in the ocean water they amount to 3.5 per cent. This increase in concentration must have begun to affect, in some degree, the chromatin, rendering it uncertain in its control of the metabolism of the cell and also of the transmission of inherited characters. When the nucleus developed, it was, so to express it, to protect the chromatin from such effects, for inorganic salts are wholly absent from it although the cytoplasm of the cell, animal or vegetable, may be more or less densely charged with them.

The nucleus, on this conception of one of its functions, therefore, developed when the concentration of the salts in the cytoplasm had considerably increased and when it was about the same as in the sea water of the period. The cyto-

plasm must have adjusted itself to this concentration, which could no longer affect the chromatin, and when evolution had produced vertebrates the cells of such, bathed in a plasma with constant inorganic composition, must have inherited to a certain extent this adjustment. The inorganic composition of such cells may then be regarded as indicating the composition of the ocean water when the nucleus had evolved.

To ascertain what this composition was, one must take for analysis more or less undifferentiated cells such as amebae, leucocytes and unfertilized ova of the lower vertebrates. Amebae or leucocytes cannot be obtained in sufficient numbers to furnish material for such analyses, but ova can be used and analyses of those of the common herring gave, in per cent:

Na	K	Ca	Mg	Cl
0.08175	0.1795	0.00458	0.00138	0.2937

The excess of potassium over sodium (Na:K::100:219.9) is in contrast with what obtains in the ocean today, in which the sodium is to the potassium as 100 is to 3.61. That the ocean water of the earliest geological period was much richer in potassium than in sodium is indicated by analyses which have been made of the waters of lakes in regions where nearly all the surrounding surface rocks are of pre-Cambrian origin. The water of Reindeer Lake, situated about 400 miles north of Winnipeg, and surrounded wholly by Archean rocks, contains at least twice as much potassium as sodium. So also do the waters of Rachel See, Würm See and Ronig See, of the Bavarian Highlands. The ocean water of the Archean must have thus been richer in potassium than in sodium.

The salts in the ova amount to 0.5609 per cent, or less than one-sixth of the concentration in the ocean of today. If this was inherited, then the animal cell, as such, evolved before the end of the first sixth of the whole geological part of the history of the earth.

This estimate may not be confirmed when analyses of other undifferentiated animal cells have been made, but so far it is of interest as indicating that after life first began

on earth from fifty million to one hundred and fifty million years had passed before the cell nucleus had evolved and become fixed as an organ.

There is not much uncertainty, if any, about the origin of the inorganic composition of the blood plasma and lymph of vertebrates. The first circulatory fluid of invertebrates was the sea water in which they lived, as it is today in a number of forms. It passed through openings into the channels of the primitive vascular system, and when in higher forms, as they developed, this system became closed off from the exterior, the fluid it contained was still sea water of that early period, as still are, in the composition and concentration of their salts, the blood plasma and lymph of vertebrates of today. This is seen on comparison of the ratios of the elements in it with those in the sea water of today:

	Na	K	Ca	Mg
Ocean water of today	100	3.61	3.91	12.1
Human plasma	100	6.75	3.1	0.7
Mammal plasma (average)	100	6.6	3.2	0.76

The concentration of the salts in the plasma of mammals is about 0.89 per cent (0.87 to 0.91 per cent), while in the ocean they amount to 3.5 per cent, that is, really four times as much as it must have been when the first vertebrate, the eovertebrate, appeared. The Amphibia and Reptilia began in the Carboniferous Period and the Mammalia began in the Triassic. As these were chiefly land forms they transmitted to their descendants the inorganic composition of their blood plasma derived from their ancestors of the Cambrian or Ordovician.

The concentration of the salts in the ocean has ever been increasing steadily, and with this increase there has been an alteration in the ratios of the elements therein to each other. The potassium and calcium have increased, but not proportionately, for the former has been, and is, constantly eliminated to form the mineral glauconite, scattered over the floor of the ocean, and in the sedimentary deposits of various periods, while of the calcium always added, a

part has gone to form the limestone deposits. The sodium and magnesium have always been increasing in the ocean, and the latter relatively more rapidly than the sodium. This would account for the ratio of the two, 100:12.1, in the ocean water of today, as contrasted with the ratio of 100:0.8 in the blood plasma of mammals.

On the concentration of salts in the plasma of those vertebrates which have had a marine habitat since their origin, the gradually increasing concentration of the salts in the sea has had a marked effect. This is seen in the elasmobranchs (sharks, dog fishes and rays) which have been marine since their origin in the Ordovician or early Silurian. The concentration in the plasma of the sand shark, *Carcharias littoralis*, was found to be 1.938 per cent, slightly more than twice that in the blood plasma of mammals. The ratios of the elements to each other are, however, but slightly changed, particularly in regard to magnesium, the concentration of which is relatively far below that in sea water.

In invertebrates with a closed circulation which have been marine as long as the elasmobranchs have, the blood plasma is practically sea water. This is the case in the horseshoe crab (Limulus), which has always been marine since the close of the Cambrian. In the blood of this the concentration of the salts found was 2.98 per cent, whereas in the ocean water of the habitat of the horseshoe crabs whose blood was analyzed, it ranged from 2.9 to 3.12 per cent. The sea water thus controls the composition of the plasma in Limulus. It does so also in the case of the lobster, Homarus, descended from a fresh water form of the Cretaceous. The concentration of the salts in its plasma was found to be 2.852 per cent, practically the same as that of its habitat, but the ratios are not the same, as may be seen:

	Na	K	Ca	Mg
Sea water	100	3.61	3.91	12.1
Limulus	100	5.62	4.06	11.2
Homarus	100	3.73	4.85	1.72
Carcharias	100	5.75	2.98	2.76
Mammal (average)	100	6.6	3.2	0.76

The sea water has dominated almost completely the inorganic composition of the blood plasma in Limulus, less so in Homarus, and very much less so in Carcharias, although it has increased therein the Na:Mg ratio, which, however, is only about one-fourth that in the blood of Limulus.

The circulatory fluid of the eovertebrate must have been, therefore, sea water of the time, and the concentration and proportion of the salts in it then obtaining were maintained in the blood of the vertebrates which exchanged the marine for a land habitat in the early Carboniferous, and from which later mammals developed. The blood plasma of the latter is, on its inorganic side, then, but the sea water of the early Cambrian, when the ratios of the elements and the concentration of these were different from what they are now.

The maintenance of these through hundreds of millions of years is undoubtedly a function of the vertebrate kidney. There is in invertebrates no organ or organs having this function, for the coxal glands of the lobster, which are excretory, maintain the ancient ratios of the inorganic elements in its blood plasma but do not control the concentration of these, and in consequence the salts of its blood are as concentrated as those of its habitat. In the whales, the Cetacea, on the other hand, which have had a marine habitat almost as long as the lobster (since the early Eocene), the concentrations of the salts and the ratios of the elements therein are the same as in the blood plasma of the horse and pig, which, with the Cetacea, were derived, it is held by some paleontologists, from a mammal form of the Triassic.

In the long ages the kidney has ever thus performed functions with a constancy and regularity which are unrivalled in the world of life, except by those of the cell nucleus which is, of course, of vastly more remote origin. This constancy contrasts with the variations in functions which other organs in vertebrates have undergone. It has made the Vertebrata, with all their range of development, possible, and without it there could be no change of habitat from sea to land or fresh water and back again to sea, for with each such change there would be a variation in the inorganic composition of the internal medium, an impossible handicap

to overcome in the evolution of vertebrates, the highest form of life on the globe. In other words, without this control of the composition of the internal medium there would be no vertebrates.

In conclusion, and to summarize, there were three great epochs in the story of life on the earth.

The first of these was the generation of life itself as an ultramicroscopic organism, the protocyte, as a product after many millions of syntheses of amino acids, derived from the first constituents of the atmosphere and water of the earth in the beginning of geological time, had achieved the composition of a complex capable of repeating itself by syntheses and thus initiating the long reign of life on the globe.

The second was the evolution of the cell nucleus as a sanctuary, as it were, to protect the chromatin from the action of the salts of the sea water ever increasing in concentration and ever invading the cytoplasm of the cell. This protection enabled the chromatin to transmit to offspring cells and organisms inherited characters, and thus to rendei evolution from stage to stage possible.

The third was the development of a renal organ which controlled and stabilized the composition of the internal medium, the blood plasma, bathing the cells of vertebrates and thus providing for constancy in the primal concentrations of the salts in the cytoplasm of each, inherited from the time when the cell nucleus was evolved.

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Chapter III

THE ANIMAL ANCESTRY OF MAN

William K. Gregory

"know thyself"

THE almost hopeless egocentrism of man, his deep prejudices and his aversion to his "poor relations," the apes and monkeys, make it extremely difficult to secure complete and ungrudging acceptance of the consequences of man's status as a regular member of the order of Primates. To this day the discovery of man's place in Nature, as recognized for instance by Linnaeus in 1759 and confirmed since then by thousands of separate items of proof, remains virtually unknown to the masses of the "educated" and, with some exceptions, is commonly ignored by college presidents. Even the word Primates, except as applied to certain ecclesiastics, is not to be found among the seventy thousand common English words listed in a recent abridged edition of Webster's dictionary. Yet a good part of what man is now, even many of his parasites, diseases and structural weaknesses, to say nothing of his mental characteristics, come to him by way of his primate ancestors. When we give up the traditional method of the ostrich in dealing with such unsavory facts, our eyes will be open to the wholesomeness of the fruit of the tree of knowledge.

It is therefore the object of the present chapter to indicate a few of the multitudinous ways in which man's animal ancestry conditions his present biological status, to trace the main stages of his "ascent to Parnassus," and at the same time to show our obligation to our lowly predecessors, each of which did his share in testing, rejecting or transmitting the innumerable "basic patents," or natural adjustments, that have proved requisite for our survival in a world of inexorable competitive tests.

The general reader may ask why in the following pages we speak so confidently of the "sequence from fish to man,"

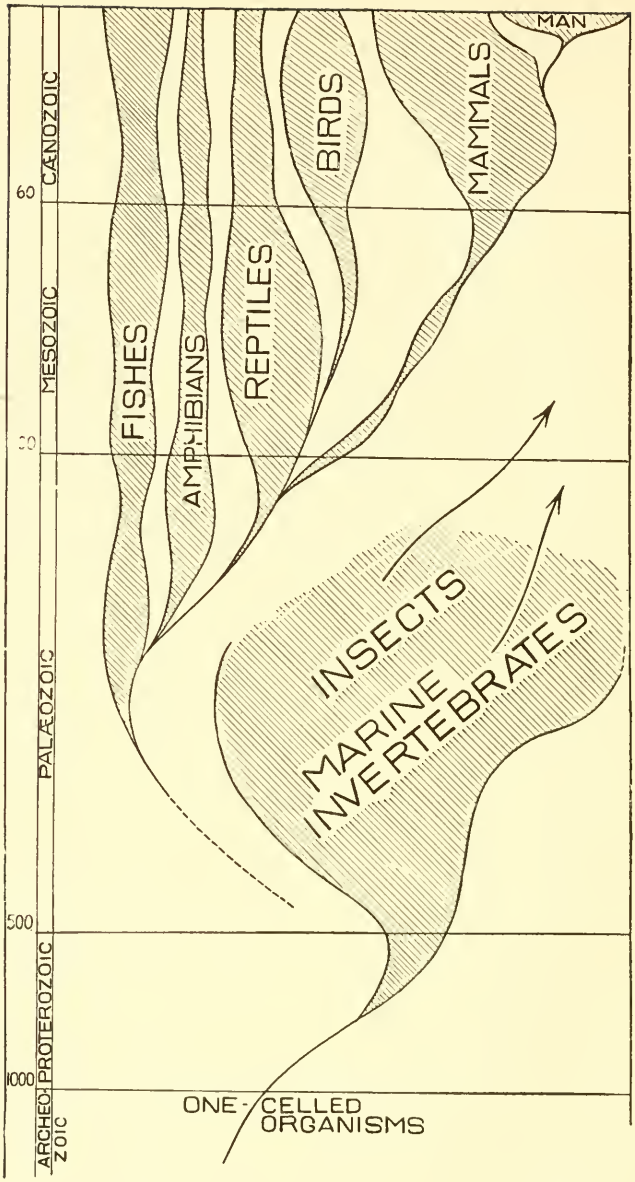


Fig. 1. Genealogical tree of animal life.

Figures at left give estimated time in millions of years from beginning of each epoch to present, according to Barrell's estimates, based on measurement of rate of disintegration of radioactive ores since they were crystallized at different geological ages. (After Gregory, Our Face from Fish to Man. G. P. Putnam's Sons.)

when he may have read elsewhere that scientists are still disputing whether this or that particular fossil is or is not the missing link. The argument may be compressed into the following brief statement: When we study the recent and fossil vertebrates as a whole, and when we study at the same time the comparative anatomy of their organs, we find that the vertebrates fall into larger and smaller natural groups which may be arranged in the form of a tree, with main trunk, boughs, branches, twigs and leaves. Mankind, by all the evidence of comparative anatomy and kindred sciences, belongs on one of the small twigs nearest to the anthropoid apes; the man-ape branch surely belongs in the Old World or catarrhine division of the Primates, and thus the groups, one by one, may be traced down to the main vertebrate trunk.

Again, the record of fossilized organic remains, or palaeontology, imperfect as it is, offers fully concordant evidence that the main stages of ascent from fish to man have occurred in the following order:

I. *Proterozoic* ("Age of Primitive Life")

1. Pre-Cambrian: first definite traces of life (algae, worm-tubes, etc.).

II. *Palaeozoic* ("Age of Invertebrates and Fishes")

2. Cambrian: early stages of main phyla of invertebrates.
3. Ordovician: first traces of fish-like forms.
4. Silurian: earliest well-known fish-like forms (ostracoderms).
5. Devonian: lobe-finned, air-breathing fishes.
6. Lower Carboniferous: swamp-living amphibians.
7. Upper Carboniferous: land-living primitive reptiles.
8. Permian: mammal-like reptiles of several ascending grades.

III. *Mesozoic* ("Age of Reptiles")

9. Triassic: cynodont reptiles or pro-mammals.
10. Jurassic: archaic insectivorous mammals.
11. Cretaceous: primitive placental insectivores.

IV. *Caenozoic* ("Age of Mammals")

12. Eocene: primitive lemuroid primates.
13. Oligocene: proto-anthropoid stock.

14. Miocene: varied anthropoids, including some with pre-human patterns of the molar teeth.

15. Pliocene: probable emergence of "tertiary man."

v. *Psychozoic* ("Age of Man")

16. Pleistocene: primitive man; beginnings of modernized man.

17. Recent: civilized man.

It is true that there are larger or smaller gaps between each of these stages in the present imperfect state of our knowledge, but within each large group there is a wide range of variation in particular structures, some recalling the previous stage, others prophetic of later stages. It is only the few fortunately situated persons who have spent years in handling and studying the original materials all along the line from ostracoderms to man, who are in a position to appreciate fully the weight of this concordant testimony of systematic zoölogy, comparative anatomy and palaeontology as to the evolution of man; but even the young student of biology quickly realizes the significance of the famous blood-relationship tests and of the embryological proof that man resembles other mammals in the basic features of his development and in his subjection to the laws of heredity.

MAN'S DEBT TO THE EARLIEST ORGANISMS

As a citizen of the terrestrial biota man inherits all the rights and privileges but also the responsibilities and liabilities of his status. The body of man, as a mass of water, of frothy protoplasm and protoplasmic by-products, is a labile, combustible mixture, a chemical engine, generating the power by means of which man makes a place for himself in the world of life (Martin). Obviously this engine must be more or less regularly supplied with water, oxygen, nitrogen, carbon and other well-known staples. Hence perhaps the greater part of man's activity is devoted to securing and consuming these necessities. Again, this chemical engine will work efficiently only within certain limits of temperature and pressure. Hence man, like other organisms, seeks those parts of the earth in which the temperatures and pressures are most conducive to his welfare, and strives

by means of clothing, houses and the like, to protect his chemical engine from injurious and sudden changes in the surrounding medium.

As man belongs to the animal rather than to the plant kingdom, he has no chlorophyl-bearing leaves to store up the sun's energy for his use, nor can he derive his raw materials directly from the soil or from the atmosphere, but in common with all other animals he must consume simpler organisms which have already elaborated the raw materials and stored up the energy for him.

Man is a many-celled animal, or metazoan, and as such each human being consists of a vast and shifting democracy of individual cells, which are organized into cooperative and mutually dependent systems of organs, tissues and the like.

We need not discuss fully here the still vexed question as to what group of invertebrates the oldest chordate ancestors of man were derived from. It will be sufficient for our present purpose to note that if, with Professors Patten and Gaskell, we try to derive them from the common stem of the arachnids (scorpions, spiders, etc.) we must conceive that in the transitional stages an entire reorganization was effected, involving radical displacements and transformations of every part of the body. Now while all these changes are clearly conceivable under the terms of the hypothesis, the evidence advanced in support of them has never been accepted by the majority of those best qualified to judge of its value. On the other hand, if we hold with Professor E. B. Wilson and others that the vertebrates belong to that great division of the three-layered animals in which the middle embryonic layer, or mesoderm, arises from pouches lying above the enteron, or primitive gut, then we have to admit that, so far as known at present, the palaeontological record lacks the transitional stages between the vertebrates and their assumed sack-like ancestors and that the vertebrates and the starfish group apparently represent two widely divergent end stages of an unknown common stem.

CITIZEN MAN OF THE PHYLUM CHORDATA

At any rate, the "phylum Chordata," to which man and all other vertebrates belong, very early adopted a highly

efficient type of locomotor apparatus, the starting-point, as we shall see, of a long series of successive modifications, from the lancelet to man.

The developmental history of Amphioxus and other lowly chordates (Delage) indicates that at a very early period some two-layered, jellyfish-like forms gave up the free-floating life of helpless plankton and began to wriggle on the bottom of the rich inshore feeding-grounds. At this time perhaps the mesodermic pouches already mentioned as being on either side above the primitive gut became rhythmically contractile, like the bell of a jellyfish. While the details are quite obscure, it is plain that some such stage must have preceded the appearance of the perfected muscle pouch, which is the unit of the locomotor apparatus of all vertebrates and one of the most important of the basic patents to which all vertebrates, including man, owe the possibility of their subsequent careers.

These primitive contractile pouches probably at first surrounded the little bags of potential eggs or sperm which had been derived from the walls of the primitive gut; even in the embryos of higher vertebrates (including man) the blocks of tissue which give rise to the body muscles and to the segments of the backbone first appear on either side, above the primitive gut and above the longitudinal strip of tissue that gives rise to the eggs or sperm. Meanwhile at a very early period the mesoderm began to develop a median longitudinal groove. This groove, at first opening below into the primitive gut, finally became closed off as a tube filled with clear elastic tissue (Shumway). Why it did this we do not know, but the step was of momentous consequence to the future history of the race, for thereby the beginnings of a backbone were attained.

Along the middle of the back behind the brain and above the notochord was a long paired groove or tube forming the main nerve cord, with lateral branches, the spinal nerves, leading out to the muscle pouches, which, as we have seen, had already budded off from the primitive gut. By means of these primitive "spinal nerves" and of the spinal cord and brain, the contraction of the segmental muscle pouches could be timed and integrated effectively into cooperating

and opposing groups. By means of the already bewildering connection systems of the central nervous system, stimulations of the primitive sense organs (representing the senses

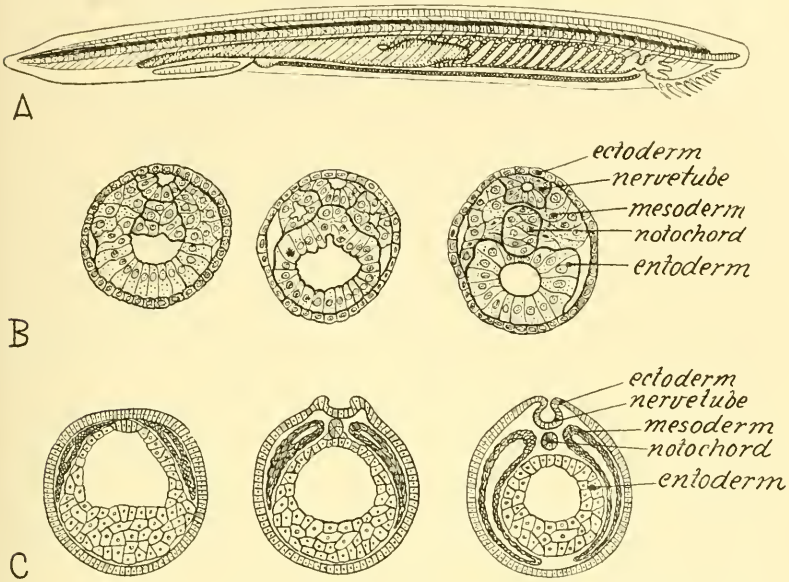


FIG. 2. Lancelet (Amphioxus), lowest existing chordate.

A. Diagram of anatomy of adult animal.

(After Marshall and Hurst, Practical Zoology.)

B. Section of embryo, showing relations of mesoderm and entoderm.

(After Cerfontaine, from Shumway's Vertebrate Embryology, John Wiley & Sons.)

C. Cross-sections of three stages of development in frog, showing relations of mesoderm to outer and inner germ layers.

(After Hyman, Laboratory Manual for Comparative Vertebrate Anatomy, Chicago University Press.)

of feeling, taste, smell, sight, balance, bodily position, etc.) could be organized and directed toward successful motor responses. All this matter lies within the special field of the neurologist and is fully dealt with elsewhere in this book (Chaps. III, XI). The present chapter is concerned primarily with the muscular and skeletal elements of the vertebrate locomotor apparatus rather than with the nervous mechanism of direction and control.

At a very early period the primitive muscle pouches became transformed into zigzag-shaped muscle segments,

or myomeres, arranged in a closely packed series on either side of the body, quite in the manner of the fleshy muscle flakes in modern fish. This stage is fully realized in Amphioxus, the very lowest of the fish-like chordates still existing. In normal fish-like vertebrates that move through the water, the body is "stream-lined," with a rapidly widening "entering angle" and a long sloping "run." In forward locomotion the muscle segments on one side, immediately behind the head, begin to contract first and the contraction is then passed backward toward the tail. Meanwhile the muscle segments on the opposite side, immediately after the initial contraction, begin their contraction, so that the head is alternately bent slightly from one side to the other as the waves of contraction run along the body, with increasing amplitude, to the tail. Presumably the continuous notochord acts as an axial rod or spring. At first the wriggling body does not need any accessory steering or propelling structures, but in later stages folds of skin, originally not in themselves movable, grow out and serve as keels and rudders. From this relatively simple beginning, as we shall presently see, the evolution of the locomotor apparatus, at least in its main outlines, from fish to man is fairly clear.

But before proceeding to the higher stages let us return to the basic patent, the contractile muscle pouch. Why was it contractile? Each muscle segment of an adult fish (Fig. 3) consists of a zigzag of striped muscle fibers fastened at either end into the connective-tissue septa that divide the muscle segments. It is the striped muscle fiber, then, that is the smaller unit of contractility. But what, in turn, makes it contract? Under high magnification a striped muscle fiber is seen to be composed of two different kinds of material, represented by the dark and the light-colored cross-stripes. Physiologists (Martin) tell us that when a muscle swells out and shortens, the force at work is analogous to the force of surface tension and that the frothy nature of protoplasm supplies a relatively enormous surface for the operation of the forces of surface tension exerted between the materials of the dark and the light bands of the muscle. But how does the nervous discharge from the central nervous system release the forces of surface tension which had up to

that moment been held in balance? Here we come to a problem with which the physiologists expect to be struggling for a long time to come.

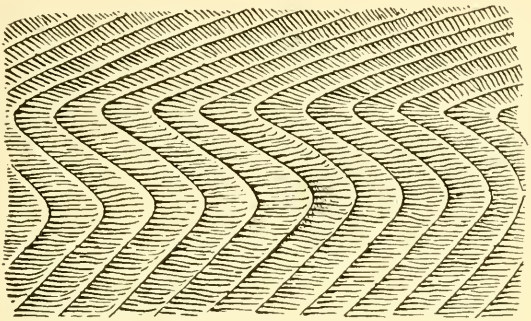


FIG 3. Arrangement of muscle fibers and muscle septa (myosepta) adherent to inner side of skin of a modern shark.
(From Gregory, *Proc. Amer. Philos. Soc.*)

Meanwhile we may emphasize the fact that from the evolutionary viewpoint man has inherited the striped muscle fiber, which is the smaller unit of his entire locomotor system, from the very oldest vertebrates, and that a large part of the human nervous system, like that of other vertebrates, is concerned with the regulation of the locomotor organs and with their effective coordination with other major systems.

The known record of fossilized remains shows that the ostracoderms, which were the immediate forerunners of the vertebrates, were already in existence in the Ordovician and Silurian periods, perhaps half a billion years distant from the present day. Even at that inconceivably remote epoch the most fundamental problem of vertebrate evolution had already been solved and with regard to the ground-plan of their anatomy the ostracoderms were actually far nearer to man than they were to the one-celled starting point of life. For these fish-like chordates were already bilaterally symmetrical, with head and tail and the ability to move in a forward direction. In their heads they had paired sense organs representing the senses of smell, vision and balance, while the main divisions of their brains, as shown by study of their

fossilized brain casts, were of the primitive vertebrate type; the mouth, gill chamber and digestive tract were beneath the brain and spinal cord and the primary

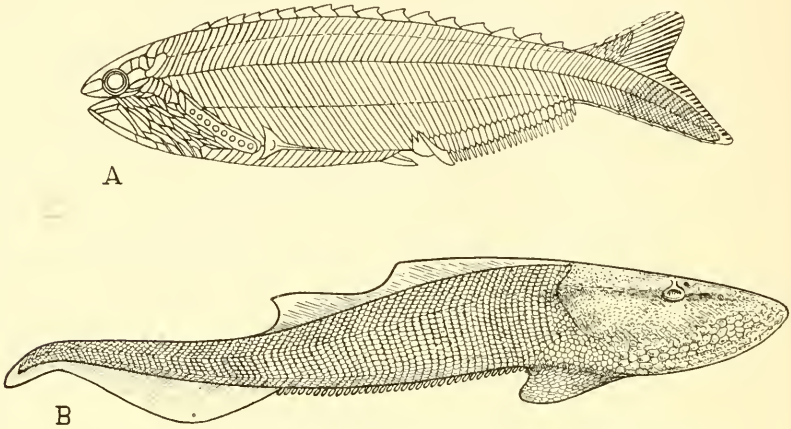


Fig. 4. Two of oldest known forerunners of backboned animals.
A. Pharyngolepis B. Aceraspis.
(After Kiaer, from Greorgy, *Proc. Amer. Philos. Soc.*)

locomotor organs consisted of a closely packed series of zigzag muscle segments on either side of the long axis of the body. Probably also they possessed a notochord or elastic axial rod just below the nerve cord, as do all their less modified descendants.

But these ostracoderms were, strictly speaking, not yet vertebrates for the reason that they had not yet acquired a jointed bony vertebral column, or backbone. The known ostracoderms, according to the convincingly thorough studies of Stensiö, were related to the existing class of cyclostomes, or lampreys and hag-fishes, rather than to the true fishes, within which there is much reason to suppose the line leading to land-living vertebrates later arose.

In the ostracoderms, according to Stensiö's evidence, the mouth opening was in series with the openings leading to the gill pouches, as it is in the embryos of all higher vertebrates. Thus we probably should not have tonsils and thyroid and thymus glands any more than we should have had a tongue

and vocal cords, if the initial steps in these arrangements had not been taken by our earliest chordate ancestors.

Man is also indebted to such very early chordates for another "invention" of the greatest importance, namely the bone-cell. Apparently originating in the deeper layers of the skin, the bone-cells later invaded the connective-tissue partitions between the muscle segments and ultimately gave rise to the internal skeleton. Perhaps the physiologists may be able to find out why the calcium phosphate and calcium carbonate were deposited in the Haversian system of capillaries by these peculiar cells, instead of being cast off by the excretory system.

Our catalogue of debts to the ostracoderms, or to some of their contemporaries, is further increased by the fact that they seem to have been the first of the chordate series to develop a "head shield," or bony mask covering the entire gill chamber and inner brain-case. In the more typical ostracoderms the surface head shield appears to have been all of one piece; but in certain of the anaspid ostracoderms the head was covered by small dermal plates, somewhat after the fashion that was adopted by our own ancestors.

All recent evidence tends to support the view not only that the modern cyclostomes are the, in some respects degenerate, descendants of certain of the ostracoderms but that Amphioxus represents a still further degenerate derivative of the same stock.

OUR FOREBEARS ATTAIN THE GRADE OF VERTEBRATES

In the first chordates the elastic axial tube, or notochord, as seen in Amphioxus, is continuous and unsegmented; but later when the vertebrate grade of organization was attained, rods and blocks of skeletal tissue began to be secreted under the influence of the muscle segments, and as these blocks increased in importance they gradually replaced the primary backbone, or notochord, and gave rise to the secondary backbone or vertebral column. In the ostracoderms apparently only a notochord was present; in the arthrodires (a group of extinct fishes of the Devonian period) the rods above and below the notochord had become hard enough in the tail region to leave their imprints in the surrounding

matrix; in the early ganoid and dipnoan fishes the incomplete blocks or half-rings secreted in the elastic membrane around the notochord may be seen in various stages of development; in the oldest amphibians each vertebra was a complex of eight pieces; and it is only in the higher vertebrates that they become reduced in number. Meanwhile the notochord loses its functional importance in the adult but may always be identified in embryonic stages.

THE ORIGIN OF JAWS AND TEETH

The internal skeleton of the mouth and gill pouches in the ostracoderms remained, so far as the material indicates, in the purely cartilaginous stage, if indeed it was developed at all. In the sharks these cartilaginous supports of the mouth and gill arches became strengthened by the deposition of calcium carbonate; but in the more direct line of forms leading to the higher vertebrates the primary jaw cartilages very early became overlaid by bony plates bearing teeth. These teeth at first were nothing but minute thorns like those borne by the skin all over the body in certain ostracoderms and in modern sharks; but in and around the mouth these dense bone-like thorns specialized into true teeth; meanwhile those on the surface of the body gave rise to the enamel-like scales, while those on the top and sides of the head fused into the smooth skull and jaw plates of the early ganoid fishes.

Thus while the better known ostracoderms appear to have been approximately ancestral to the modern Agnatha, or so-called "jawless" cyclostomes, some remotely related types of early chordates gave rise to the Gnathostomata, or typically jaw-mouthed series of forms including the sharks and their allies the crossopts, or lobe-finned ganoids, the actinopts, or true ganoids (ancestral to the modernized teleost fishes) and finally the dipnoan, or double-breathing fishes.

AN IMPORTANT EXPERIMENT IN BREATHING

Very early in the history of the lobe-finned ganoid stock, which seems to have lived in swampy streams subject to occasional drying, a small accessory breathing organ was

developed in the shape of a pouch for the retention of swallowed air. This was located in the throat behind the gills and was richly supplied with blood vessels. Perhaps

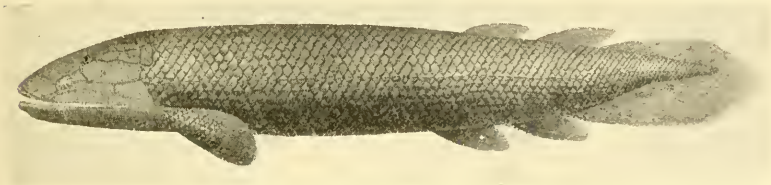


Fig. 5. Lobe-finned fish from Devonian of Russia. Restoration of Diplopterus by Pander.

it was derived from one of the earlier gill pouches which had become enlarged for the reception of air swallowed above the surface of the water, rather than for the extraction of the dissolved air from the water passing through the other gill chambers. However that may be, this accessory breathing organ proved to be of incalculable importance to its possessors for it opened up to them the possibility of invading the dry land and finally of disputing its possession with the insects, who had also invaded it from the water but at an earlier date. At the same time some of the lobe-finned fishes acquired exceptionally strong and fleshy fan-shaped paired fins, by means of which their still more highly evolved descendants were enabled to complete their conquest of the dry land. Thus man owes to these ugly-looking denizens of the Palaeozoic swamps two of his most indispensable possessions, namely lungs and limbs, not to mention many other improvements that they initiated, such as the development of checker-like bony centra surrounding the primitive notochord, the arrangement of paired bony plates on the roof of the skull, the development of a double shoulder girdle of underlying and surface elements and the production of a pelvis or bony base for the pelvic fins, dividing the musculature of the thorax from that of the tail.

THE TETRAPODS INVADE THE LAND

The earliest four-footed vertebrates appear to have sprung from a still undiscovered family of fishes which

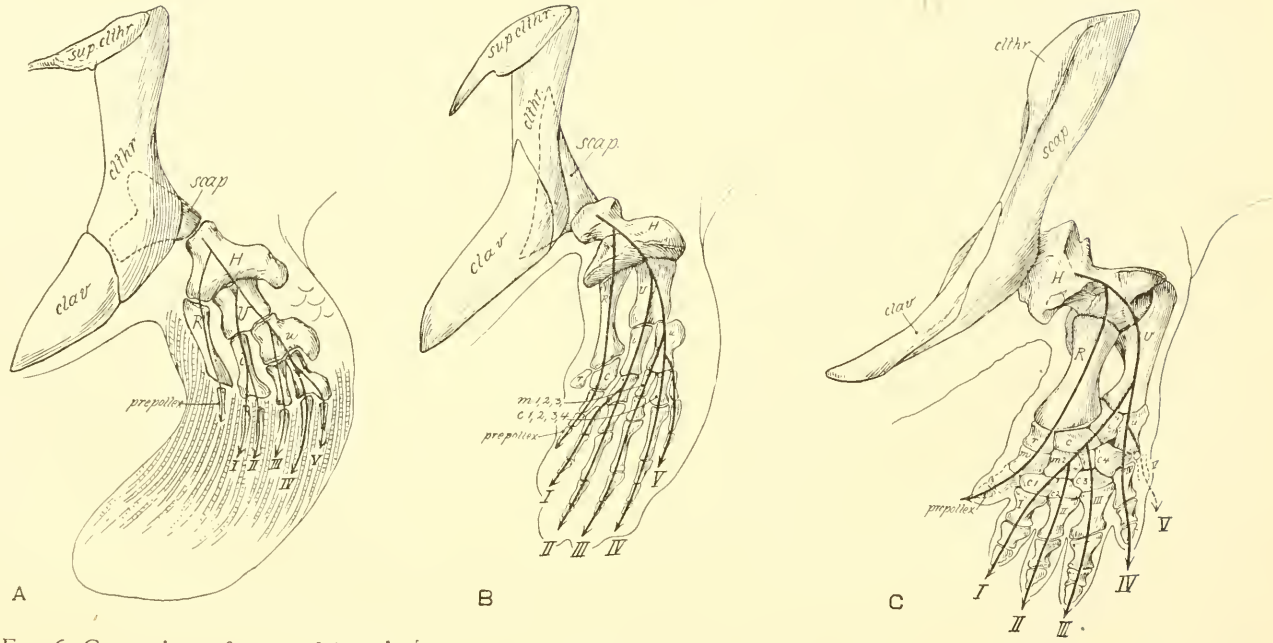


Fig. 6. Comparison of pectoral limb of Devonian lobe-finned fish (A), Permian amphibian (C) and hypothetical intermediate stage (B). (From Gregory, *Proc. Amer. Philos. Soc.*)

combined certain characters of the crossopt, or lobe-finned fishes, with others of the dipnoan group, while avoiding the peculiar specializations of either. When these adventurous pioneers first pushed their way up on to the dry land they were still using the old wriggling movements of the body invented by the very earliest chordates. In some of those forms in which the body was very long and the paired paddles were relatively small, the wriggling movements greatly predominated and in several lines the incipient paired limbs became reduced and degenerate, thus giving rise to snake-like or eel-like amphibians. In the lines that were more nearly related to our own ancestry, on the contrary, the fore and hind paddles, corresponding respectively to our arms and legs, became larger and stronger, the internal bony rods of the extremities, due to the new stresses of terrestrial life, became shifted and modified into the highly characteristic five-rayed hands and feet which were safeguarded by all the later stages in the line of ascent to man. Indeed man owes to these earliest amphibians the entire ground-plan of his anatomy, including the skeletal and muscular parts of his locomotor machinery. Beneath the successive modifications acquired in adaptation to later special life habits, man shares this tetrapodal ground-plan with tens of thousands of other species of land-living vertebrates of the great classes Amphibia, Reptiles, Birds and Mammals, which are collectively bracketed as the superclass Tetrapoda, or four-limbed animals.

Let us consider a little more in detail the mechanism of the tetrapod locomotor machinery, especially in so far as it has served as a starting-point for that of man. Even in the stage of the air-breathing fishes the simple arrangement of zigzag muscle segments which had sufficed to produce the wriggling movements of earlier forms had become complicated, first by the outgrowths of humps of the body-wall surmounted by folds of skin to serve as keels and rudders, and secondly by the extension of buds from the zigzag muscle plates into the bases of these primitive fins, enabling the fish to warp them and finally to move them independently of the general body movements. By the time of the lobe-finned fishes the fore and hind pair of paddles had already

acquired a set of muscles which served to raise, lower, bend or warp the paddles or to move them forward or backward. When some of these fish scrambled out on land the muscles

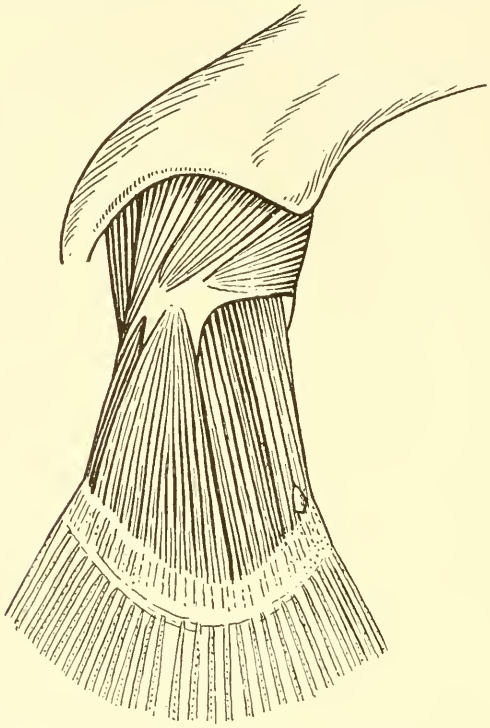


Fig. 7. Musculature of fore paddle of existing lobe-finned fish Polypterus. (After Klaatsch, Die Brustflosse der Crossopterygier.)

of the paddles became further strengthened and differentiated, so that soon they were able to support the weight of the body (Gregory, 1915).

These primitive limbs were at first short, thick, held far out from the body and sharply bent at the elbows and knees. The serratus muscles on either side of the neck sent strips to the inner surfaces of the shoulder girdle and thus the fore part of the body was slung between the U-shaped shoulder girdle, which had been inherited from the fishes.

At this stage the pelvis had no direct connection with the backbone. In front view it was V-shaped, with the opposite femora spreading out on either side from the lower part of

the V and with the backbone lying between the limbs of the V but connected with them only by muscles. In side view the pelvis as a whole appeared like an inverted Y, with the

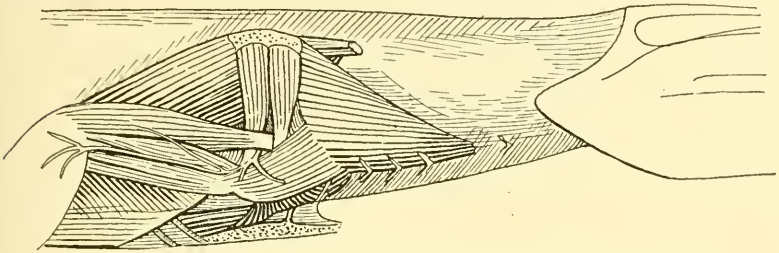


FIG. 8. Musculature of upper arm and shoulder girdle of crocodile.
(After Fürbringer, Zur vergleichenden Anatomie des Brustschulter-apparates und der Schulter-muskeln.)

ilium, or inverted stem of the Y directed upward and backward. As a whole the pelvis lay between the muscle masses of the abdomen and those of the tail and it gave attachment to both (Romer).

When such an animal raised itself off the ground the body was slung like a suspension bridge between two piers, the scapulae of the pectoral girdle forming the front pair of piers and the ilia of the pelvic girdle forming the rear pair.

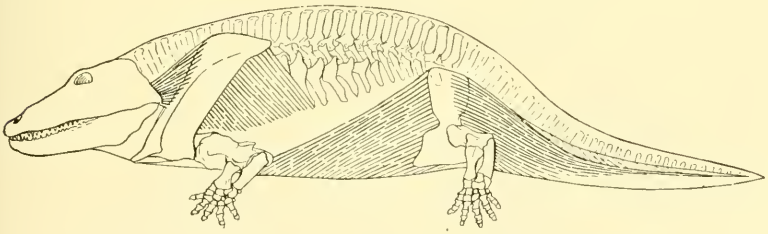
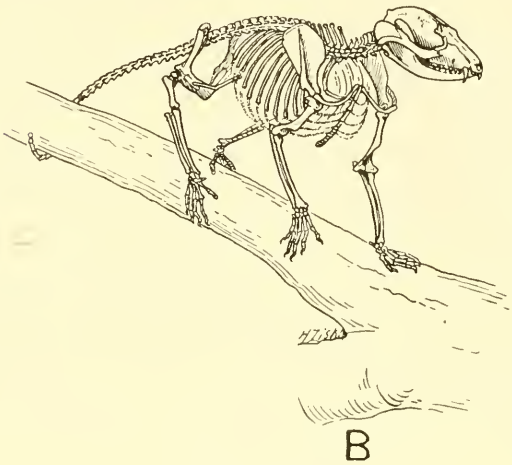


FIG. 9. Bridge-like construction of primitive tetrapod.
(From Gregory, *Proc. Amer. Philos. Soc.*)

Between these the ribs and backbone formed another superposed jointed cantilever bridge supporting the head and the viscera and acting as a movable base for the most powerful muscles of the body. In general, forward progression under such an arrangement involves a series of alternate and rhythmical extensions and flexions, rockings, bendings and twistings. For instance, while the right hind limb is

extending and pushing, the left fore limb is flexing and pulling; meanwhile the weight is swinging between the left hind limb and the right fore limb, the pelvis is turned



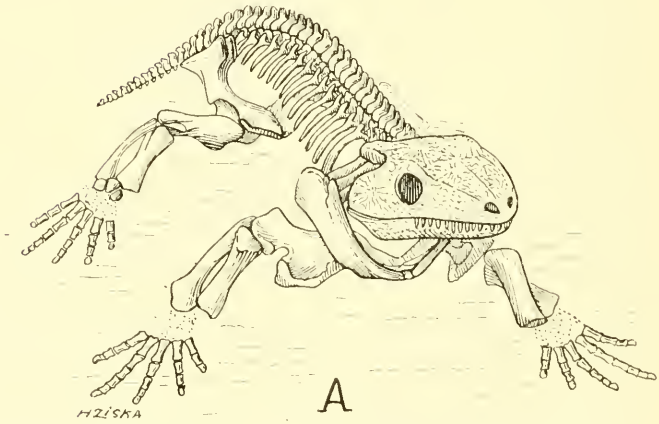


Fig. 10. Primitive reptilian and primitive mammalian postures.
A. Primitive reptile (*Seymouria*) of Permocarboniferous age.
B. Primitive mammal (opossum), survivor of Cretaceous marsupial stock.
(From Gregory, *Proc. Amer. Philos. Soc.*)

slightly toward the right, while the pectoral girdle is turning in the opposite direction; both are also being rocked transversely in opposite directions.

As long as the animal crawls with the belly near the ground, the lurching, sinuous movements are pronounced, but by the time of the higher mammal-like reptiles of the Triassic period a notable advance toward the mammalian mode of locomotion had been achieved, in that the body was beginning to be raised further from the ground and the feet to be drawn in toward the mid-line. Meanwhile several of the ribs in the sacral region of the backbone became widened out at the farther ends and attached by ligaments to the pelvis, which thus began to assume even greater importance in the mechanism of locomotion.

OUR ANCESTORS BECOME WARM-BLOODED

At this point let us turn aside from the consideration of the more conspicuous parts of the locomotor apparatus in order to trace the internal improvements that were prerequisite for its final development. In the lower vertebrates, including the fishes and reptiles, the body temperature is both relatively low and relatively variable, so that the animals are not able to maintain their own body temperature and vital activities at a high level during severe changes in the surrounding medium. The mammals are able to do this, not only because their red corpuscles, being both far more numerous and smaller than those of the lower vertebrates, effect a quicker and larger consumption of oxygen in a given time, but also because they have more efficient lungs and a special bellows-like organ, the diaphragm, which acts in a way like a forced draught; while its piston-like action, described by Sir Arthur Keith, no doubt accelerates the circulation and consequent metabolism. Moreover the body is covered with hair, which encloses a layer of non-conducting air, and the skin is full of sweat glands and oil glands, which further assist in the regulation of the body temperature; in addition to these are the complete separation of the venous and arterial blood in the heart and several other details leading to more rapid aëration of the blood and a greater liberation of energy.

The higher physiological status of mammals is also shown in their improved methods of reproduction. Whereas with few exceptions reptiles lay large eggs, well stored with yolk,

the higher mammals retain the excessively minute eggs within the body of the mother and nourish the young till birth by means of the placenta, or "afterbirth," after which

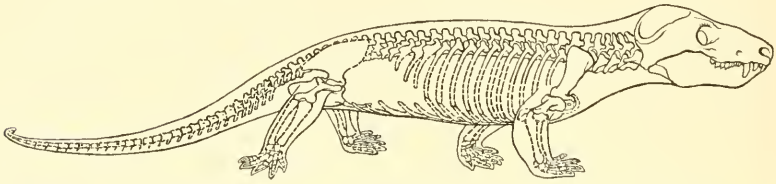


FIG. 11. Cynognathus, a progressive mammal-like reptile from Triassic of South Africa. Tentative restoration by Gregory and Camp.

they feed them with milk from the maternal mammary glands. The monotreme mammals of Australia (including the duckbill platypus and the spiny anteater) resemble the reptiles in so far as they lay large eggs well supplied with yolk, as well as in the ground-plan of their reproductive organs and in certain characters of the skeleton; but they feed their young by means of milk secreted by the mammary glands, and in their brains and many other organs they are true mammals, although standing as the lowest surviving grade of that class.

The superiority of the mammalian over the reptilian grade of organization is a matter of direct observation. The evolution of the primitive reptilian to the promammalian and thence to the mammalian grade, which is so plainly indicated by comparative studies of recent reptiles and mammals, is supported by the available palaeontological evidence, which is relatively abundant during the Permian and Triassic periods when the mammal-like series of reptiles gradually approached the mammalian grade (Figs. 11, 16 D and E).

The fragmentary fossil history of the mammalian class itself during the enormous lapse of geologic time that is represented by the rocks of the Triassic, Jurassic, Lower Cretaceous and Upper Cretaceous periods is preserved in a few of the museums of the world in the form of small collections of fossils for the most part consisting of fragments of jaws containing teeth, all of which are of priceless value as documents (Simpson). In the Triassic certain of the cynodont

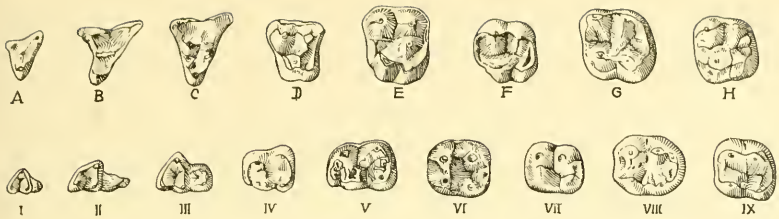


FIG. 12. Structural stages in evolution of upper and lower molar teeth of man. Scales various.

A–H, upper molars, left side.

A. Upper Jurassic, triangular stage (pantotherian).
(After G. G. Simpson.)

B. Cretaceous, triangular stage (Deltatheridium).
(After Gregory and Simpson.)

C. Lower Eocene "tritubercular" stage (Didelphodus).
(After Gregory.)

D. Middle Eocene, transitional stage (Pronycticebus).
(From Gregory, after Grandidier.)

E. Upper Eocene, tubercular stage (Necrolemur).
(From Gregory, after Stehlin.)

F. Upper Miocene, primitive anthropoid (Dryopithecus) stage.
(From Gregory, after Pilgrim.)

G. Pleistocene, primitive man (Le Moustier) stage.
(After Gregory.)

H. Recent, human stage.

I–IX, lower molars, right side.

I. Jurassic, tritubercular stage, with incipient heel (Pantotherian).
(After G. G. Simpson.)

II. Cretaceous, primitive tuberculosectorial stage (Deltatheridium).
(After Gregory and Simpson.)

III. Lower Eocene, tuberculosectorial stage, with low heel (Deltatherium).
(After Gregory.)

IV. Middle Eocene, transitional stage (Pronycticebus).
(From Gregory, after Grandidier.)

V. Upper Eocene, tubercular stage (Necrolemur).
(From Gregory, after Stehlin.)

VI. Lower Oligocene, five-cusped proto-anthropoid stage (Propliopithecus).
(From stereoscopic photograph by Prof. J. H. McGregor.)

VII. Upper Miocene, five-cusped anthropoid stage (Dryopithecus).
(After Gregory.)

VIII. Pleistocene, primitive human stage (Le Moustier), retaining five cusps.
(After Gregory.)

IX. Recent, human stage, after disappearance of fifth cusp.
(After Gregory.)

reptiles so nearly approached the mammalian grade in so many characters of their dentition, jaws, skull, backbone and limbs that they almost deserved to be called mammals. In the uppermost Triassic and later ages the Multituberculates flourished. These were peculiarly specialized rodent-like forms, probably independently derived from the cynodont grade and certainly not in line with the higher mammals. Then in the Jurassic period there were various members of at least seven different families of small mammals representing early experiments along mammalian lines. Most of these families left no recognizable or known descendants in later ages, but in one of them, including several famous fossil jaws from the Lower Jurassic of Oxford, England, to which the name Amphitherium was applied, the lower molar teeth distinctly foreshadow the "tuberculo-sectorial" type. This was characteristic of the earliest placental mammals of the Age of Mammals, and the whole science of odontology or evolutionary study of the teeth (Osborn, 1907; Gregory, 1922) leads us to predict the discovery of tuberculo-sectorial lower molars in the Jurassic forerunners of the placental stock, of which the order of Primates was a later outgrowth.

Only a single humerus and a single femur belonging to these far-off Jurassic mammals are sufficiently well known to have been closely studied but even although it is not clear as to which kind of contemporary jaws and teeth they belong with, yet again they are of great value; for, as recently shown by Dr. G. G. Simpson, the precise arrangement of their various parts and processes, in the light of what is known of the relations of bones and muscles among recent reptiles, monotremes and typical mammals, shows that these limb bones of Jurassic mammals were intermediate in details between the cynodont type below and the typical mammalian grade above. In other words, these Jurassic mammals were raising their bodies further from the ground and preparing the locomotor apparatus for its next great conquest, the invasion of the trees. It is not without significance also that in the Cretaceous period preceding the great expansion of the mammals at the opening of the Age of Mammals (Osborn, 1910), the dominant type, so far as

known, was closely related to the existing opossums, which are arboreal.

THE PRIMATES ASCEND INTO THE TREES

The high grade of vitality, the relatively advanced methods of reproduction and a progressive improvement in brains and intelligence, all led to the final triumph of the placental mammals over their competitors the marsupial mammals, which were for the most part crowded into far-away corners of the world such as Patagonia and Australia. Possibly this higher vitality of the primitive insectivorous placentals, joined to a high degree of variability and plasticity in hereditary characters, early enabled them to branch out and adapt themselves for many methods of locomotion and of feeding, according to the well-established principle of adaptive radiation. Unfortunately the fossil history of the placentals during the later aeons of the Age of Reptiles is extremely meager but early in the Eocene epoch, or first division of the Tertiary period or Age of Mammals, the placental stock had already branched out into insectivores, carnivores, various herbivorous hoofed mammals, rodents and so forth. The direct ancestors of the Primates during this period also are still undiscovered but the fossils from early Eocene times show that even at this immensely remote time (estimated by geologists as perhaps fifty or sixty million years ago)(Barrell) the order of Primates had already begun to separate into several of its grand divisions as we know them today: first, there were forerunners of the modern tree-shrews, classed by many authors under the more ancient and primitive order Insectivora, but foreshadowing the Primates in many features; secondly, there were primitive lemuroids, structurally at least related to the ancestors of the varied modern lemurs of Madagascar; thirdly, there were the tarsioids, small forms with much enlarged orbits, related to the existing spectral tarsier of the East Indies.

The higher primates (including the platyrrhine, or New World monkeys, and the catarrhine, or Old World series of tailed monkeys, anthropoid apes and man) do not begin

to appear in the fossil record until the Oligocene, or second great epoch of the Tertiary period, and so far as present evidence indicates they were a distinctly later series than

FIG. 13. Incomplete fossil skeleton of very primitive primate (Notharctus) from Eocene of Wyoming.
(After Gregory.)

the early Eocene radiation of tree-shrews, lemuroids and tarsioids.

Taken collectively, the lower Primates were represented in Eocene times by a great number of genera and species, founded mostly on fragmentary jaws but in some cases known also from various other parts of the skeleton. In the several instances in which the structure of the hind feet is known the great toe is very large, provided with a flat nail and set off at an open angle from the other digits, which were long and slender. In all the recent primates this kind of great toe is a sign of tree-climbing and an intensive study of the skeleton of many different types of Primates from Eocene to recent times can lead only to the conclusions that the ancestral stock of the entire order acquired many of its peculiar characters in the trees (Gregory, 1920, 1927, 1928) and that this momentous series of events, of far greater importance to mankind than any celebrated in secular history, took place at a very early date in the history of the placental mammals, perhaps even before the close of the Cretaceous period.

With this brief review of the earlier fossil records of the rise of the Primates before us, let us return to the consideration of the evolution of their locomotor apparatus.

In such a specialized swift-running type of mammal as the horse, the limbs have become modified into slender, suddenly extensible compound levers, and in full flight the body is catapulted forward by the sledge-hammer strokes of the solid hoofs. In this case the middle metacarpal bones of the forefeet and the middle metatarsals of the hind feet become greatly elongated, while the remaining metacarpals and metatarsals become more or less reduced and the digits below these have even disappeared entirely. In the line leading to man, on the other hand, the process of digital reduction was avoided, because long before the lateral digits could be reduced through running on the ground, our ancestors took to the trees, where all five digits of the hands and feet were needed for climbing. It is also to this early ascent into the trees that the Primates, including man, doubtless owe the retention of other relatively primitive mammalian features in many parts of the skeleton. For although arboreal life eventually takes its toll in the way of specializations, leading finally to cul-de-sacs from

which retreat is usually impossible and in which extinction is inevitable, yet it is an easily verifiable fact that in the tree-shrews and lemurs the earlier stages of arboreal life conserved many skeletal characters which were very early lost by related mammals that became specialized either for swift running, or leaping on the ground, or digging, or swimming.

We are now in a position to consider some of the ways in which the primitive mammalian skeleton became adapted for arboreal habits (Morton). When, as described above, the sacral portion of the vertebral column became attached by ligament to the inner sides of the pelvis, the animal acquired one of the first prerequisites for rearing up on its hind legs, that is, by contracting the longitudinal dorsal muscles the creature could, so to speak, raise the draw-bridge and balance it upon the rear pier of the double suspension bridge. It will readily be seen that arboreal life put a premium upon this ability, as also upon the possession of limbs that were equally well adapted for pushing and for pulling. At first the Primates were little more than quadrupeds that ran along the tops of the branches and leaped like squirrels from branch to branch, differing widely, however, from normal ground-living quadrupeds in their grasping hands and feet. Such indeed are the tree-shrews and lemurs of the present time and such were their predecessors in Eocene times. Some of the leaping types, such as the sifakas and indris of Madagascar and still more the galagos and spectral tarsiers, specialized in leaping on the long hind limbs, rearing the forepart of the body as described. In these hopping forms as the backbone is reared upward, the knee is bent and the femora are directed downward and backward, the opposite condition to that which took place in man (Morton). In another line of specialization leading to the baboons, the animals started from a fully developed monkey stage; spreading from the forests into more or less open savannahs, they spent more and more time running on the ground and gradually lost the typical monkey-like configuration of the body and became more or less dog-like, the fore and hind limbs being subequal in length, the hands and feet becoming more or less paw-like, with somewhat reduced thumb and great toe and slightly enlarged middle

digits. In the typical South American monkeys, on the contrary, the skeleton is highly specialized for arboreal life. The limbs are long, giving the animal a long reach and the long cylindrical tail is unusually thick and muscular, comprising many spirally-wrapped muscles and tendons which enable it to coil up like a watch-spring and to wrap itself around branches. Its flexible tip even functions as a sort of fifth hand. In general the skeleton of the South American monkeys is radically different in leading features from that of man and every bone of it is readily distinguished from its human homologue.

In all Primates great skill in balancing the body and in judging distances in leaping and climbing are obviously necessary, so that in the comparative study of the brains of lemurs, apes, monkeys and man, neurologists have found an increasingly high degree of development of all those parts of the brain that serve first to correlate the sense of vision with the senses of balance and of bodily posture, and secondly, to initiate the appropriate stimuli to the muscular system so that precision of movement and balance may be habitual.

This great skill in balancing, together with the possession of grasping hands and feet, early led both the New World and the Old World divisions of the Primates to use one or the other of the four extremities in grasping for objects of food, while the remaining three were employed in maintaining the body in its always unstable equilibrium. The habit of sitting upright, which enabled both hands to be used in the manipulation of the food, led in the Old World division to the development of special pads called ischial callosities at the hind end of the pelvis. Again, the habit of sitting upright in the ancestors of the anthropoid division of the Old World series, together with the increasing length of the limbs, finally resulted in the peculiar method of climbing which not until our own time has received a name, notwithstanding its literally revolutionary significance in the history of man. This habit of "brachiation" (or swinging by the arms), as it was aptly named by Sir Arthur Keith, rescued us from monkey-hood and by turning the backbone of our ancestor up on end it literally set him on his feet

and not only raised his face toward the sky but encouraged him to use his hands and brains in working out his own salvation. Like all other great discoveries which disturb the complacency and the traditions of mankind, this one has been either neglected, waved aside or ridiculed; but we shall presently see that when the masking effect of man's present life habits is taken into account, his very bones testify and his inward parts reveal the signs of his brachiating origin.

In the present imperfect record of Primate life we first come upon the brachiating habit and its anatomical correlates in the gibbons of Southeastern Asia. It is true that some feeble attempts at brachiation are occasionally offered by some of the longer-limbed catarrhine monkeys or even by the spider monkeys of the New World series. But these skilled tumblers are mere beginners; their performances, wonderful as they are when considered as feats in balancing and in ballistics, pale in comparison with the dazzling exhibitions of the gibbons, which are the true *virtuosi* of the upper branches of the jungle. With all the abandon due to perfect mastery of the technical details, they hurl themselves from the springing bamboo stalks, keeping themselves upright in the air and catching the next hold on the branches with the greatest ease.

Some of the gibbons of the genus Hylobates have begun to pay a price for this virtuosity; their arms and hands are excessively long and their thumbs considerably enfeebled, since like a trapeze performer they tend to use the fingers as hooks. But these specializations are less pronounced in the hoolock gibbons, in which the thumb is vigorously developed. Moreover the single known fossil femur from the Miocene of Germany (named Pliohylobates), which appears to belong to a primitive gibbon, is distinctly stouter than that of its modern relatives. It is a reasonable inference therefore that the earliest gibbons were somewhat less slender, less fully specialized for advanced brachiating habits than are their modern descendants, and in view of the various souvenirs of a non-brachiating catarrhine ancestral stock that are retained even in the modern gibbon, such an inference becomes highly probable. Again, the small fossil

Fig. 14. Skeleton of gibbon, mounted in brachiating pose.
(Courtesy of The American Museum of Natural History.)

jaw from the Lower Oligocene of Egypt, to which the name Propliopithecus has been applied and which appears to be in the line of ascent to the gibbons also, retains all or nearly all the characters which might be predicated of the jaw of the common stem form of all the anthropoid series, including man. The lower teeth in this jaw are each more primitive, that is, more like those of still older primates, than are the corresponding parts in modern gibbons. Hence the palaeontological evidence, slender as it is, lends support to the conclusion based on comparative studies of the teeth, skull and many parts of the anatomy of the recent Primates, namely, that the *later* specializations of brachiation seen in the gibbons had not been assumed by the direct ancestors of the higher anthropoid group.

Nevertheless, repeated consideration of the subject must also support the view that the gibbons on the whole retain the basic features of the earlier stages of brachiation, namely, the maintenance of an upright posture at right angles to the general plane of forward motion, that was also prerequisite for the emergence of man. The relative nearness of the gibbons on the one hand to the ancestral stock of the anthropoid-man series, and on the other hand to the older catarrhine stock, has been recognized by all authorities. The gibbons are definitely more primitive (that is, more like the lower Primates) than any of the great apes or man in many characters of the dentition, of the skull, vertebral column, pelvis, etc., as well as in the brain and in many features of the viscera (Keith). Their pelvis is remarkably primitive; it retains clear traces of the ischial expansions characteristic of the Old World monkeys, while the blade of the ilium is but little expanded transversely.

When the brachiating gibbon comes down on the ground, he does not run on all fours like a monkey, he does not swing on his long forearms as crutches like an orang, he does not walk on all fours with bent knuckles as do the chimpanzee and the gorilla; on the contrary, he walks or runs upright like a man, with his femora overextended, so as to be nearly vertical and parallel with his backbone. His gait on the ground differs from that of man in that the arms are held upward, the knees turned outward and the

great toe inward. In such a position the gibbon is meeting and solving the same problem of balancing the whole forepart of the body upon the pelvis and hind limbs that is solved more completely by man. Sir Arthur Keith, in searching for the early history of man's upright posture, found that in the gibbon the arrangements of the diaphragm, lungs, pericardium, and many other internal organs, manifest many characteristically human adjustments to upright posture, and he concluded that man had derived many of his structural and functional adaptations to the upright posture from an older brachiating stage.

In conclusion, the annectant position of the gibbon between the lower Old World Primates and the great-ape-man series is fully documented by the monographic studies of Tilney on the brain of Primates and of Keith on the viscera; and if the inference were made that because the gibbon is specialized in a few features his basic method of brachiation may be ruled out of the line of advance leading to man, such an inference would appear to be not in accord with either the morphological or the palaeontological evidence. Quite the reverse, while the brachiating gibbon is a living witness of the ultimate derivation of man from an arboreal quadrumanal monkey, he is also far more man-like than monkey-like in many features of his viscera and in his general adaptation to the upright posture.

MAN EMERGES ON THE GROUND

Up to the present point we have traced in outline the general history of the vertebrate locomotor apparatus, showing how the simplest fish-like forms contain the potentiality and the ground-plan of the sequence of animals that emerged from the swamps, invaded the dry land, ascended into the trees and finally turned the backbone at right angles to the plane of progression and gave rise to the noble grade of brachiators. All the existing anthropoid apes retain clear traces of derivation from a primitive brachiating stem form, perhaps represented by some of the various species referred to Dryopithecus and allied genera, which roamed over Europe and India during the Miocene and Pliocene times.

Apparently the orang-utan was the first to branch off from the common stock. It rapidly attained great size, especially the old males, and became excessively specialized

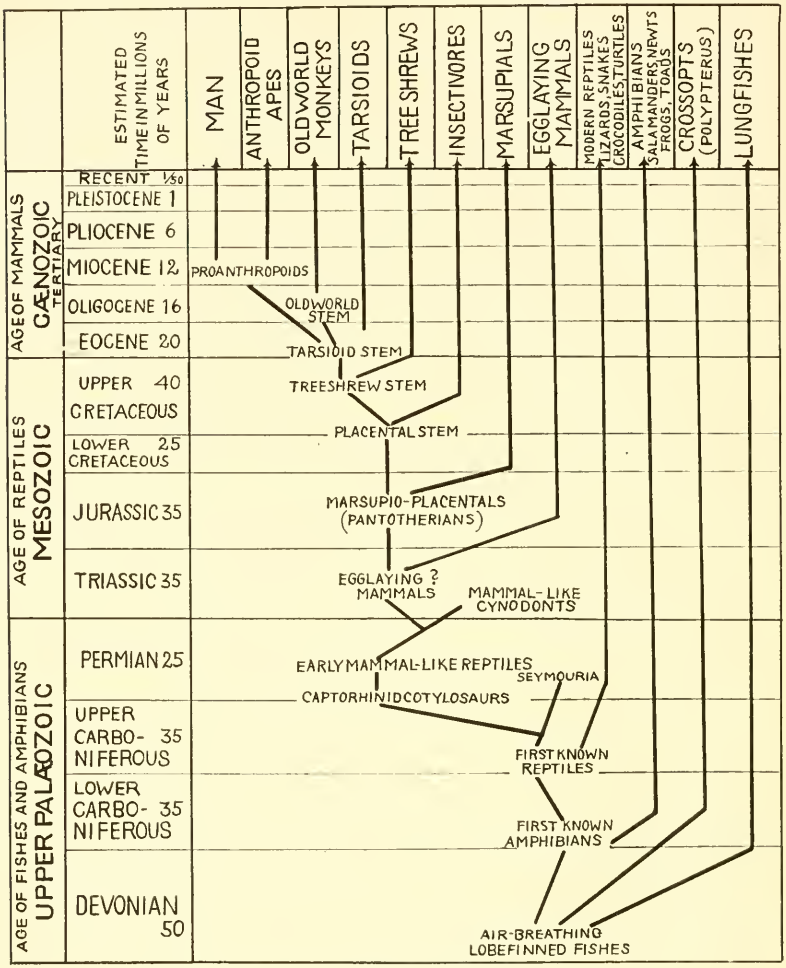


FIG. 15. Structural stages in rise from fish to man.

Starting from upper right-hand corner, "living fossils" form a series that gradually approaches man in general structural plan. Each "living fossil" is also a surviving witness of a corresponding stage in past ages.

for arboreal life, using chiefly the suspension grasp of both the hands and feet, which are now extremely long and hook-

like. After the orang had begun to diverge, the common stock contained the ancestors of the chimpanzee, gorilla, man and possibly of other species now known chiefly from fossil teeth and jaws of the Dryopithecus group. The common stock was probably intermediate in size between the siamang and the smaller species of chimpanzee. By Upper Miocene times in India there was already a wide range in size, as indicated by the fossil teeth of anthropoids, some being but little larger than those of siamangs, others nearly as big as those of gorillas.

The known African anthropoids, the chimpanzee, the gorilla and the extinct Australopithecus (Dart), show the most unmistakable marks of close kinship with each other. Among recent forms the chimpanzee on the whole probably retains the greater number of primitive characters. The range of variability in existing chimpanzees is very great, especially in regard to external features, details of skull form, size of teeth, degree of wrinkling of enamel on the molars, and many other characters. In some chimpanzees the basic patterns of the premolars and molars rather closely approximate the primitive human type, but the canine teeth exhibit the opposite tendency toward enlargement. In many races of anthropoids there seems to be a tendency to gigantism, the body weight mounting to many fold greater than that of the primitive anthropoid stock represented by the tiny fossil lower jaw of Propliopithecus. Very heavy bodies are not favorable for extreme agility in the trees unless a cautious swinging movement is adopted, as in the orang. Hence in order to maintain this agility it was necessary for the chimpanzee to acquire a surprisingly high degree of muscular strength.

The typical chimpanzees are forest animals that apparently spend most of their time in the trees and have therefore had time to become specialized considerably beyond the stage of the "common ancestor" of the higher apes and man. For instance, at least in many chimpanzees the thumb is reduced. When either the chimpanzee or the gorilla walks on the ground it commonly assumes a position which is superficially like that of a quadruped, but on closer inspection we see that these animals differ profoundly from true

quadrupeds in the fact that they rest the weight of the forepart of the body not upon the palms of their hands but upon their flexed fingers, a souvenir of the grasping action of the hand during brachiation. Usually the chimpanzees when on the ground stay near the forests, but explorers have sometimes seen them crossing wide areas of savannah country in going from one patch of forest to another. The finding of the fossil skull named Australopithecus in a region hundreds of miles south of the forest-living anthropoids, in a formation of which the lithologic characters indicate open country for long periods, supports Dart's view that the most man-like known member of the higher ape stock was already in course of invading the open country as did the ancestors of man.

We are not yet sure whether man branched off before or after the gorilla separated from the common stock. The late Professor G. Schwalbe after a most thorough analysis concluded that man branched off from the fork that also gave rise to the chimpanzee. The modern old male gorilla has become extremely un-manlike in its excessive body size, huge baboon-like muzzle and teeth and certain other features. All these characters, however, may have been rapidly acquired after the gorilla separated from the main stock. The blood tests, the brain structure, the anatomy of the hands and feet and many other anatomical characters indicate that the relationship between gorilla and man is far closer than was formerly suspected. The ape-like jaw of the Piltdown skull indicates that even as late as early Pleistocene times there were some human beings with strongly ape-like characters of the jaw and teeth.

The almost human hand, foot and brain of the gorilla suggest that a secondarily quadrupedal, ground-living phase may have succeeded the purely erect arboreal stage and preceded the erect ground-walking stage, notwithstanding the initial mechanical disadvantages encountered by a heavy-chested form in assuming the erect posture (Morton). Even now in spite of his gigantism or of his short hind legs, the young gorilla has no difficulty in standing upright or in carrying boxes with his forearms while walking in the erect position. The quadrupedal gait recorded by Hrdlička in

babies of various races might be reminiscent of a primitive quadrupedal ground phase following the erect aboreal phase. But on the whole the present evidence seems to favor the view that when man's ancestors came down out of the trees they held the body erect while walking, as does the gibbon.

While there are literally thousands of items of evidence for the inference that man is a specialized peculiar offshoot of the anthropoid stock, the exact time of his separation from that stock and the more precise description of its anatomy are matters of inference as to which there is room for differences of opinion. The known fossil record of man's nearest relatives, while very meagre, indicates that during the Eocene, or first grand division of the Age of Mammals, only the lower grades of the Primates were in existence. By the time of the Lower Oligocene the short-jawed predecessors of the anthropoid group were established. In the Miocene and Pliocene epochs varied species of anthropoid apes roamed over Europe and India, some of which foreshadowed man in the patterns of their molar teeth. Then there is a blank in the record and by the time of the Upper Pliocene and Lower Pleistocene several widely different types of human skull were already in existence. There is considerable indirect evidence that the rate of evolution in the earlier races of mankind was far higher than it was in other groups of animals and it is not unlikely that the rapid emergence of man as a creature of the open plains took place in the vast periods of time represented by the Miocene and Pliocene epochs.

We are not yet informed as to whether this emergence took place in Asia, Europe or Africa. The claims of the high plateau region of central Asia as a possible center of distribution of the nascent Hominidae have been urged by Professor Osborn (1926), and several fossil teeth of unquestionably human type have been found imbedded in a cave deposit in China that contained other fossil mammals of apparently Pleistocene age. But the origin of man from the anthropoid stem must be sought in a far older epoch, perhaps the Miocene, so that there would be plenty of time, if man originated elsewhere, for him to have reached eastern Asia by Pleistocene times. Also it must be admitted that the three

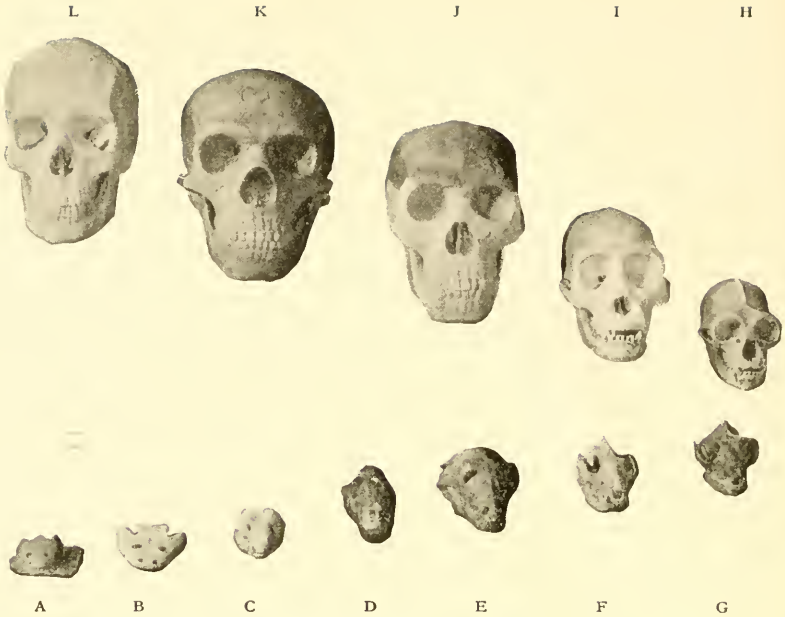


Fig. 16. Structural stages in evolution of skull from fish to man.

A. (Lower left). Restoration of skull of Osteolepis, a Devonian lobe-finned fish. Based on original fossils in American Museum of Natural History and on Pander's specimens.

B. Restoration of skull of Permocarboniferous amphibian (Trimerorhachis minor). Based on fossil specimens in American Museum of Natural History.

C. Permocarboniferous primitive reptile (Captorhinus). From specimen in American Museum of Natural History.

D. Permian mammal-like reptile (Scymnognathus). Restoration of skull based on fossil specimens in American Museum of Natural History.

E. Triassic mammal-like reptile (Cynognathus). Restoration of skull by Prof. A. S. Romer, based on fossil specimens in British Museum (Natural History).

F. Recent opossum, "living fossil" mammal type, surviving from Cretaceous period.

G. Eocene lemuroid primate (Notharctus). Restoration based on fossil skulls in American Museum of Natural History.

H. (Top row, right). Skull of recent gibbon, representing little modified survivor of Oligocene proto-anthropoid stock.

I. Immature gorilla skull, representing modified descendant of Miocene anthropoid stock.

J. Lower Pleistocene Pithecanthropus. Cast of original skull top, with Prof. J. H. McGregor's restoration of face. Represents one of primitive human stages.

K. Upper Pleistocene Neanderthal stage. Restoration of skull by Prof. J. H. McGregor from original fossil specimens.

L. Recent human stage, with high forehead and relatively small jaws.

known anthropoids which are unquestionably nearer to man than any others are the three African forms, the chimpanzee, the gorilla and the extinct Australopithecus. Also the European fossil species *Dryopithecus rhenanus* and *Dryopithecus fontani* in the detailed patterns of their molar teeth appear to be especially related to the African group and therefore, according to the evidence of blood tests, etc., to man.

CONCLUSIONS

In conclusion, the theory of man's derivation from lower vertebrates according to the general sequence of stages outlined in this article may claim to be distinctly more than a trial hypothesis, since it rests upon many converging lines of evidence. It is in fact an outgrowth of the general advances of the past half-century in vertebrate palaeontology, vertebrate zoölogy and taxonomy, human and comparative anatomy, anthropology, embryology, physiology and related sciences. The theory of the brachiating ancestry of man rests in the first place upon the general subject of the classification and evolution of the vertebrates as a whole. A host of zoölogists and palaeontologists have established the fact of man's place in nature: he is a member of the anthropoid-human division of the higher Primates, which may be traced to the stem of the order of Primates; these in turn derive from primitive placental mammals related to the existing tree-shrews; thence we pass downward through the imperfect records of the Age of Reptiles to the progressive mammal-like reptiles of the Triassic; downward again by plainly recognizable morphological stages to the theromorph stem forms in the Permian; still downward to, or near to, the captorhinomorph division of the cotylosaurs; and thence to the horizon of the varied eotetrapods of the Coal Measures; in the Devonian we see the crossopterygian and dipnoan forerunners of the Tetrapoda and below that a long gap to the varied ostracoderms of the Silurian, which show us the early chordate stem in various guises. Below that the rest is darkness, except that comparative morphology throws considerable light on the origin of the basic chordate locomotor apparatus which all the later forms inherited in part.

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Chapter IV

THE EVOLUTION OF THE BRAIN

George H. Parker

NO organ is so distinctive of man as his brain. Long recognized as the seat of his mental life, it is that portion of his body most concerned with his personality. Here take place those changes that give rise to his sensations, his memories, his volitions; here arise his emotions, the figments of his imagination, his dreams; and here too, in abnormal states, appear those idiosyncracies and moods that pass over step by step into insanity. In short, the brain is the organ of his mind, his very soul. Not that the brain alone is all this, for this organ is buried in his body, which, as an environment, yields among other things the whole range of internal secretions determining as they do in so many ways the setting for the individual life. But notwithstanding the importance of these surroundings, the brain harbors what is one's truest self and in this respect no other organ in us is its peer.

Man's brain more than any other part separates him from all other creatures. Even its weight shows this. Two living animals only, the elephant and the whale, have brains heavier than his. The elephant's brain weighs about 12 pounds, that of a large whale about 10 pounds, while man's brain turns the balance at almost exactly 3 pounds. All other mammals such as the horse and the cow and even giants like the rhinoceros and the hippopotamus have smaller brains than man. The gorilla, a close relative to man and slightly heavier in body than he is, has nevertheless a brain scarcely one-third as large. Thus man outstrips all other living animals, except the elephant and the whale, in the absolute weight of his brain.

Every one is familiar with the fact that the size of an animal's brain is roughly proportional to that of its body; the elephant has a gigantic brain, the mouse a diminutive one. But it is not so commonly known that large animals

have disproportionately small brains and small animals relatively large ones. In the cat, an animal of medium size and therefore appropriate as a standard, the weight of the brain is about 1 per cent of that of the body. In the Indian elephant, whose bodily weight may be from 6000 to 7000 pounds, the brain, large though it is, is only about 0.2 per cent of this weight, or one-fifth the percentage of the cat's brain. The condition in the elephant represents fairly well that characteristic of most large mammals.

The opposite extreme is clearly illustrated by small animals like the rats and the mice, whose brains are large compared with their bodies. Thus the brain of the harvest mouse, whose bodily weight is about 7 grams, represents over 5 per cent of this weight, or five times the percentage of the cat's brain. Disproportionately large brains are common among small mammals. The same seems to be true of birds; witness the relatively large size of the brain in the smallest of these, the humming bird. And this principle also appears to apply to insects, for among the castes of worker ants the brain is rather uniformly large even when the body is very small.

Apparently each phase of animal life requires a certain minimum of brain wherewith to carry on its nervous and mental activities, and when for one reason or another the body as a whole suffers an exceptional reduction, the brain does not undergo a corresponding decrease. When on the other hand the size of a stock of animals through evolutionary growth becomes excessively large, as in the case of the elephants or the whales, the brain follows this trend to a certain extent, in response to increased skin surface and musculature, but only in a restricted way, for the sense organs and muscles of a large animal are after all not much more complicated or appreciably more numerous than those of a smaller one. Hence the necessity of proportional increase in the central nervous organs of such a stock does not obtain. Thus in such an evolutionary growth as that of an elephant or any other large creature, the central nervous organs, though they undergo some increase, fall noticeably behind the general growth of the animal as a whole, with the result that the proportional size of these organs is markedly

less than what might have been expected. In both sets of changes, decrease and increase, the brain seems to lag behind the rest of the animal, and gives evidence in this way of a degree of independence not commonly associated with animal growth. The brain in its evolution, as compared with other parts, exhibits what may be described as an organic conservatism for it tends to maintain its size irrespective of the surrounding flux.

The amount of brain substance in different animals is often taken as an indication of their intelligence, and in a measure this is justified. Thus the brain weights of three animals of about the same bodily size, a very large dog, a gorilla, and a man, are respectively 135 grams, 430 grams, and 1360 grams, a rough measure of their comparative mental powers. Even among the races of men such differences are not unknown. Thus the brain of the Australian native weighs only about 1185 grams, an amount quite compatible with his low mentality.

But such measures are necessarily of only very general applicability. When the weights of various human brains of European stock are compared great individual differences are to be observed from the extreme of microcephaly to that of macrocephaly. Microcephalic brains are those of 1000 grams or less. Such brains are known to range as functional organs down to a little under 300 grams. But individuals possessing brains of this size are always abnormal and often idiotic. Macrocephalic brains range from 1500 to somewhat over 1900 grams. Individuals thus equipped are by no means always geniuses, but in many cases are abnormal or even idiotic. It is, however, interesting to observe that many highly intellectual men have, if not macrocephalic, at least unusually heavy brains. If the weight of the average male brain of European stock is taken as 1360 grams, and if the weights of the brains of male European intellectuals are compared with this as a standard, it is found that the brains of the majority of such individuals are heavier than this standard. Thus of 46 brains of intellectuals, 33 were heavier and only 13 were lighter than the standard brain. The average weight of these 46 brains was a little over 1440 grams or 80 grams heavier than the standard. The heaviest

brain in the series was that of the celebrated French zoölogist Cuvier, with the unusual weight of 1830 grams. The lightest brain was that of the recently deceased dean of French littérateurs, Anatole France, who reached great distinction notwithstanding the fact that his brain weighed only 1190 grams. These records show that though it is possible to attain high intellectual standing with a brain subnormal in weight, the individual whose brain is above the average in weight has on the whole a better chance at such attainment than his small-brained competitor. Nevertheless it is perfectly clear, when all the facts of brain weight are taken into account, that beside quantity of brain there are other elements concerned with intelligence. Prominent among these without doubt is the organization of the brain materials, an element that is summarized in the expression quality of brains, and for which a physical measure is difficult to devise.

In the human species the brains of the two sexes vary slightly. The weight of the average European male brain, as already stated, is 1360 grams, that of the female brain 1250 grams, a difference of 110 grams or about 4 ounces. This difference has been made the basis of an unfavorable comparison of the sexes in man, but as may be inferred from what has already been said, the ground for such a comparison is extremely hazardous. The difference in the weights of the brains in the two sexes is more likely correlated with the differences in the weights of the male and female bodies than with different orders of intelligence. The body of the average European male weighs about 70 kilograms or a little less than 155 pounds; that of the average European female about 55 kilograms or a little more than 121 pounds, a difference of 15 kilograms or about 33 pounds. This difference, which implies a somewhat larger physical task on the part of the male nervous system than on that of the female is probably the real explanation of the small difference in the weights of the two classes of brains rather than different degrees of intelligence. From another standpoint the female, seems to have the advantage over the male, for, assuming the correctness of the weights of the brain and of the bodies male and female given in this paragraph, the brain of man is

only about 1.9 per cent of his total weight, while that of woman is about 2.3 per cent, an excess of a fraction of 1 per cent in her favor.

Roughly speaking, the brain of man is about 2 per cent of his total weight or twice the corresponding percentage of an average animal such as the cat. The percentage in man, however, does not by any means reach the 5 per cent attained in such small mammals as mice. Here apparently occur the highest percentages known between brain and body weights, a condition dependent rather upon the requirement of a minimum amount of brain substance for normal function than upon excessive mentality.

The brain is the most complicated organ in the vertebrate body. It is a most intricate arrangement of centers and connections that far exceeds in complexity the most elaborate telephone system. It is at once the despair and the joy of the working neurologist, for its complications seem limitless, while the problems hidden in its details are of the first order.

To know the brain we cannot consider it separately from the spinal cord, that strand of nervous tissue which stretches from the brain backward through much of the body. In the fishes the brain is only a fraction of the weight of the spinal cord. In the frog the brain and cord are about equal. In all higher animals the brain gains over the cord till in man the cord is represented by a rod of nervous tissue somewhat thicker than a lead pencil, roughly a foot and a half long, and with a weight of some 26 grams or about a fiftieth that of the brain. These changed relations are not due to a reduction in the cord but rather to an excessive development of the brain. Starting in the fishes as a relatively inconspicuous organ the brain grows in proportionate size till in man it far overtops all other parts of the nervous system.

To gain some acquaintance even in a superficial way with the organization of the human brain, it is best to look first at the brain of some simple representative vertebrate, such for example as that of a frog. The brain of this animal lies in a bony skull and upon exposure it is seen to consist of an elongated stem or axis which expands here and there into special prominences or lobes. The spinal cord of the frog, which is of relatively uniform thickness, gradually enlarges

where it passes forward into the head and thus forms the rear section of the brain, the medulla oblongata (Fig. 1). In front of this is a slight tongue-like elevation, the cerebel-

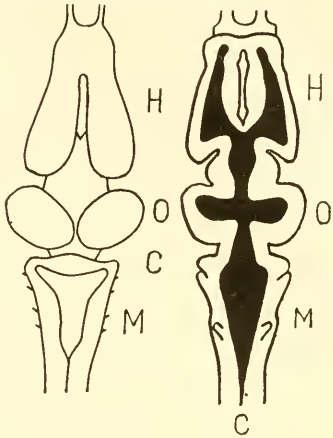

Fig. 1. Fig. 2.

Fig. 1. Frog's brain seen from above.

c, cerebellum; h, hemispheres; m, medulla oblongata; o, optic lobes.

Fig. 2. Frog's brain opened from above to show ventricles.

c, central canal of spinal cord; h, hemispheres; m, medulla oblongata; o, optic lobes.

lum, which is followed midway on the length of the brain by a pair of conspicuous prominences, the optic lobes, on the right and on the left. A little in front of these lobes the stem of the brain branches into two relatively large elongated bodies which, because of their general structural agreement with parts in the brains of the higher animals, are called the hemispheres. These lobes terminate the brain at its front end.

If a transverse section of the frog's spinal cord is examined under a microscope a small pore can easily be observed near its center. This pore is the so-called central canal which runs lengthwise in the cord. The cord therefore is a hollow structure and may be compared not inappropriately to a very thick-walled tube. The central canal of the cord can be traced forward into the brain where it expands into a succession of chambers known as the ventricles of that structure. As the cord enlarges at its front end to form the medulla

oblongata the central canal enlarges, giving rise to the hindmost ventricle of the brain (Fig. 2). In front of this the canal narrows in the region of the cerebellum to expand again into a partially paired ventricle in the optic lobes. Again it narrows and then once more enlarges at the roots of the hemispheres into each of which a branch passes to expand in the given hemisphere as a lateral ventricle. Thus both cord and brain are hollow structures, tube-like in character, with a continuous series of cavities from hind end to front. The group of animals known as chordates, namely the vertebrates or back-boned animals, and certain closely related invertebrates such as the sea-squirts, are all characterized at one stage or another by the possession of hollow central nervous organs such as have been described for the frog. This condition is in strong contrast with that of the majority of invertebrates such as the insects, crabs, snails, clams, worms and the like, all of which have central nervous structures formed of solid masses of nervous tissue without ventricles or other cavities. The cavities of the vertebrate cord and brain are of great importance in facilitating the exchange of nutritive and other fluids in these organs. In animals like the vertebrates where such parts come to be of great size and thickness a special means for the exchange of fluids is necessary, a state of affairs not called for in those more lowly organized creatures whose bulk of nervous tissue is relatively small.

The spinal cord and brain of the vertebrate reflect in a general way the conditions of the animal's body immediately external to them. The cord is chiefly concerned with the nervous activities of the trunk, namely the whole of the body exclusive of the head. The trunk is relatively uniform and carries upon it no special sense organs such as the head does. It is therefore not surprising to find that the cord is of relatively uniform diameter for the successive nerves that pass out from it are distributed each to nearly equal areas of skin and masses of muscle and hence duplicate each other step by step along the length of the animal. Only in the trunk of higher creatures where the front legs and hind legs or their modifications, wings and arms, are especially developed does the cord show obvious local differences. In

such instances the highly developed extremity with its extra skin and muscle is represented by a slight local enlargement in the cord to meet the increase of function. Otherwise this structure is extremely uniform throughout its length.

Far different is it with the brain. This central organ lies within the head and the head, as is well known, carries the chief sense organs of the body. In a typical vertebrate, such as the frog, there are three pairs of these organs, the nasal cavities, the eyes, and the ears. Of these the foremost are the nasal cavities, the nerves from which enter that part of the brain that is designated the hemispheres. The nasal cavities being chiefly concerned with smell, this region of the frog's nervous system may therefore be designated as the olfactory brain. The nerves from the frog's eyes enter the second important part of this central organ, the optic lobes, and hence this region may be called the visual brain. Finally the nerves from the ears terminate in the anterior part of the medulla oblongata in close proximity to the cerebellum. This region might therefore be supposed to be the auditory brain, but it is well known that the ears of vertebrates are organs of a complex nature and that they have quite as much to do with enabling the animal to maintain an upright position and with other matters of equilibrium and of posture as they do with hearing. In fact in such creatures as the frog where the sense of hearing is in a relatively undeveloped state, the ears are in all probability more concerned with positional relations than with hearing. Hence this portion of the central nervous organs may be designated as the positional brain without however denying to it a number of other functions, one of which, for instance, is hearing. In this way three important functional regions may be distinguished in the brain of the frog, the olfactory, the visual, and the positional, reflecting the three important sense organs, the nasal cavities, the eyes, and the ears.

On first inspection scarcely any resemblance can be seen between the brain of a frog and that of a man. Instead of a stem moulded into several lobes as the brain of the frog is, the human brain seems to be a more or less oval mass covered externally by a most intricate system of convolutions

(Fig. 3A). On closer study, however, the brain of man reveals in all particulars the same ground plan of structure as that seen in the frog, the chief point of difference being the relative development of its several parts. If the cerebellum and the hemispheres of a human brain are cut off, the stem that is left reproduces in many respects the essentials of the frog's brain (Fig. 3 B and C). The human spinal cord enlarges at its front end to form in the brain stem of man the medulla oblongata, as it does in the frog. In place of the small tongue-like cerebellum in the frog man possesses a complex and much convoluted cerebellum of relatively large size. The medulla and the cerebellum in man together represent a positional brain as they do in the frog. Above this section of the brain in man but quite hidden from view is a pair of optic lobes forming a part of the so-called corpus quadrigeminum of human anatomy. These lobes mark the terminations of many of the optic nerve fibers and represent the visual brain of the frog. In front on the underside of the hemispheres of the human brain are the olfactory tracts and lobes connected by nerves with the nose. They correspond to what has been called the olfactory brain in the lower animals and are entirely overshadowed in man by his enormous hemispheres.

Thus all the important parts in the brain of the frog recur in proper relations in the stem of the human brain, but the human brain differs from that of the frog in the very considerable development of its cerebellum and particularly of its hemispheres. This excessive growth of these two parts can be traced step by step in the animals intermediate in position between the frog and the higher mammals. In the frog and its relatives the stem of the brain and the three functional regions already pointed out are all clearly open to view from above. In reptiles the cerebellum and the hemispheres are relatively larger than in the frog, but they do not cover up in any important way the stem of the brain. In the lower mammals, such as the rabbit, the cerebellum and the hemispheres have enlarged sufficiently to cover most of the stem so that from above little of the medulla oblongata and none of the optic lobes can be seen. Finally in man the hemispheres have so far exceeded in growth

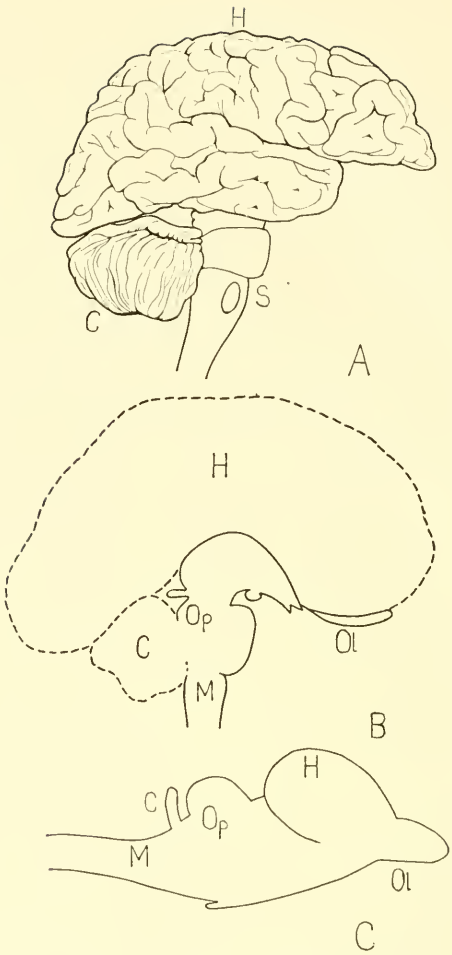

Fig. 3. Comparison of the human brain (A and B) with the frogs brain (C).

A. Human brain seen from side. C, cerebellum; H, hemispheres; S, stem of brain.

B. Human brain cut lengthwise to show stem. Dotted outlines show cerebellum, C, and hemisphere, H. Stem of brain is shown in solid outline. M, medulla oblongata, positional brain; OP, optic lobe, visual brain; OL, olfactory lobe, olfactory brain.

C. Frog's brain seen from side for comparison with human brain. C, cerebellum; H, hemisphere; M, medulla oblongata; OP, optic lobe; OL, olfactory lobe.

all other parts of the brain that they have covered not only the stem but also the cerebellum so that the external view of the human brain is almost entirely that of its hemispheres. Thus the brain of man differs from that of the frog chiefly in the disproportionate growth of two of its parts, the cerebellum and especially the hemispheres. How disproportionate this growth is may be judged from the fact that in man the stem of the brain represents about 2 per cent of its total weight, the cerebellum about 11 per cent, while the hemispheres account for 87 per cent. The distinguishing feature of man as an organism is his intelligence and the distinguishing feature of his brain is the relatively enormous size of the hemispheres. Hence it is natural to conclude that the hemispheres are that part of his brain concerned with his intelligence, a conclusion confirmed by many other lines of evidence.

In the earlier part of this chapter the statement was made that the brain was the most complicated organ in the vertebrate body. This complication, which is as apparent in the spinal cord as in the brain itself, is due to the enormously intricate system of centers and connections that go to make up the structure of these parts. The essential element in this structural complexity is the nerve cell or neurone. The structure of these nervous units is discussed in chapter VIII. The cell bodies of neurones are commonly concerned in the formation of nerve centers and their processes, the nerve fibers, are the means of connection between these centers. A true nerve cell or neurone consists not only of a cell body but also of such nerve fibers as grow out from that body and since in some instances these fibers are extremely long the spread of a single neurone is sometimes very considerable. Thus in the hemispheres of the human brain are certain cell bodies whose nerve fibers extend downward not only through the brain but through the spinal cord almost to its lower end. Here they terminate in contact with a second set of neurones whose nerve fibers may extend as components of one of the nerves of the leg to the muscles of the toes. Thus the first neurone has its origin in the head and the second terminates in the toe; together they represent a length about equal to that of the human body. When it is

remembered that most animal cells are of microscopic proportions and quite invisible to the unaided eye, the extraordinary character of the nerve cell or neurone must be evident.

The number of neurones in the central nervous system of man is inconceivably great. A single instance will suffice to illustrate this statement. The gray layer that covers the exterior of the human hemispheres is of great uniformity in thickness and in structure and thus lends itself easily to an estimation of the number of neurones contained in it. This number on good grounds is believed to be nine thousand two hundred and eighty millions (9,280,000,000), a number which, prodigious as it is, is approximately only about one three thousandth of the twenty-six millions of millions (26×10^{12}) of cells estimated to be present in the body of the adult human being. It is clear from this one number alone that it is no exaggeration to say that the human brain contains millions upon millions of neurones. The interrelations of these elements must establish a system whose intricacies are unbelievably great.

Notwithstanding the enormous number of neurones in the central nervous organs of man, these elements conveniently fall in accordance with their functions into three classes. These classes are the sensory or receptive neurones, the motor or effective neurones, and the communicating or internuncial neurones. They can be most clearly illustrated in the spinal cord where nervous relations are relatively simple as compared with the brain.

The spinal cord gives out from its sides right and left a regularly arranged series of spinal nerves. As these nerves emerge from the cord they are seen to arise by two independent roots, one dorsal and the other ventral. The dorsal root has upon it an enlargement or ganglion. It has been known now for somewhat over a century that these two roots differ in the kinds of fibers that comprise them. A dorsal root is made up of sensory or receptive fibers. These are distributed to the skin and to the sense organs concerned with the deeper parts of the body, such as those in the muscles and the tendons. A ventral root, on the other hand, is made up of motor or effective fibers which are distributed

to the voluntary muscles and by means of which muscular movements are excited.

The cell bodies of the dorsal fibers are contained in the ganglia of the dorsal roots and the fibers themselves pass from these cells on the one hand to the regions of sensory termination either in the skin or among the muscles and on the other hand into the spinal cord, where they branch and extend up and down that organ. These sensory fibers are as numerous as to give rise to about one-fourth of the substance of the cord.

The cell bodies of the ventral neurones are large elements lodged within the cord; their fibers pass directly out of the cord and gather into bundles, the ventral roots. Each ventral root unites with a dorsal root and thus constitutes a spinal nerve. In such a nerve the two classes of fibers, sensory and motor, retain their individuality though they are as closely applied one to the other as are the wires in an electric cable. The ventral fibers of course make their way as motor components of the spinal nerves to the muscles that they control.

These two classes of neurones, sensory and motor, together afford the basis for the simplest type of reflex connection. When the foot of a human being is pricked with a pin, it is instantly withdrawn, the act being essentially a reflex. The pricking of the skin stimulates the peripheral branches of a sensory neurone and thus generates a nervous impulse that passes over the sensory fiber to the cord. Here it is transferred to appropriate motor neurones that transmit it to the muscles by which the foot is withdrawn. Thus these two types of neurones together are sufficient to carry out a simple reflex act. It is, however, an open question whether in man such simple reflexes ever really occur. Certainly in the majority of reflex arcs more than two neurones are included. These intercalated neurones are strictly speaking neither sensory nor motor. They represent the third class of elements already mentioned, the communicating or internuncial neurones, which are characterized by the fact that they connect one nerve center with another but do not extend beyond the central organ of which they form a part. Such neurones commonly run lengthwise or crosswise

in those organs where they occur. In the spinal cord of man internuncial neurones make up fully two-thirds of the mass of this organ.

The conditions that obtain in the human cord afford a basis for the understanding of those in man's brain. This organ like the cord is provided with nerves but the cranial nerves, twelve pairs in all, are very individual and not of the same uniform character as the spinal nerves. Some of the cranial nerves, such as the olfactory, are purely sensory but most of them are mixed motor and sensory like the spinal nerves. The majority are easily reducible to the plan of a spinal nerve, but with a predominance in either sensory or motor elements. In one respect, however, they are very unlike spinal nerves. They contribute to the formation of the central organ with which they are connected only a relatively small amount of substance. In consequence the mass of the brain is made up almost entirely of internuncial neurones. In fact, entire sections of the brain are formed exclusively of this type. Thus the whole of the cerebellum is internuncial in composition and the same is true of the human hemispheres. Since these parts together constitute 98 per cent of the weight of the brain and because much of the remaining 2 per cent is also composed of internuncial material, it follows that the human brain, in contrast with the cord, is formed almost exclusively of this type of nerve cell.

When the evolutionary history of the sensory, motor and internuncial neurones is traced, an interesting sequence is disclosed. In the simplest form of nervous system to be met with such, for instance, as that seen in the tentacles of sea-anemones, the only nervous element present is a sensory neurone that extends directly from the surface of the animal to the subjacent muscle. By means of such a nervous element the muscle is set in action much as a trigger sets off a gun. Since this type of nervous organization includes only one form of neurone it may be designated mononeuronic. The form of neurone here involved is most akin to the sensory neurones of higher animals, which may therefore be looked upon as approaching most nearly the primitive ancestral type.

The second evolutionary stage in the nervous system is that seen in most parts of the sea anemone's body and in coral animals and jellyfishes. In this type a nerve cell intervenes between the primitive receptive neurone and the muscles and represents what may be called a primitive motor neurone. This motor element transmits the impulse received from the sensory neurone to the many muscle fibers with which it is connected. Such a type of nervous system, since it is composed of two kinds of neurones, has been called a dineuronic system.

From a dineuronic system it is an easy step to a system in which beside the sensory and the motor neurones there are intercalated internuncial neurones. Indeed, polyneuronic systems are found in the worms, the crabs, the insects, the snails, and all higher animals including man.

When representative animals possessing this kind of nervous system are examined they are seen to exhibit two important phases in the evolution of the parts concerned. These phases pertain first of all to the composition of the nervous system so far as the three types of neurones are involved and, secondly, to the location of the system in the animal.

The cellular composition of the polyneuronic systems varies in different animals. In the worms and other like forms the central nervous organs are composed predominantly of sensory and motor neurones with only a moderate number of internuncial elements present. In higher animals such as the crabs and insects the internuncial neurones show a larger increase than the sensory and motor elements. This increase of the internuncials becomes excessive in the vertebrates till in man the brain, as already stated, is almost exclusively internuncial. Moreover those parts of the human brain which are most important to man, the hemispheres proper, are entirely internuncial.

The second important feature of the polyneuronic systems relates to their location. In the sea anemones and jellyfishes the nervous system is for the most part a thickened portion of the outer skin and thus is in reality a part of the outer covering of the animal. This condition is also realized in some worms though in the majority of these animals the

nerve strands have separated from the skin and have sunk into deeper situations within the body. In higher forms such as the crabs, insects, snails, and back-boned animals the nervous organs with their growth in size have migrated well away from the skin and occupy positions relatively deep in the body. In other words, the nervous system, at first simple in cellular composition and later complex, migrates from its place of origin, the outer skin, to a deep situation in the animal where it is at once in closer average proximity to the various parts it has to serve and where also it gains protection from external injury.

In the embryonic growth of the human being few changes are more interesting and significant than those shown by the spinal cord and brain. These organs in the adult are deeply imbedded in the interior of the body and yet, when their development is followed, they are found to arise in a very different region. The general changes seen during the origin and growth of these parts in man are common to all vertebrates and in fact are seen more clearly and easily in many of the forms lower than man.

If the developing egg of the common frog is watched from hour to hour the beginnings of the spinal cord and brain and their gradual growth and migration can be followed with great certainty. This is more easily accomplished in an animal whose egg develops freely outside the body as the frog's egg does, than in one whose embryonic growth takes place within, as in man. The rate of development in the frog is largely dependent upon the temperature of the water in which the eggs are immersed, but in ordinary spring weather the first traces of the brain and spinal cord in the frog's eggs begin to appear about two days after the eggs have been laid and fertilized. Once the nervous system has started to form its growth is relatively rapid. Within a day or so after its first appearance it is well advanced in its separation from the outer skin and on its path of inward migration.

It is important for our present purpose to follow briefly a few of the details of this developmental process. The egg of the frog, before any trace of central nervous organs can be seen in it, is a small sphere composed of many cells which

are arranged to form on the one hand a partial covering or outer skin and on the other a central mass of rather complex organization. The central mass eventually gives rise to almost all of the internal organs of the frog. The outer skin or ectoderm, as it is technically called, sooner or later covers the growing embryo completely and becomes in the end the outer skin of the adult frog. But before this happens other transformations occur.

As already stated the first changes that lead to the formation of the brain and spinal cord begin about two days after the egg is laid. These changes consist of a thickening of the ectoderm along what will later become the chief axis of the embryo. The band or plate of thickened ectoderm thus formed is called the medullary plate (Fig. 4 A). It extends from what will eventually be the head of the embryo back to its hind end. During the formation of this plate its right and left edges rise and its center is depressed along a line corresponding to the axis of the future animal. In this way a longitudinal groove or ditch is produced which deepens as the plate folds upon itself and sinks into the embryo (Fig. 4 B). As the groove becomes deeper the edges on either side fold over and meet, thus converting the longitudinal groove into a longitudinal tube, the medullary tube, whose walls are the folded plate and whose cavity once communicated freely with the exterior. Sooner or later this tube becomes entirely closed, breaks away from its mother layer, the ectoderm, and sinks still deeper into the body of the growing embryo (Fig. 4 C).

The fate of the anterior and the posterior halves of this tube is very different. In the posterior half the walls thicken rather uniformly and give rise to the materials out of which the adult spinal cord is formed. In this process the cavity of the tube diminishes proportionally and becomes the central canal of the adult cord.

The anterior half of the embryonic medullary tube is destined to become the brain. The walls in this part, as in the other, also thicken but the thickenings in the brain region are very local, giving rise to eminences and outgrowths such as the cerebellum, optic lobes, hemispheres, and the like that characterize this part of the central nervous organs.

The cavity of the anterior part of the medullary tube, as might be expected, changes eventually into the series of brain ventricles. In this way the spinal cord and brain

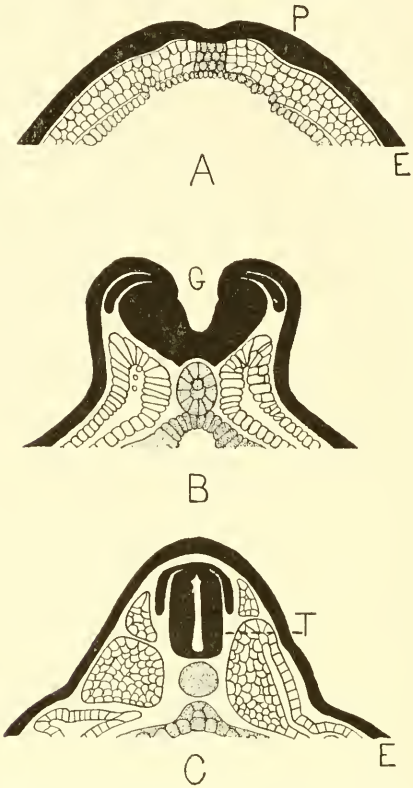

Fig. 4. Three stages in development of central nervous organs as seen in sections across axis of embryo frogs.

A. Early stage showing medullary plate, P, as thickening in ectoderm, E.

B. Later stage showing depression of thickened medullary plate to form medullary groove, G.

C. Final stage showing completed medullary tube, T, separated from outer ectoderm or embryonic skin, E.

of the adult frog develop from the outer skin or ectoderm of the embryo and migrate into their final position in the deeper part of the body. What has been said of the development of the central nervous organs in the frog holds true for all other vertebrates, man included, for even in us these organs have an external origin.

This truly remarkable growth of the central nervous system of man and other vertebrates from the ectoderm of the embryo is of great significance when the stages in the evolution of the nervous system in the lower animals are recalled. It will be remembered that in the simplest animals in which a nervous system occurs, the sea anemones, the coral animals, and the like, this system is a part of the outer skin. This condition, it will be recalled, is also realized in certain worms, but in others the central nervous organs have broken away from the outer skin and have migrated into a deeper situation where they regularly occur in crabs, insects, snails and other higher animals. That is to say the brain and spinal cord in the developing vertebrate repeat a series of changes that is seen in the successive evolutionary steps in the lower animals. They illustrate an important principle in embryology, namely, the so-called law of recapitulation which may be stated briefly as follows: in the development of any of the higher animals the creature passes temporarily through stages that are permanent conditions in the lower forms. Thus in the early stages of embryonic growth in vertebrates the nervous system is temporarily a part of the outer skin, a condition that is permanent for this system in sea anemones, coral animals, and others of the same general type.

The evolution of the vertebrate brain takes place on lines quite different from those followed by the cord. This is well seen in the sensory relations of the two structures. So far as our conscious life is concerned the spinal cord has to do chiefly with the sensory impulses from the skin. These impulses enter the cord, excite reflexes or other types of movement, and make their way to the brain to call forth appropriate sensation such as touch, pain, cold, hot, and the like. Although these sensations are in reality resident in the brain itself we refer them to the stimulated spots in the skin. If we prick the end of a finger with a needle, we have a sensation of pain and we think of the pain as resident in the tip of the finger though as a matter of fact it is in the brain. This is the common rule for most cord sensations. They are referred by us to the spot on the surface of the body where the stimulation occurred. This reference is not always

accurate but for skin sensations it is commonly so. Deeper sensations are less accurately referred. It is not always easy to tell exactly which tooth aches and deeper pains, as the physician well knows, are systematically mislocated. Nevertheless the reference is more or less trustworthy and always to some spot either in the body or more commonly on it. Since most of our daily sensations originating through the cord are skin sensations this sensory reference is usually to organs on the surface such as those of touch and temperature. These sense organs may therefore be called surface receptors. All the skin sense organs connected with the cord belong to this class and represent a primitive and very ancient type of mechanism.

In strong contrast with the spinal cord and its surface-receptors is the brain with its sensory equipment. The brain through its own nerves possesses a full outfit of surface receptors which are located in the skin of the face as the cord receptors are in that of the trunk. But in addition to these surface receptors the brain also has three pairs of special receptors of its own, the nasal cavities, the eyes, and the ears. In all these the sensory activities are usually referred not to the bodily location of the organ itself but to some distant point outside the body and commonly far away. The odor of the morning coffee is not referred to the nose where the stimulation occurs but to the coffee percolator across the table. Similarly the form of an approaching friend is not seen in the eye where the image is but far away down the street, and the overture played by the orchestra is not heard in the ear but as coming from the distant band of musicians. All these sense organs differ from the surface organs in that the sensations called forth by them are referred to distant points far beyond the body. They are therefore called distance receptors and in most animals they are, as in man and other vertebrates, peculiar to the head. They are undoubtedly the most important single factor in the evolution of the vertebrate brain for without them we would have remained simply spinal-cord animals.

The three distance receptors in the vertebrates have without question arisen separately and at quite different times. They are modified surface receptors that have evolved

in complexity hand in hand with the growing central organs. The original state from which they arose is well shown in such lowly animals as the earthworm. This creature has no nasal cavities, eyes, or ears and yet it responds to odors, lights, and sounds, and keeps itself oriented to gravity. All these functions are carried out by the receptors in its skin, but its responses are such as to justify the view that its nervous states have not the least relation to distance reception but are akin to surface reception. This most probably is the condition that characterized the ancestral vertebrate. To this creature every sensory stimulation, whether it was from trunk or head, partook of the nature of surface reception, and was devoid of any element of distance. From this state of primitive surface receptivity the vertebrate with its equipment of distance organs must have developed.

The first of these distance receptors to appear in vertebrates was the organ of smell, for in Amphioxus, the simplest of the fishes, we have an animal with a well-developed olfactory pit, but without ears or eyes, though in the deeper parts of its body are the elements out of which eyes could be evolved. Amphioxus swims without orientation to gravity, it responds to light though it cannot be said to see, and it undoubtedly senses its way more or less by means of its olfactory organ. Like the celebrated Nantucket captain who knew the sea by the smell of the lead, this primitive fish probably scents its way about. Its brain reflects this meager receptor outfit, for it is scarcely more than a slight swelling of the front end of the spinal cord.

All fishes higher than Amphioxus and all other vertebrates possess ears and image-forming eyes. The evidence from the lowest of these, the lampreys, is that the eyes evolved in advance of the ears because the ears, entirely absent from Amphioxus, exist in a very primitive state in the lampreys, whereas the eyes which were already foreshadowed in Amphioxus show in the lampreys evidence of high differentiation.

As a distance receptor no organ is more important to the vertebrate than the image-forming eye, for by its means an animal can respond not only to light, as the earthworm does.

but to the details of a luminous field as the higher animals are able to do. With the growth of eyes of this type in the early vertebrates came the concomitant development of the optic lobes of the brain, a step that established these organs as the chief receptor centers of the simpler vertebrates.

All fishes that possess eyes also have the so-called ear sacs. These simple ears are chiefly concerned with positional relations, equilibrium and the like. But they also have to do with hearing and both functions develop hand in hand in higher forms influencing the growth of the brain in the region of the cerebellum and the medulla oblongata. Thus this third and last kind of distance receptor contributes its share to brain formation.

In this way the evolutionary growth of the vertebrate brain and with it the head has resulted from a change of its primitive surface receptors to distance receptors whereby highly specialized nasal cavities, eyes, and ears were the external products and an olfactory, a visual, and a positional brain were the internal results. These collectively establish in the vertebrates what has been called the stem of the brain.

But this stem carries with it more than the three sensory segments just accounted for. Of the additional elements in the brain stem, the chief one is found in the region of the hemispheres. In the lower vertebrates the two lobes at the anterior end of the brain, the so-called hemispheres, are largely concerned with olfaction. This sensory activity, as already intimated, is the first to develop distance reception. It is, therefore, not surprising to find that in vertebrate evolution the hemispheres came to be organs of unusual importance. Not only did distance reception for the olfactory function reside here, but the hemispheres developed as centers which integrated all the sensory activities including the receptive functions of the skin, of the organs of taste, of sight and of hearing. Thus the hemispheres of the higher vertebrates came to represent a field upon which was reflected the sensory activities of the whole body. Moreover, to this field were transferred eventually all those motor centers which we ordinarily associate in ourselves with volitional movements. Thus by a process of accretion the hemispheres

appropriated by evolutionary steps all that body of nervous activity that we associate with conscious life and volitional effort. What the hemispheres have thus taken over is by no means all of our nervous doings. The lower part of the brain stem, the spinal cord, and such subsidiary centers as the sympathetic system have buried within them an untold mine of nervous activity that never really reaches this upper level but that nevertheless has potentialities which are only beginning to be appreciated in the study of the subconscious. That which has emerged in the course of the differentiation of the hemispheres in the higher vertebrates occupies a place quite separate from that of the original olfactory centers and represents in a measure a novel system superimposed upon the older olfactory brain. This new growth within the hemispheres, chiefly visible in the mammals, is astoundingly expanded in man in whose brain it is represented by the relatively enormous convoluted surface so characteristic of the exterior of that organ. This growth is called the neopallium and in the higher animals it has so overgrown and overshadowed the ancient brain stem as to have reduced this primitive part to relative inconspicuousness.

In the neopallium of man take place all those complicated activities that we associate with personality. Here resides our mental life—our sensations, memories, and volitions; here imagination has its play, and here too when maladjustments occur moods arise and insanity may reign. Descartes believed that the pineal body was the seat of man's soul, but modern science knows that the neopallium is the correct location. Here all that is most characteristic of us takes place and in fact the activity of the region is in all probability a manifestation of our real inmost selves.

Thus the evolution of the brain of man finds its roots in those elemental nervous operations connected with the muscular responses of such simple animals as the sea anemones whence have sprung the differentiated sense organs and central nervous organs of higher animals. By the conversion of these sense organs from surface receptors to distance receptors and by the simultaneous growth of central organs as repositories of experience there has been established in the hemispheres of the mammals and particularly of man that

marvelous organ, the neopallium, which is at once the highest center of nervous differentiation and the real seat of the soul.

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Chapter V

MENTAL EVOLUTION IN THE PRIMATES

Robert M. Yerkes

MANY of us doubtless would be profoundly impressed if by watching a cinema record, run backward, we were able to trace to their prenatal beginnings the personality, character, temperament, intellectual traits, mannerisms and other characteristic modes of reaction of one of our intimate friends. Let us assume that the pictorial record adequately represents the psychological and psychobiological characteristics of our friend from day to day throughout a half century of existence, and, further, that in the picture the physical appearance of the individual is so far conventionalized that the mental appearances, as we may call them, dominate the attention and interest of the observer. Under these circumstances what is likely to be the experience of the open-minded, well-informed layman who eagerly watches the retracing of mental development? With considerable assurance we predict the following:

The first few years of the story will yield him an agreeable sense of familiarity and intelligibility. The friend will not only be definitely recognized in the pictorial representation, but there may appear a delightful sense of intimacy and understanding. Gradually, as the years and then the decades are retraced, the feeling of familiarity will lessen and finally it will give place to one of strangeness; the individual is no longer identified or even identifiable as one's friend, save perhaps by the specialist in psychobiology. Instead, the representation is that of a more or less obviously typical human mind and personality. By this time the initial agreeable glow of understanding has given place to surprise, doubt, and the observer probably looks and feels puzzled. But even more surprising experiences are in store for him, as reaching back a few more years the representation gradually loses its resemblance to what the layman knows as human behavior, mentality, and personality, and comes to suggest

quite as strongly the observed psychobiological characteristics of some other type or types of organism. The chimpanzee, monkey, or in accordance with personal familiarity, the horse, dog, or cat may come to mind. No longer then is the picture distinctively and unmistakably human. "Why, it might perfectly well be some other kind of being," exclaims the amazed onlooker.

And now as the record continues to unroll, surprises crowd one another, for the suggestion or definite appearance of the behavioral and mental characteristics of other types of animal than the human become more insistent, and doubt as to whether the record really represents human development gives place to the conviction that one is being deceived and that the picture really represents some stage in the psychobiological development of a yet more lowly and primitive mammal than the chimpanzee, monkey, or even the lemur. Presently perhaps the behavior of the fish is so definitely suggested that the observer again utters exclamations of amazement and incredulity.

Although such a pictorial record as we imagine never has been made and could be obtained only with extreme difficulty, it is not impossible. Were one to observe, instead of our hypothetical record of mental development, a chronologically comparable record of the development of the body, the effect on the lay observer would be very similar. No description of the evolution of the human mind known to us is more incredible, more difficult to understand as natural process, or more at variance with certain well-established social traditions, including beliefs and superstitions, than is the actually observable series of events between the fertilization of the ovum and the maturation of the human personality.

Among the preconceptions, superstitions, or inadequately founded beliefs which we should brush aside in order fairly and profitably to examine the evidences of genetic relation among different types and conditions of mind, is the assumption that man possesses rational intelligence, whereas other animals are endowed with instinct. Critical and sustained study of animal behavior indicates on the contrary that although among existing primates man is the reasoner *par*

excellence, other animals also are intelligent and some of them at least exhibit rational forms of intelligence. For the ancient inadequate formula, "Man is rational; brute, instinctive," the present-day psychobiologist substitutes the statement: Every living organism, by virtue of inherited structures and developmental tendencies, is instinctive and also in widely varying degrees capable of individual adaptations which are more or less definitely intelligent. Within the order Primates, to which we shall confine our discussion of the evolution of mind, we may not say that one type is more instinctive than another, although it is definitely established that intelligence differs both quantitatively and qualitatively. To undertake our present task with the conviction that man is mentally unique and therefore without genetic relation to any existing or extinct type of animal, would be quite as prejudicial to the discovery of the truth as would be initial assumption that the human mind has evolved from that of the gorilla.

Ignoring technicalities of classification, it will serve our purpose to group existing primates in five classes: lemurs, tarsiers, monkeys, apes, and men. We shall make no reference to extinct or fossil forms. The first two of our classes are represented today by animals which strike the layman as squirrel-like rather than monkey-like, and indeed they resemble the flying mammals. Between these primitive and often called pro-simian creatures and the distinctly manlike primates are the New and Old World monkeys which, differing extremely in appearance, exist in many genera and species. Most closely resembling man, and on the whole differing little if any more from him than from the monkeys, are the four primate types assigned to the class apes, or, more explicitly, anthropoid apes: the gibbon, orang-outan, chimpanzee and gorilla.

As in turn we review what is known of the mode of life, adaptive capacity, and mental traits of each class of primate beginning with the most primitive, we discover unmistakable evidences of increasing resemblance to man in the progress through lemur, tarsier, monkey and ape. To the specialist in psychobiology this is no less impressive and no less strongly suggestive of genetic relations than are the struc-

tural resemblances which have been exhibited in the earlier chapters of this volume. We presume to make this general statement because the remainder of our chapter is an exposition of the facts upon which it rests.

Standing as guide posts in the path of individual development and in that of descent are certain signally important groups of psychobiological phenomena. They include: (1) receptivity, or the psychobiological relation of organism to environment through the senses; (2) behavioral adaptivity, or the adjustment of organism to environment, (a) blindly, (b) with insight, or (c) with foresight—phenomena which are distinctively organic and primarily if not exclusively psychobiological; (3) ideational processes, creative imagination, abstraction and generalization, as conditions for adaptation through modification of the environment instead of by self-adjustment—a long step in primate evolution; (4) the use of symbols, the growth of language, and the final dominance of speech—phenomena which, although appearing in other classes of primate, become conspicuously important in man; (5) inborn reactive tendencies, emotions, sentiments, drives, and ideals, and (6) social relations in experience, organization, and institution.

To each of these vast assemblages of phenomena in the life of the primate we shall in turn briefly attend, for together they clearly mark the main highway of individual development and the less readily followed, because less direct, course of mental evolution.

RECEPTIVITY AND THE PRESENT DOMINANCE OF DISTANCE RECEPTORS

It is observable that in the development of man the senses of touch, temperature, smell and taste become functional prior to those of vision and hearing. Likewise among the classes of primates appear differences in the senses which roughly correspond to those of individual development. Crudely put, in evolution as in development we pass from the dominance of mechanical and chemical stimulation to that of vibrational. The observable trend is from sensitivity to and awareness of the immediately present object or event to that of the spatially or temporally distant. For touch

acquaints the animal only with its immediate physical environment, whereas taste, smell, hearing and sight bring it into relation with increasingly remote objects and events. As we develop during the first few months after birth, we are rapidly projected into environment, and the physical self is enabled to sense and respond to, investigate and adjust to, increasingly numerous and distant qualities and objects of its world.

We may not assert it as fact, but the evidences strongly suggest that as our senses develop, so also have they evolved in the course of racial history. Like our embryonic selves, our early ancestors knew the world chiefly through contacts and chemical changes. But our less remote ancestors, monkey-like creatures perhaps, and our infant selves, lived in a world which was enriched by innumerable sounds and sights. This contrast between a world of contacts and tastes and one predominantly visual and auditory transcends our present powers of psychological description.

It is not alone by addition of senses, or even by multiplication of qualities within a sense mode, that development and evolution proceed; a given sense may become either simpler or more complex, its keenness may diminish or increase during individual or racial history. Less generally known is the fact that the functional significance of a sense may change tremendously by reason of integrative psychobiological processes which enable the organism to perceive varied aspects and relations as contrasted with simple qualities of objects, and which thus prepare the way for new types of behavioral adaptation. For example, in individual development and in evolution vision begins with awareness of light. Later the animal comes to perceive form, size, texture, distance, spatial relations, color. The adult sees both more and differently than the newly born infant; the ape sees more and differently than the lemur, and man sees vastly more than any other primate. Observation indicates that the trends of receptivity in development and in evolution roughly agree. This fact is peculiarly significant because we may follow as exactly as we will the story of development and by the results may be guided in our search for phylogenetic relations.

Among existing classes of primate new senses have not appeared, but the distance senses of hearing and sight have greatly increased in complexity and in perceptual value. Replacing to a marked degree the mechanical and chemical senses, they have become the dominant channels of communication between the primate and its world. The degree of dominance of visual and auditory receptivity and perception increases from lemur to man.

PREËMINENTLY IMPORTANT ASPECTS OF BEHAVIORAL ADAPTATION

An animal adapts psychobiologically to its world as known. If its knowledge be limited to simple awareness, through contact, chemical action, vibrations in air or ether, of the existence of media about it and of objects and occurrences in those media, it cannot adapt as do monkeys, apes and men. There must be perceptual acquaintance with objects in relation. An animal obviously cannot respond to an apple as a spherical form of definite size, distance from the perceiver, texture and color, if it is sensed merely as a dark spot against a lighter background. Perceptual configurations are definitely known to become more numerous, complex, and useful as bases for adaptive behavior from conception to maturity in human life and from lemur to man in the phylogenetic series. We may not trace the progress step by step in either case, but the trend toward increasing richness and efficiency of perceptual consciousness is wholly apparent.

In still another way than through the guiding awareness of the presence, qualities, and relations of objects and events, perceptual consciousness conditions adaptive ability. It is a basis of motivation. An animal strives for objectives only within the limits of its consciousness. There is a stage in human development, as there are stages in evolution, when neither the quantity nor the quality of an objective clearly influences the organism. The less preferred object tends to induce the same response as the more preferred; a small bit of candy or fruit tends to induce as strenuous effort to obtain it as does a large bit. We say there is lack of dis-

crimination and of suitable adaptation to certain essential features of the situation. Either the subject does not perceive the differences in point or for some other reason it is incapable of regulating its activities in accordance with them. From lemur to man no less obviously than from infancy to maturity, motivation becomes increasingly complex. New factors appear and adjustments of behavior become more serviceable and more nearly adequate.

Behavioral adaptation, or as we should have called it a few years ago, habit-formation, may occur with or without insight and foresight. It is our immediate task to try to trace in development and in evolution the appearance and history of different types of adaptation. We shall begin with a form which often is designated as "trial and error," but we shall use the expression "blind trial" in order to contrast it with insight and foresight.

(a) *Blind Trial.* A box containing a bit of candy or a rattle is presented to a primate subject. The only way to obtain the object within is to open a door which is held by a hidden mechanism whose release may be effected by pushing a lever at one side of the box. This is a type of problematic situation which many investigators have presented to animals as a test of intelligence or of ability to profit by experience. Obviously, insight is precluded by the characteristics of the situation. The subject, whether lemur, monkey, ape, or man, manipulates the box and sooner or later by happy accident operates the mechanism of release. Thereupon it obtains the desired object, and thereafter when the same problem is presented it may exhibit more or less perfect adaptation. This type of experiment has been cited as one in which solution by trial is inevitable.

As contrasted with situations in which insight is either impossible or highly improbable, there are those in which we should naturally expect it to appear, were the animal capable of it. Such, for example, is the milk-containing glass bottle whose contents the primate desires. Observation reveals that neither the human infant nor any of the other primates, with the possible exception of certain of the anthropoid apes, is likely to respond to this situation initially with direct and perfect adaptation. Instead, a series of

trials, more or less obviously ineffective and wasteful, eventually leads to skillful manipulation of the bottle and the drinking of its contents.

By comparing the typical performances of human infants at various ages and of representatives of the various classes of primate in like situations, we discover that adaptation by trial and error, in other words blindly or without insight, is characteristic of all ages and types, but that the quickness of adaptation on the basis of blind trial, and also the probability of indication of insight, tend to increase as development progresses and also as we progress from the more primitive toward the less primitive primate type.

(b) *Insight.* The use of objects as instruments in connection with behavioral adaptation is peculiarly significant of insight. Such ability is virtually unknown in the lemurs and tarsiers, so far as one may infer from observational report. It appears in the monkeys, and is obviously more varied and important in the anthropoid apes and in man. The monkey may use a stick to draw within reach objects which are not otherwise obtainable. But when the objective is so placed that the stick must be used to push, direct and pull it around an obstacle through a devious course which sometimes tends away from and again toward the subject, the monkey fails utterly, whereas the ape may succeed. Herein we discover a contrast, if not a transition. Insightless and persistent trial and error may ultimately result in success, whatever the type of primate in question. But ordinarily it is not difficult for the observer to distinguish between blind trial and that which is guided by perception of relation of means to end and of the desired object to the waiting hand of the animal. To the human adult this problem of a roundabout course seems extremely simple; its solution is grasped instantly. But for the infant it is a real problem which prior to a certain stage of development, attained only after several months, is utterly insoluble. Ability to handle a stick deftly and to direct it toward an objective does not assure success: there must in addition be a measure of insight into spatial relations, and the subject must be able to translate its perceptual experience and its insight into adaptive activity.

In a metal pipe, or elongated wooden box, open at both ends and securely fixed in position, a desired object is so placed as to be beyond the reach of the watching subject. Nearby, but not so close to the pipe as to be viewed simultaneously with it, is a stick which might serve as instrument to push the object through and out of the pipe. The situation presents a type of problem appropriate alike for infants, children, and the various classes of infrahuman primate. As in the case of the problem just described, the human subject must develop for several months before he is able to solve the pipe and stick problem. Never, so far as we have been able to learn, has such a problem been solved by lemur-like primates or by monkeys. It has, however, been solved in several instances by the chimpanzee, under conditions which seemingly precluded the possibility of chance or of previous experience with a similar problematic situation. At the level of the apes we discover, it seems, that measure of selective adaptation and of insight which renders possible prompt adjustment to this type of novel problem. Man, beyond a certain stage in childhood, has no particular difficulty in understanding and adapting to such a situation.

By yet another simple experiment we would exhibit the contrast between lemur and monkey, on the one hand, and ape and man, on the other. If food or other desired object be suspended beyond the reach of the subject and a number of boxes be placed within easy reach, we naturally should expect a human subject to solve this problem promptly by building the boxes into a pyramid, so placed that from it the objective can readily be reached. This type of solution is not possible to the human infant, but appears at a certain stage of childhood. It is impossible, so far as we know, to monkeys and to more primitive primates, but certain at least of the anthropoid apes succeed. Indeed, the chimpanzee and orang-outan in this type of experiment very clearly manifest their adaptive superiority to the monkey, to the human infant, and to the very young child.

These several illustrative experiments, chosen from among scores which are available in the scientific literature or in our experience, indicate the major grounds for the statement that behavioral adaptation with insight or partial understanding

of a problem, instead of being limited to man as has commonly been assumed in the past, is shadowed forth in the monkeys and definitely and convincingly exhibited by certain of the anthropoid apes. Again, it is clearly indicated that the evolution of insight in the primates in many respects resembles its development during human infancy and childhood.

(c) *Foresight.* Entirely inadequately we have described adaptation with blind trial, and, by contrast, adaptation with insight. A third variety of behavioral adjustment may now be considered. We shall call it foresight or preadaptation. It begins to appear during human childhood and becomes increasingly conspicuous with progress toward maturity. Is it discoverable in other types of primate? The brief reply is: In the lemur and tarsier it probably does not appear; even in the monkeys it has not been definitely established by reliable observation and the chances are that in them, if it appears at all, it is in extremely simple form; in the anthropoid apes it occurs, but much less frequently and in less effective form than in man.

Instances of ape foresight or preadaptation are not abundant in the literature, nor are the best of them comparable in psychological complexity with such adjustments as those of the man who dons a raincoat because the weather report is unfavorable. On the other hand, the action of the child who hides forbidden candy so that its mother may not confiscate it is closely paralleled by certain adaptive activities in the apes which obviously imply anticipation.

According to trustworthy reports, an ape, after observing the prospective work of the day, may come to its tasks eagerly or reluctantly. When confronted with a situation which demands planning and proper relating of a succession of acts, it may behave appropriately and successfully. Thus, for example, in the absence of a necessary mechanism it may go in search of it and having located it bring it into use. There are indeed in the systematic experimental literature, as well as among miscellaneous observations, several peculiarly interesting examples of what appears to be anticipation of events and appropriate preadaptation. But manifestly the apes differ markedly from man in the extent

to which foresight leads to preparedness for a contingency. All that we may safely say is that the beginnings of foresight and preadaptation are obviously discoverable in the anthropoid apes.

To summarize, adaptation by trial and error, insightless effort, appears in all existing types of primate and throughout the course of individual development. By contrast, adaptation with insight has not been discovered in the lemur or tarsier, perhaps is present in rudimentary form in the monkeys, clearly manifests itself in the man-like apes, and is conspicuously important in adult man. Its development may be traced in the course of individual history, for whereas the newborn infant is incapable of selective adaptation, the young child commonly exhibits it, and the manifestations of insight become increasingly numerous and complex as the individual approaches maturity. Likewise there is marked contrast from type to type and from stage to stage of development in evidences of foresight and resulting preadaptation. It appears reasonably certain that this mode of behavioral adaptation does not appear in lemur, tarsier, or monkey, that it is discoverable in the anthropoid apes, and from this evolutional beginning becomes preëminently important in adult man. Like selective adaptation, it may be traced in individual development, originating during infancy and becoming increasingly conspicuous through childhood and maturity. It seems indeed as though the story of our own development were traceable through the following modes of adaptation or habit-formation: From the "blind trial" of fetal life and infancy, through the selective adaptations of late infancy and childhood, with their extending and enriching insights, to the foresights and preadaptations of adolescence and maturity.

If at any point our description has given the impression that in either development or evolution one of these principal modes of adaptation tends to replace or supplant another, we should correct it, for the more primitive or simpler type always, it seems, tends to persist after the appearance of a psychobiologically more complex and more efficient mode of adaptation.

REPRESENTATIONAL OR IMAGINAL PROCESSES

For ages mankind has assumed and believed that ideation, thought, and reasoning are distinctively and probably exclusively human. But recently the development of new techniques and the accumulation of observational data, through the comparative study of psychobiological phenomena in the primates, have essentially altered the status of knowledge. It is now legitimate to state that ideas, simple thought processes, and primitive forms of reasoning exist in the anthropoid apes, or that functional equivalents cause the animals to act as though experiencing ideas and directed by thoughts. One may take one's choice as between the natural inference that similarity in adaptive behavior implies similarity in the essentials of experience or that rationality may be simulated by some mechanism which is possessed by apes but not by men.

Within the compass of a few paragraphs typical observations or evidences of representational processes, or their functional equivalents, in the infrahuman primates may be indicated but not adequately described. In accordance with analysis of human experience these processes are of two principal types: the reproductive and the creative. The former are usually called memory processes; the latter, processes of constructive or creative imagination. Either type of process may involve imagery, and if the subject of observation is capable of experiencing images they are almost certain to appear in any representational process.

Whereas in mammals other than the primates, notably in rats, guinea pigs and rabbits, a problematic environmental situation cannot ordinarily be responded to appropriately for more than a few seconds, and at best a very few minutes, after it has disappeared from view; monkeys, apes and men apparently are able to respond adaptively and as if with definite memory of the situation after much longer intervals of delay. Typical experiments will render this important psychological contrast clearer.

The subject sits before three doorways, through one of which when released it may pass to get its dinner. Everything in readiness, the experimenter exhibits for a moment the

prospective food and permits the animal to see it placed beyond a particular one of the doorways. Thereupon, by use of a suitable screen the animal's view of the food is cut off, and the three doorways or reaction areas therefore appear to it exactly alike. For a definite period, say ten minutes, the animal awaits opportunity to respond. It then is released and makes choice among the doorways. As thus far indicated by observations, this demand for response on the basis of prior sensory experience is more easily and successfully met by the monkey than by the rat; by the ape than by the monkey, and by man than by ape. The temporal span of memory, or period during which the animal may be kept waiting without losing its power of correct response, increases very rapidly from rat to man. No experiments with lemurs are available, so we refer to the rat instead. Although further observation may essentially modify the findings, it is indicated at present that the rat ceases to respond adaptively after delays exceeding a few seconds, whereas monkeys, apes and men may succeed after many hours.

An essentially different and more exacting test of the existence of memory processes has recently been employed to exhibit the ability of various primates. The subject faces a group of boxes which are visually alike except, for instance, in color. Into one of the boxes it sees food put. A screen is then drawn between the subject and the boxes, and the latter are interchanged so that the food container cannot be located by its initial position but must instead be identified by the visual quality of color. After a stated interval of delay, which in the course of experimentation has ranged from a few seconds to nearly an hour, the screen is removed and the animal given opportunity to seek the food. At the present writing, in addition to man, only the chimpanzee and gorilla have demonstrated their ability to react successfully in this type of situation after delays of at least ten minutes. It may not safely be inferred that all other types of organism are incapable of such response, but it is safe to infer tentatively that success in this type of memory experiment is more readily and more frequently achieved as we progress from the various orders of mammal, through the several classes of primate to man.

It has been discovered that the subject's natural basis of choice in this type of memory test is the position of the food container. When absolute position, or both absolute and relative position are eliminated and correct response depends on recognition of the object by some such visual datum as color, form, size, or distance, the task is much more difficult, save for man, who is able to recall and recognize the food container by reason of visual or kinesthetic-verbal imagery. Whether the chimpanzee or gorilla remembers and recognizes the correct box through the functioning of visual images or otherwise we do not know, but at least it is evident that there is closer functional resemblance between what may legitimately be called memory responses of ape and man than between those of monkey and man or monkey and other mammals.

To the question: Do memory images or their functionally equivalent biological processes appear at certain stages in mental evolution and in certain classes of primates, and thereafter become increasingly important as bases of adaptive response to a situation which is not continuously present to the senses, we offer our opinion that the observational data now available justify an affirmative reply, but they justify also emphasis on the desirability of further inquiry and the extreme importance of additional observations.

Another and quite different but equally impressive exhibit of memory response is provided by the behavior of primates toward individuals intimately known but from whom they have been separated for long intervals. We are familiar with the evidences of recognition of friends by dogs, cats, and other domesticated animals, but similar intimacy of acquaintance with the behavior of monkeys and apes is limited to a few individuals. Yet in these creatures the definiteness and complexity of response is even greater than in the other mammals, and, judging by the reports available, it appears after prolonged periods of separation. There are well-authenticated statements that the chimpanzee, orang-outan, and gorilla may recognize species or human acquaintances after many months of separation, and at least one instance has been recorded of the recognition of a man by a chimpanzee after separation of nearly four years. In

these instances, to judge from our own experience, the behavior frequently is so distinctive, appropriate, and indicative of identification of the particular individual that one is not tempted to question the existence of memory processes. Whether or not they be experiences of the human order we shall not presume to say, although it is entirely clear that if they are not comparable with our own mental content they are at least aspects of psychobiological processes which serve the same purpose as does reproductive imagination in man.

Creative or constructive as contrasted with reproductive imagination has seldom been sought for by the experimental student of animal behavior, but by various authors it has been suggested that the use of environmental objects as tools or instruments may imply the presence of constructive imagination. Such activity is virtually lacking in other mammals than the primates: it appears in steadily increasing variety and frequency from lemur to man. Narrowly limited in the monkeys, to judge by existing information, it is far more conspicuous and serviceable in the apes, although even in them markedly less well developed than in man.

The use of objects as aids in adaptation marks the beginning of behavioral adaptation through modification of environment as contrasted with the process of self-adaptation. It is observable that whereas most existing animals, more or less rapidly and in various ways, as also in varying degrees, adapt to their environment, man is distinguished by the extent of his ability to shape environment to his needs and desires. Thus he extends the possibilities of adaptation and enormously increases the potentialities of his life. It is by virtue of his constructive imagination and his manual dexterity that he is able increasingly to control his world.

For our present interest in adaptation the important question is: Are there evidences in ape, monkey, or other primate of the use of objects as tools or of their modification to serve as such?

Already the fact of occasional use of sticks and other simple objects as implements has been recorded by us for both monkeys and apes. The latter, however, greatly excel

the former in the variety and skill of instrumental adaptations. When it comes to the seeking out, creation, or construction of tools, pertinent records although few are obviously important. By Köhler* it has been reported for the chimpanzee that a branch may be broken from a convenient tree to serve as means of reaching and securing distant food. This author also reports for the chimpanzee the joining of two sticks, either of which alone was too short to meet the animal's need. The sticks were hollow and they were of such size that it was possible for the chimpanzee to insert the end of one into the aperture of the other. In this instance clearly the subject had at hand the materials of a serviceable tool, but except as brought into the relation which we have described these materials remained valueless as aids to the solution of the problem of obtaining food. Köhler supplies yet another type of observation which clearly belongs in this category, for he describes a chimpanzee as reducing the size of one end of a stick so that it might be inserted into the hollow end of another, that thus the two might be constituted a serviceable instrument.

All of these adaptive activities may be classified as toolmaking, since it appears that the ape is endeavoring so to manipulate or modify a portion of its environment as to render it serviceable in the solution of a certain practical problem. As we intimated above, observations of this sort are relatively few and we may only tentatively conclude that the anthropoid apes are generally capable of such expressions of what in ourselves we should unhesitatingly call constructive imagination. If however the chimpanzee, without human suggestion, tuition, or other definite aid, modifies environmental objects for certain definite purposes, it would be scarcely more reasonable to deny constructive imagination in it than in man. Our tentative conclusion, based largely on unpublished data, is that the apes possess creative imagination.

Investigation of memory and related processes in monkeys and apes has made it abundantly clear that psychobiologically there is a vast gulf between lemur and ape and even between monkey and ape, for it is only in the latter that

*Chap. 4 and 5.

clear indications of reproductive memory images or their functional equivalents and of the germs of constructive imagination appear.

Without reproductive imagination an animal presumably cannot adapt selectively; without creative imagination it is difficult to see how it could construct tools. It is our tentative conclusion from such observational data as we have knowledge of, that man's marvelous power of adaptation through control of his environment is presaged in the anthropoid apes. He is not the sole possessor of constructivity.

Logically this discussion should be extended to consideration of behavioral indications of the evolution of the processes of abstraction and generalization, but for practical reasons this is undesirable. Observational data, as it happens, are few and of uncertain value. Already we have presented the grounds on which we base the affirmation of the existence of both reproductive and creative imaginal processes in the apes and with less certainty in the monkeys. We do not feel justified in devoting additional space to this section by considering such evidences of the beginnings of abstraction and generalization as may be found in the accounts of primate behavior. It must suffice to state that not only are the evidences meager, but they very definitely suggest that no existing primate, except man, is capable of anything beyond the most rudimentary, or, developmentally considered, the most primitive forms of abstraction and generalization. This condition is so importantly related to our next topic, language and the use of symbols, that it will necessarily receive certain further attention in that connection.

LANGUAGE AND THE FINAL DOMINANCE OF SPEECH

Thinking, except in terms of concrete experience, depends upon symbols and is facilitated by them. Doubtless it is beside the point and indicates a certain limitation of insight to inquire whether thinking prepared the way for talking or the reverse—whether function anticipates structure! Undeniably, symbolism is of extreme importance in human life. It therefore is necessary to ask in this discussion of evolutionary process, whether there appear in birds or mammals languages comparable in functional essentials,

if not in degree of complexity and usefulness, with human speech, and whether the behavior of existing primates suggests or definitely indicates the evolution of ability to use symbols and the presence of linguistic systems of expression. The first of these questions is easily answered; the second is more difficult.

Intercommunication evidently occurs in various types of bird and mammal, as also in certain classes of primate; but in most instances it appears to be primarily affective, instead of serving to transfer such intellectual processes as those of perception and ideation, inference and practical judgment. Yet precisely these forms of experience are accompaniments of, and presumably essential to, behavioral adaptations with insight and foresight, which occasionally are discoverable in the apes. The use of symbols, we venture to assert, is not so highly developed in any bird or mammal as to justify the application of the term language. When we direct attention to the apes we at once discover diversity of opinion and description, for there are those who attribute vocal language both to apes and monkeys, whereas more critical and conservative authorities assert that only man may properly be said to speak.

The following should bring us to a pause. We humans are prone to consider ourselves the measure of all things. Unreflectingly we accept our most notable psychobiological achievement, language, as a measure of the development of mind. This surely is indefensible, for it may be that such other varieties of symbol as gesture, facial and bodily attitude, limb and finger movements, are more naturally and effectively employed by a particular type of animal than are sounds. Actually, human deaf mutes use a sign language. Why then may not infrahuman primates exhibit other modes or even systems of linguistic expression than the vocal?

Our reply is, they do. Especially in monkeys and apes appear evidences of intercommunication through transfer of mental state by such behavioral signs as we have mentioned. Although we should hesitate to describe it as language, we must nevertheless recognize its functional significance and suggest that in all probability there is no greater contrast between the status of the use of symbols by ape

and by man than in their respective perceptual experiences, creative imagination, insight, foresight, and thought.

It is said that apes possess a vocal mechanism similar to that of man and are capable of producing a variety of sounds. The fact that they communicate otherwise than by talking possibly should be attributed to lack of special tendency to reproduce or imitate sounds in such manner as to facilitate the growth of a system of vocal expressions. Certain it is that they imitate intelligently many actions that they see.

Probably the most important single difference in the intellectual expressions of ape and man is the linguistic. For whereas our ideas, memories, imaginings, thoughts, and intents are expressed by spoken or written language, the relatively meager and simple cognitive experiences of the apes gain expression through bodily attitude, facial expression, gesture, trunk and limb movements, and vocalization. There is no single system of signs or symbols comparable with human speech, or indeed with any other highly organized form of language. One must grasp and understand or interpret the total picture of ape behavior instead of depending, as is possible among ourselves, on some single form or aspect of behavior, such as vocal symbol. It may not be doubted, however, that the apes, despite their linguistic inferiority to man, communicate readily and to an eminently serviceable degree.

Scarcely more than the beginnings of symbolism have been discovered in the primates, but from those beginnings, as from the modes of behavioral adaptation which are observable in monkeys and apes, it is possible, and we think probable, that human symbolism and even speech have evolved. The subject demands and richly deserves more systematic, persistent, ingenious, and determined investigation. Curiously enough, for every unit of human energy expended on observation of animal symbolism, a hundred have been used for surmise and speculative discussion. Why is man so ready to ignore discoverable fact and to indulge in vain imaginings?

Since man is preëminently and undeniably the talking animal, and since further his elaborate system of vocal symbols immeasurably facilitates both self-adaptation and

the mastery of environment, may it not be that language is his most important single behavioral achievement, and that human supremacy is due to linguistic facilitation of thought and intercommunication? Probably the common ancestor of ape and man used symbols very simply and seldom, if at all. The human line of descent tended toward linguistic development, which in turn furthered the accumulation of a vast body of social tradition. The ape line, tending by contrast toward the utilization of bodily attitude instead of vocalization to express emotion and idea, progressed more slowly, haltingly, and without the accumulation of racial tradition or notable mastery of environment.

This possible general contrast between the distinctively human and non-human directions of primate evolution deserves further consideration, because it appears that survival of a type, its geographical distribution, and its multiplication, are conditioned very largely by its ability to control environment. While the apes were struggling to adapt themselves to unpredictable variations of climate and food supply and failed or succeeded, diminished or increased, in accordance with circumstances wholly beyond their control, early man imagined and wrought for himself protective coverings and shelters from heat and cold, from sun and storm, so that he might live almost anywhere on earth, whereas other primates were restricted by climate and food supply to certain limited areas. Where they perished miserably from starvation due to drought, flood, or devastating storms, he has sown and reaped, with foresight accumulated and stored supplies, and multiplied both sources and varieties of natural and artificial products, until largely independent of environmental accidents. It appears that during the era of differentiation of man from other types of man-like ape, progress by self-knowledge and self-adaptation was more narrowly limited and offered fewer opportunities for discovery and ingenious control than did the molding of environment or mutual adjustment of self and environment. And the result, not yet completely achieved, although clearly indicated in its trend, and reasonably predictable from the present status of primates on the earth, is the failure of the man-like

apes in their struggle for survival and their eventual disappearance from the earth, and the steady advance of man toward perfection of life and of its earthly setting.

EMOTIONS AND THEIR EXPRESSIONS

By those who should know, it is said that the chimpanzee more strikingly resembles man in its affective life than in any other psychobiological respect. So like the human are its common expressions of feeling, emotion, mood, and sentiment, that the observer is possessed by a sense of sympathetic understanding. We have advisedly used the terms feeling, emotion, mood, and sentiment because the chimpanzee exhibits in varying degrees these several forms of affective experience. Probably there is no primary human emotion whose counterpart may not be discovered in this organism, or, for that matter, in any one of the man-like apes. Only apes and men commonly manifest in unmistakable ways joy, elation, anticipation of pleasure or discomfort, depression, melancholy, dread, fear, terror, suspicion, resentment, anger, dislike, sympathy, friendliness, solicitude, jealousy—the list might be extended almost to the limit of human experience. To those who are intimate with the ways of the anthropoid apes, their actions, whether emotional or cognitive, are as meaningful as words.

Even to the relatively inexperienced observer it usually appears that the affective life of the apes is more nearly human than is the intellectual or cognitive. Likewise for the scientist it is a commonplace that the affective expressions of ape and man are remarkably similar; their expressions of cognitive and volitional experiences markedly different. Indeed, the two widely sundered and at the same time similar classes of creature live in sharply contrasted perceptual worlds and react to aspects of those worlds with extremely different interests and possibilities of insight and foresight. They may "feel" alike, while "acting" differently!

In support of our general statements we present a single, but we believe typical, instance of the approach of primate to human affective experience and expression. We have selected the appearance of sympathetic relation between mother and infant.

Among existing vertebrates there may be observed everything from total lack of maternal interest in offspring and of affection and solicitude for them to its obvious and much vaunted degree of perfection in man. Radical differences are apparent even among existing classes of primate, for the sentiment gains in strength and complexity of expression, persistence, and likewise in degree of resemblance to the human, as we progress from lemur to ape.

In the monkeys the phenomena are deeply impressive and irresistibly suggestive of human experience. Only those who have had occasion to try to study a mother monkey and her baby can appreciate the strength of her attachment. She is continuously watchful, suspicious of all comers, and she strenuously resents and resists every attempt of the observer to approach the infant or to separate it from her. This may occur even when she is on terms of friendly intimacy with the observer. Of the chimpanzee, to mention only that anthropoid ape for which information is most nearly adequate, the same is true. If the infant ape be injured or taken from the female, maternal distress is commonly indicated by violent attempts at defense or recovery, by extreme restlessness and appearances of anxiety, and by grievous crying or screaming.

Evidently parenthood as affective experience and expression more closely approaches our own in monkey and ape than in the more primitive primates, such as the lemur and tarsier, or in any other inferior mammal. Unless the observer is biased, he is not likely to escape the force of the indications that parental sentiment may very well have evolved from the relative carelessness of the lemur to the intense sympathetic attachment and solicitude of the anthropoid ape, and thence to the experiences of man.

Important also is the fact that whereas intimate relations between mother and infant continue for only a few hours or days in most mammals and are said to be relatively transient even in the primitive forms of primate, they last for weeks and months in the monkeys, and even for years in the man-like apes. The chimpanzee may and often does nurse her infant for two years, and even thereafter she may protect and train or instruct it and attend to its needs.

SOCIAL RELATION AND ORGANIZATION

Human social relations are conditioned by sentiments, and the evolution of social life in the primates almost certainly has paralleled the evolution of affective experience and expression. Man and ant, by radically different evolutional change, have attained highly serviceable forms of social relation and organization. It is illuminating to contrast the social life of these two types of creature. Whereas human social evolution is characterized by the enhancement of the value of the individual as social object, that of the ant is similarly marked by subordination of the individual, through specialization, to the welfare of the group. Among men and apes the social unit is the family; among ants it is the colony.

Through the several classes of primate one may trace the evolution of social consciousness and its behavioral manifestations toward mutuality of interest, self-subordination. coöperation and altruism.

Were we to pursue further the topic of evolution of social consciousness and the appearance of social types of organization and institution in the primates, we should encroach on the materials of the next chapter, "Social Evolution." Therefore we bring to a close this brief presentation of evidences of mental evolution in the primates, forthwith summarize our conclusions, and suggest a few books which the interested reader may find helpful.

CONCLUSIONS

Critical comparison of the psychobiological characteristics of existing classes of primate: lemur, tarsier, monkey, ape, and man, as definitely suggests evolutional changes during descent as do the findings of comparative anatomy and embryology.

Because in a short chapter it is impossible to present the varied materials and evidences of mental evolution systematically and completely, we have selected six conspicuously important aspects of the highly complex mental and behavioral life of the primates to exemplify materials and degrees of resemblance and to supply typical indications of their relation in descent.

The selected categories are: (1) receptivity, sensibility, and the transition from contact to distance reception, which finally achieved its proximate consummation in human vision; (2) modes of "habit-formation," "learning," or behavioral adaptation, and their essential forms of experience, which seemingly progressed on the basis of perceptual configuration, and with increasingly complex motivation, from "trial and error," through adaptation with insight, to preadaptation by reason of foresight; (3) representational processes and the correlated behavior of memory and imagination; (4) the use of symbols, the development of language, and the final dominance of speech in man; (5) emotional, or more generally speaking, affective experience and expression, and finally (6) social experience, behavior and organization.

In each of these spheres of psychobiological interest the observationally determined order of increasing degree of resemblance to man is: lemur, monkey, ape, and the facts support the hypothesis that existing primates represent, in some instances, steps in the line of human descent, and in others, diverging lines of evolution.

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Chapter VI

SOCIETAL EVOLUTION

W. M. Wheeler

WHEN as children we first escape from the "big, buzzing, booming confusion," which to our infantile consciousness represents the surrounding world, we distinguish an indefinite variety of different things. Somewhat later we notice that our world also contains a vast number of very similar objects. All this most of us take for granted and never give it second thought during the remainder of our lives. But if we happen to become philosophers or scientists, this composition of reality strikes us as worthy of closer study, though we may entertain little hope of learning why our world should be made up of such an extraordinary number of similars and dissimilars. As our knowledge increases, we observe a pronounced tendency in the numerous like objects to form cohering aggregates, and this tendency seems to be universal in its range from the electrons that make the atoms, the atoms that make the molecules, the molecules that make the masses, from sand dunes and oceans to planets and suns, and their aggregates, the constellations and nebulae. When we turn to living things we find the tendency even more pronounced so that the like entities cohere to form peculiar integrated systems known as organisms which, on analysis, reveal themselves as hierarchies of living entities. We find living molecules, which are themselves systems of inorganic molecules, atoms and electrons, organizing themselves to form cells, cells to form persons, persons to form societies consisting of single families and finally multi-familial or group societies like the one into which we are born and in which we are constrained to live till the end of our days.

Yet closer observation has revealed the startling fact, emphasized only within recent years, that the similar entities when integrated or organized as wholes, i.e. as systems or organisms, exhibit new and unpredictable

behavior (qualities) as compared with the behavior of their components. Thus when sodium and chlorine combine chemically to form common salt, we observe that it behaves in a manner very different from either of its constituent substances in isolation. Similarly, a personal organism behaves very differently from its individual cells. A new phenomenal "level" has been created, so to speak, which is not a mere sum or resultant of the component units but a novelty, or "emergent." This term, like the noun "emergence," has in this connection the meaning of "emergency" and is not to be understood in the ordinary sense which implies simply a manifestation or revelation of behavior, or properties previously existing in the components of the system or organism. It should also be noted that in order to bring this consideration into harmony with present physical theory, we must not regard the various components and emergent wholes (systems and organisms) as static things, or as so many lumps of inert matter, but as activities or movements, albeit of very various velocities. Such an attitude enables the scientist to avoid the embarrassing contradictions and inconsistencies with which our thinking has been seriously infected by age-long indulgence in dualistic (materialistic and spiritualistic) notions of reality.

Leaving the physicists, chemists and astronomers to deal with the inorganic aggregations and systems, we may turn to their counterparts, the associations and societies among living things. Here the cohesion and organization of like elements, or components, is indeed astonishingly diverse and complicated. Some of the wholes which they constitute are very loose and temporary and may be called aggregations, like the swarms of dancing midges or the collections of hibernating lady-bird bettles in the mountains of the Pacific States. Others are very persistent and consist of very interdependent, and therefore very intricately organized, parts, like the multicellular bodies of most plants (Metaphyta) and animals (Metazoa). Less highly organized are the wholes represented by the colonies of the social insects, the flocks and herds of birds and mammals, and the societies of man. Table 1 enumerates the various categories of associations and societies.

TABLE I

TYPES OF ASSOCIATIONS AND SOCIETIES

A. *Associations* (Unstable, temporary, incompletely organized wholes, primarily dependent on environmental stimuli)	1. Mere aggregations or agglomerations.			a. Homotypic b. Heterotypic
	2. Breeding, feeding, hibernating, sleeping, and migratory associations.			a. Homotypic b. Heterotypic
	3. Predatory association.			Heterotypic
	4. Parasitic association.			
	5. Symbiotic or mutualistic association.			
	6. Mimetic association.			
	7. Communities (biocoenoses)			
B. *Societies* (More nearly permanent, organized wholes or systems, primarily dependent on interindividual stimuli)	A. Homotypic	1. Persons (multicellular)		
		2. Mainly nutritive societies (closed)		(Colonies, corms, etc.)
		3. Mainly reproductive societies (closed)		Subsocial insects Social wasps Social bees Ants Termites
		4. Mainly protective societies (closed and open)		Flocks, herds, schools, etc.
	B. Heterotypic	5. Mainly reproductive mixed societies (closed)		"Mixed colonies" of wasps Bumblebees Ants
		6. Mainly protective mixed societies (open)		Flocks of different species of birds, herds of different ruminants, etc.
	C. Human societies (Group societies)			

The associations, of course, vary greatly in the number of their component individuals, from many millions as in the migrating swarms of locusts, to as low as two, in most host and parasite associations among insects. Many species often assemble to form aggregations on the same tree or flower, or under the same stone, and these aggregations may be either homotypic; i.e. consisting of members of the same species, or heterotypic, when individuals of more than one species assemble. These and other aggregations may also result from very important or urgent activities of the individuals, such as feeding, breeding, hibernating, sleeping or migrating. Comprehensive reviews of such cases, with citation of the pertinent literature, have been recently published by Deegener (1918), Allee (1927) and Brues (1926). Special instances of the very small associations are also seen to center about nutrition in the cases of predators, i.e. carnivorous animals and their prey, between parasites and their hosts, insects and the plants they pollinate, mimetic organisms, mainly insects, and their models and in what are known as the communities, or biocoenoses,

which are great heterotypic associations of numerous animals and plants occupying the same type of environment and entering into the most diverse and intricate relations with one another, e.g. the biota (fauna and flora) of a tropical rainforest regarded as a whole, that of a bog, sand dune, desert, lake, etc. In all these cases the associations are more or less unstable and temporary, because not very highly integrated. Their integration, in fact, seems to be largely determined by general, extrinsic or environmental stimuli.

The societies, as distinguished from the associations, are more permanent, organized wholes which depend primarily on the behavior of the component individuals towards one another. In order to be with its fellows the social individual will not infrequently seek to adjust itself even to a harmful or fatal environment or situation. Hence societies, as a rule, can be established only between individuals of the same species, i.e. of the same genetic origin, but there are exceptions in which individuals of two or more species may form single societies (ants, bees, wasps, compound flocks and herds of birds and mammals). We may therefore distinguish homotypic and heterotypic societies. Human societies are in many ways so peculiar that they may be assigned to a third category by themselves.

Now it is obvious that all associations and societies are merely peculiar expressions of the most general and fundamental activities of living things, namely adaptation, and it is also apparent that the associative and social adaptations are referable to the basic physiological responses of the individual organisms to stimuli emanating from their fellows or their general environment. We may roughly divide these responses into three general categories, those which satisfy the nutritive, reproductive and protective (defensive and offensive) needs of the individual organism, respectively. The different societies may therefore be classified according to the preponderance of these several needs, in their behavior. Thus such societies as the human person, which consists of some 60,000,000,000,000 cells and such compound organisms as the Portuguese man-of-war, tapeworm, etc. are of the predominant nutritive type. All their individuals are in contact or interconnected in such

a manner that certain ones, specialized for the purpose, secure and distribute nutriment to the whole. The *raison d'être* of the society seems to be primarily the facilitation of this function. In other societies, however, like those of the social insects (wasps, bees, ants, termites) nutrition seems to be subordinated to producing and rearing as many young as possible, so that reproduction and all that it implies would appear to be the principal adaptive peculiarity of such societies. Among the flocks and herds of birds and mammals, nutrition and reproduction are less conspicuous than the forms of social behavior connected with protection. For discussions of these societies the reader may be referred to the works of Espinas (1924) and Petrucci (1906) and the recent volume of Alverdes (1927). As would be expected, primitive human societies have their closest analogues among certain gregarious mammals, and notably among the anthropoid apes.

The problem of greatest interest to the student of animal associations and societies is concerned with the precise nature of the communal bonds, or social cohesion which causes the individuals to assemble and remain together for a longer or shorter period. The aggregations in some cases are obviously the result of mere accidental propinquity due to the individuals hatching simultaneously from a batch of eggs deposited by the mother organism directly on food suitable for the young. Thus the larvae of such insects as the gypsy moth and potato bettle are too feeble to stray far from the egg cluster from which they hatch and really need not stray far from one another because they are surrounded by an abundant supply of nutriment. The same is true of plant lice which are born alive by their feeble wingless mothers and the sluggish, legless larvae of Drosophila and blow flies which hatch from numbers of eggs laid almost simultaneously in fermenting fruit or decomposing flesh. We need not assume, therefore, that such aggregations of larvae are due to fondness for one another's company or are kept together by any other bond than a simple chemotropic response to their common nutritive environment. But some aggregations and associations undoubtedly depend on stimuli emanating from the

different individuals. All animals give off heat, moisture, carbon dioxide, secretions and excretions and make movements. Simple tropistic or reflex responses to these, such as those designated by the terms thermotropism, hygrotropism, chemotropism and stereotropism, are probably sufficient to account for many aggregations and associations. Migratory crickets have been observed to huddle together for mutual warmth when the cool of evening comes on; slaters (Oniscus) are induced to assemble by the moisture which they give off, and resting locusts may be stimulated to flight by the movements of their fellows. Rhythmic emission of light in fireflies or of chirping in crickets may excite rhythmic, and according to some authors synchronous, responses of the same kind in other individuals in the immediate neighborhood ("physiological sympathy" of Ribot). Some simple aggregations are evidently the result of a number of tropistic responses. One example will suffice.

The larvae of the common blackfly (Simulium) often congregate in dense masses on stones in the more torrential parts of our streams, stand erect on their posterior ends and capture with their out-spread, rake-like mouthparts diatoms and other microorganisms as they float past. In this case we may distinguish stereotropic responses of the larvæ to solid bodies (the stones), rheotropic responses to the current and probably also chemotropic responses to the higher oxygen content of the more rapidly moving water. It will be noticed that this combination of tropistic responses constitutes an exquisite adaptation because it places the stationary larvae in the optimal enviroment for securing their food, since much more of it passes within their reach in a given time in the torrential than in the sluggish portions of the stream. Although aggregation here actually brings about a competition for the food among the individuals, this disadvantage is more than compensated by the increased supply due to the swiftness of the stream. There is an extensive and interesting literature, much of which has been reviewed by Allee, dealing with the effects of aggregations on their component individuals, but the subject cannot be further elaborated in this article.

Some authors have endeavored to derive the societies from the associations, but it is difficult to find any cogent proof of their contentions. The societies really represent very different emergent levels from the associations and have arisen in a different way, though, of course, ancient aggregative or associative proclivities may have been retained by many species and may serve to reinforce their specifically social behavior. The members of societies, as distinguished from the associations, are primarily concerned with their adaptations to one another, i.e. with neutralizing their individual antagonisms, and with their mutual adjustment and cooperation. The mass of stimuli which elicit these adaptive responses may be called the social medium. It constitutes a very complex and unstable environment for the individuals, and successful and enduring adjustment to it presupposes a high sensitivity and considerable behavioristic plasticity on the part of the consociated organisms, and this in turn presupposes a highly organized neuromuscular apparatus. It is clear therefore that societies can be constituted only by species in which the sense-organs, brain and muscular system have attained a high degree of specialization, and not by animals that have never succeeded in transcending the merely tropistic and reflex level. Social life demands at least a rudimentary memory and intelligence, if we understand by the latter the ability to respond adaptively to new situations on the basis of previous experience, or in other words, some ability to learn. It is obvious, moreover, that to such organisms social life furnishes the only adequate opportunity for much further perfecting of the intelligent activities.

Though a rather highly developed neuromuscular system is a *sine qua non* of social life, it is far from true that all animals thus equipped must become social. Tigers, hawks, spiders and tiger-beetles are richly endowed organisms, but they do not live in societies. Moreover, when we study the positions of social species in the animal hierarchy we find that they are confined to certain sporadic groups of species and that they often differ externally in no respect from the most closely related, highly specialized, non-social forms. A worker honey-bee or hornet is quite unable

to live except in a society, and yet no one could infer this fact from their structure, which differs in no essential character from that of their solitary congeners. It would seem, therefore, that some other peculiar condition in addition to the high development of the neuromuscular system is essential to the formation of true societies. This I believe to be the development of the family. So long as its members remain together, a family is, of course, a rudimental society, with reproductive, nutritive and protective functions and an unmistakable differentiation, or division of labor in its components. All the societies of insects are merely single families in origin though they may become very populous and acquire an extraordinary differentiation of their members. The family origin of the flocks and herds of birds and mammals and hordes and tribes of primitive man is also apparent; though in these societies the family is open and not closed as in insects and there is a retention in the flocks, herds and hordes of primitive aggregative or associative tendencies which seem to hark back to the ancestral fish and tadpole stages. This retention is apparent in important further developments to be briefly considered in a later paragraph.

The family implies the vital affiliation of the offspring with the parents and this can only be accomplished on the condition that the adult life of the parents is sufficiently prolonged to admit of rearing the offspring to maturity. This increase in parental longevity also permits a corresponding extension of the care of the offspring and gives the latter time for a more complicated development and greater opportunities for learning and therefore of preparation for adult life. The latter consideration has been often discussed by sociologists, psychologists and educators, but the increase of the adult life of the parents as a prerequisite to that of the young has been overlooked. It is just this latter condition which enables us to account for the beginnings and further development of the families which become the elaborate closed societies of the ants, wasps, bees and termites. Most mother insects die soon after oviposition and the young are left to shift for themselves, but in certain groups, owing to peculiarities of food or

environment, the adult life of the mother or of both parents is considerably prolonged so that it overlaps the larval period or even a part or the whole of the adult life of the offspring and thus furnishes an opportunity for close relations between the members of two successive generations. I find these conditions realized in at least thirty insect groups, which are often so remotely related to one another or related in such a manner that the family must be supposed to have arisen independently (polyphyletically) on at least as many separate occasions during the long racial history of the Hexapoda, which extends over some 300,000,000 years from the Upper Carboniferous to the present time. These families vary greatly in complexity and stability. In most cases the parents are deserted by the progeny while the latter are still young, and the rudimentary society dissolves, a condition observed in what I have called the subsocial insects (certain beetles, wasps, bees, Embiids, earwigs, etc.). In the termites, ants, higher wasps and bees, however, the affiliation of the progeny with the mother (Hymenoptera) or with both parents (termites) becomes much more intimate and prolonged, so that at least the worker caste, which constitutes the great majority of the personnel of the society, never dissolves its consociation with the parents. The single family is thus enabled to remain a society, though capable in some cases of growth to a population of hundreds of thousands of individuals. This is accomplished by partial starvation of most of the offspring so that they fail as larvae to develop their reproductive organs (alimentary castration) and even as adults, in their capacity as nurses, inhibit the further development of their gonads by starving themselves as a result of feeding the successive broods of larvae, the queen and the other adult members of the colony (nutricial castration).

In the foregoing account of insect societies nothing is said about the nature of the bonds which unite the parents and offspring and thus initiate the family or about the nature of the social medium which regulates the social behavior. I believe that we may detect these recondite factors in what I have called "trophallaxis," or exchange of food.

The larvae of many social insects (ants, wasps and termites) are not only fed by the adult members (parents and workers) of the colony, but may in turn feed their nurses with salivary or other secretions. The young are therefore a source of food for the adults and *vice versa*, and the "fondness" of the social insects for their young proves to be not some altruistic "instinct," such as love or affection, but the hunger of the individual and therefore an egoistic appetite. There is also a trophallactic relation between the adult members of the colony, which are constantly feeding one another with regurgitated liquid foods (ants) or with regurgitated semisolid foods or feces or substances (exudates) secreted from the surfaces of their own bodies (termites). So powerful is this habit that it is extended even to many of the heterogeneous insects which have managed to live in the nests of the social species, i.e. to the true guests among the myrmecophiles, which live with ants, and the highly specialized guests of termites (termitophiles). Furthermore, since the senses of taste and smell are not differentiated in insects as they are in the higher vertebrates, and since, in the former, we may therefore more properly speak of a single chemical sense, we are justified in including under trophallaxis also an exchange of odors as one of the important cohesive bonds in insect societies. There are, in fact, individual, colonial and nest odors, which the social insects are able to recognize and distinguish and therefore serve to determine many of their reactions and much of their behavior. Both the food and the odors thus constitute a regulative, circulating social medium which not only functions as a social cohesive, but in the case of the food, furthers the growth and maintenance of the society in a manner analogous to the circulating blood stream in the body of a higher animal, which is also a society of cells. Of course, the word "food" is here used in a general physiological sense, both as nutriment and as a stimulant, or excitant, because the amounts of the substances exchanged may be extremely small though of such a chemical composition as to produce pronounced reactions, just as a very small amount of alcohol may produce much more violent reactions in some people than large quantities of rice or potatoes.

The flocks, packs and herds of the higher vertebrates constitute peculiar societies, quite unlike those of insects, and might more properly be called peoples, populations or "peuplades," to use Espinas' term. They may consist of a number of associated families, of individuals of one or both sexes or of the young only. They may be loosely or intensively organized, temporary or more permanent, and either closed or open, to use the classification of Alverdes, i.e. they may either repel outsiders or admit them, even when they belong to alien species, and permit them to become members of the society in good standing. Our knowledge of these peculiar organizations is far from complete, but some of them have been recently studied with results that seem to have important bearings on human societies, which are really of the same fundamental structure. The peuplades are held together by what has been usually called the gregarious, or herd instincts, but the investigations to which I have just referred seem to show that the cohesion may be due to more concrete and observable behavioristic factors.

In their studies of birds, Schjelderup-Ebbe, Katz and Fischel have shown that the flocks are organized according to a peculiar "pecking order," in which each individual has its own status depending on whether it may peck other individuals or submit to being pecked by them. To quote Alverdes, "Schjelderup-Ebbe has shown how an order of precedence comes into existence within societies. A flock of fowls in a fowl run is not exclusive in the sense that its members make common cause against a new arrival, leaving the latter isolated. The new comer may safely attach itself to the flock, but the position it is to hold therein must first be won by fighting. For no two hens ever live side by side in a flock without having previously settled, either for the time being, or for good, which is the superior and which the inferior; the "pecking order" thus established decides which of the birds may peck the other without fear of being pecked in return. Similar pecking codes exist, according to Schjelderup-Ebbe, among sparrows, wild ducks, and possibly among many other kinds of animals. Pecking among cocks is governed by the same rules as among hens, except that the cocks exhibit greater ferocity. Such "pecking orders"

give the society concerned a certain degree of organization." This "pecking order" which would seem to be the cohesive among the peuplades, corresponding to the very different cohesive, trophallaxis, among the societies of insects, leads naturally to a complex, organized hierarchy of individuals, depending on their age, sex, vigor, and bluffing capacity. It is so suggestive of human communities, in which we have a similar hierarchy of social status based on the bivalent self-assertion and self-abasement, or sadistic and masochistic motives of the individual, that the results of further investigations on the peuplades of other Vertebrates will be awaited with interest. Perhaps what we call government in human societies is really only a glorified "pecking order!"[1]

When we turn to the societies of man we are confronted with an emergent level so much higher and so much more complicated than that of any of the other social animals that it seems to transcend analysis. Biologically it is obvious that it consists of a great number of genetically related families, and though there is among the individuals of each of these a division of labor essentially like that of the animal family, there is superadded a more elaborate division of labor which traverses the families and is quite unlike that of the unifamilial society of insects, since it is a product of learning and custom and has not become hereditary. Furthermore, his much more highly developed neuromuscular system, intelligence, memory, and language have enabled man to create and transmit from generation to generation vast accumulations in the form of stores of knowledge, elaborate institutions, constructions, mores, arts, sciences, etc., which the animals, restricted to their limited hereditary endowments and feeble individual plasticity of response to their inorganic and living environment, could neither develop nor transmit. This tradition, or social memory, has therefore been regarded as the leading peculiarity of human societies, but it must be admitted that there are some very rudimental indications of it even in the social insects.

[1] In this connection it is interesting to note that the domestication of animals depends on a similar order. Nearly all our domestic animals belong to social species and their successful subjugation implies, so to speak, a realization on their part of their defenseless inferiority in the presence of man.

Naturally the question as to what brings about the cohesion of the individuals is far from being as easily answered in human as in animal societies. To this question, which also involves the causes of the maintenance or continuation as well as the origin of human societies, the philosophers and sociologists of the past have given a number of different answers. These are all hypothetical, and none of them is altogether satisfactory. Several of them, in fact, are quite inadequate and at present obsolete, but it may be of interest to consider them *seriatim.*

1. The earliest hypothesis, if it deserves so dignified a name, is, of course, that of Genesis, according to which the male of our species was made out of clay by divine fiat on the sixth day and the female from his rib by the same process somewhat later. This statement has some extraordinary implications, only two of which need be mentioned. First, man having been created complete, he was necessarily a social being from the beginning, and inquiry into the causes of society must be useless. Secondly, owing to his special creation, man is definitively set over against the other animals and Nature in general. This is the view still taken for granted by many theologians so that for them all inquiry into social evolution and cohesion in a biological sense must be meaningless.

2. Some of the Greek philosophers, including Plato, entertained a similar supernatural view of the origin of man and his society, mainly on ethical grounds. But Plato seems also to have been inclined to regard society as having had a natural origin and growth and this view was definitively developed by Aristotle and much later by other philosophers, including de Maistre and Kant.

3. In the seventeenth and eighteenth centuries an hypothesis of the origin of human society was expounded by Hobbes, Locke and Rousseau, which seems very strange to us. These philosophers imagined that men had formed and continued to maintain their society by mutual agreement, or compact. That anything like society could owe its beginning and cohesion to such frail intellectual motives was quite in harmony with the thinking of those centuries. Of course, the corollary that men might dissolve by intellec-

tual agreement what they had built up by the same means was one of the arguments in favor of the French Revolution. At the present time the doctrine has no sociological importance, except possibly to a certain type of reformer.

4. Another intellectualistic hypothesis of societal origins was excogitated by Starcke who believed that early man took up social life because he had observed its advantages among the social insects in his environment. Similar fanciful notions have been occasionally advanced to account for more modest human inventions, e.g. the supposition that the Australian aborigines derived the boomerang from observing the circular paths described by the falling sickel-shaped leaves of certain species of Eucalyptus. While this latter hypothesis cannot be dismissed as altogether improbable, Starcke's notion becomes absurd when we consider that man must have been a social animal long before he had sufficient intelligence to observe and imitate the social insects and that, even had he conceived society as the result of such casual observations, that fact would not have enabled him to maintain it throughout his whole subsequent racial history in all parts of the world.

5. Darwin's hypothesis of evolution through natural selection is, of course, quite a different matter. According to it, social origins are really accidental, but when men had once established social relations with one another, the advantages accruing would lead to the survival of the individuals that adhered to the social habit, while those who reverted to a solitary mode of life would be eliminated. Naturally, from a human point of view, the advantages of society are enormous, and existing man has never experienced any other mode of life, but the selection hypothesis, though logical, does not go to the root of the matter. The merely evolutionary, or transformist core of the hypothesis, however, is immensely important. We should not be wrong in stating that evolution may be more easily demonstrated in ethnology, archeology, and history than in the study of living and extinct organisms.

6. If we revert to the principle of emergence, briefly considered in the introduction to this chapter, we might say that human society arose rather suddenly and discon-

tinuously when the primitive family expanded by some natural process of growth, affiliation and differentiation of individuals into the clan or tribe, but even this leaves us in the dark in regard to the actual factors which brought about the expansion and still maintain the solidarity of the individuals in the great societies of the present time.

7. Psychologists, psychopathologists and sociologists are now unanimous in maintaining that social cohesion, or what some have called the "social mind," must be constituted by the wealth of non-rational behavior which has been variously designated as the appetites, cravings, instincts, interests and emotions of the individual. Some have postulated a special "herd instinct" (Trotter) or "gregarious instinct" (Drever), while others have based human solidarity on "consensus" (Comte), synergy, or cooperation (Spencer), on altruism, sympathy, affection or even egoism (Le Dantec). It will be seen that all of these bonds are of a physiological or primitively psychological character and therefore quite different from those which we call intellectual, or rational. They are, no doubt, fundamentally the same as the primitive associative tendencies which we observe in the uniform members of the flocks and herds of birds and mammals, and may therefore be traceable to the instinctive bonds which unite the members of the family.

8. Durkheim, while accepting these tendencies as the basis of social cohesion in the more primitive human societies, has pointed out that as society develops, the strongest bonds are those produced by the continued action and intensification of the social division of labor. The associated individuals necessarily become more and more heterogeneous psychically, and therefore more and more interdependent. This increase in interdependence brings about both the cooperation and the constraint which are such conspicuous features in highly developed societies. Cooperation is not, therefore, a primitive condition, but supervenes after a certain differentiation has been developed by division of labor, or specialization among the individuals; and the constraint, restraint, inhibitions and repressions which the social unit is bound to exercise and endure have had much to do with the creation of the traditions (social heredity),

mores, laws, religious institutions, etc. which in turn constrain their creators. Durkheim's view has the advantage of referring the integration, or solidarity of society, to a principle which is universal, not only in all animal societies, but also in all multicellular organisms. This principle, the division of labor, was first recognized and named by the economist Adam Smith and only later introduced into biology by Milne-Edwards.

The very significant rôle of the primitively psychological and the relative insignificance, even in our present civilization, of the specifically intellectual processes have been most impressively set forth by Pareto in his "Traité de Sociologie" and by Sumner and Keller in their "Science of Society." A study of these works might be said to constitute a liberal education. Pareto designates the irrational foundations of social behavior as the "residues," the rationalizations of them in which we are constantly indulging, as the "derivations." Sumner and Keller's remarkable picture of the mores and of their fundamental significance, stability, and tenacity, based on exhaustive ethnological studies, forms an admirable background for Pareto's contentions, which he illustrates mainly with materials drawn from the ancient and contemporary history of European peoples. Both works are important also because they lift sociology entirely out of the valuative and moralizing slough, in which it has long floundered, onto the scientific plane. The strange light which these and many other similar studies of human society cast on our zealous social reformers and propagandists enables us to appreciate, on the one hand, the impulsive, irrational, wishful thinking which is the true drive of their own activities and, on the other hand, the extraordinary magnitude and inertia of the behavior they are trying to control and reform.

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Chapter VII

HUMAN RACES

Aleš Hrdlička

ONE of the plainest facts regarding man is that he differs, physically as well as otherwise. Physically he differs so that, except in the rare cases of "identical" or one-egg twins, every individual may readily be told apart from all others. This is individual variation, which, while general to all living forms, is most pronounced in man.

In every human community, however, from the larger family groups or "lines" onward, there are evidences of the formation of *strains*, the individuals of which approach or resemble each other in pigmentation, stature, build, and more or less even in physiognomy. The larger the human group the more such strains there usually are, and the more some of these tend to become *established*, both somatologically and territorially. Such strains now form *types*, which, if allowed further to develop and multiply and segregate, begin to assume the status of *races;* which, with time, develop again their own strains and types and perhaps races.

Thus human variation and differentiation go on; and thus they have gone on since the beginnings of man, producing various races, most of which perished in the long struggle of human ascent. But others persist to this day, and it is the study and classification of these surviving as well as their daughter races that have, long since, been one of the serious concerns of Anthropology, and that will be succinctly dealt with in the following pages.

MAN AND SPECIES

In biological classification man constitutes the ultimate distinct genus of the Primates, the genus Homo. The components of this most widely distributed genus present extensive physical variation, and this variation occurs in numerous more or less distinct strains, the larger and better

established of which are known as the human races. These races differ much in age as well as in distinctiveness; and the oldest and most distinct have appeared to some students to deserve the term of species rather than races.

The question hinges largely on the concept of a "species." This concept and its definition have never been made as clear as one would wish. A perfect, universally valid definition of a species seems in fact impossible. A species may merely be said to be a well-defined, autonomous and persistent organic unit, living in a free state of nature, not grading freely into any other unit, and generally of less perfect fecundity outside than inside of its limits. A species moreover differs from all other species not only morphologically, but also in its physiological manifestations, and in its "psychic" behavior.

When we apply such a concept and definition to man, we fail to establish separate species in this genus. Even man's most distinct strains intergrade very substantially with others, somatologically, physiologically and in mental behavior; they interbreed freely and, under normal conditions, rear normal lastingly fecund progency; and all are changeable in the direction of other units of the group, under altered conditions. There is therefore, as well recognized already by Darwin and many other eminent older students of the question, no justification for the assumption within the human genus of more than one true species, and the different strains of man may properly be regarded as just subspecies, varieties, or, most simply and intelligibly, as races.

ORIGIN OF HUMAN RACES

The phenomenon of *raciation*, i.e. of differentiation into races, is common to all living organisms. It is an important, and in higher organic forms probably necessary, step towards *speciation*, or the formation of species.

The formation of races in any geographically extensive group is more or less continuous, according to circumstances such as environmental differences, isolation, in-breeding and mix-breeding. Judging from analogies among the existing anthropoid apes, it is safe to assume that there

were distinct races already among the human precursors, and that more or less different races were present throughout the existence of man. It is not impossible, even, that more than one race of precursors were evolving simultaneously towards man, though only the most successful of such possible separate developments appears to have survived.

It may therefore legitimately be said that from the earliest times of its existence humankind was tending to differentiate into races; and that racial differentiation in man is a continuous, general life process, without sharply demarkable beginnings or end. Its causes are organic variability, adaptability to changed conditions, eventual heredity of the newly developed and sustained characters, and prolonged segregation of the new groups.

Nascent Races

Whenever a human group of some magnitude and geographical extent begins to assume lasting somatological characters that tend to differentiate it plainly from other groups of man, it may justly be regarded as a nascent race. Whether such a race becomes successful, i.e. prevails and becomes established, will depend on conditions.

The tendency towards the development of new human races may be observed in many parts of the world today. Its chief present factors are, on one hand, the basic human qualities or functions of variability and blending; and on the other hand intermixture, with unification of activities.

Wherever two or more racial elements come into such contact as will bring on free intermarriage, there will before long begin to form an intermediary type or progressive blend. In most cases such a blend, through circumstances, becomes dissolved into one or more of the parent bodies, or is so influenced by the predominance of one or another of these that it fails to reach any distinct status of its own. But in favorable cases, which are those of mixtures within large political units, there will be formed a "nation," which with time advances towards uniformity of language and habits. And such a unit, if immigration is not great, will show ever more of physical resemblances.

Precisely such phenomena took place within all the large political units or nations that exist today. Every one, without exception, is the resultant of the merging of various racial elements, and each one may now be seen to be approaching, more or less, a recognizable new type of its own, e.g. the Spanish, Italian, French, German, English, and even the American. These new types are of the order of nascent races. Could any of these nations exist for some milleniums without further material accretions from the outside, the strong probability is that a definite new secondary race would be established.

Human raciation of the present is one of the plainest and most generalized evidences of continuing human evolution.

RACE CHARACTERS

The characters that distinguish human races are morphological, physiological, chemical, psychological, and even pathological. They occur in more or less of correlations, but there are numerous and in instances important exceptions in this respect.

The principal *physical* differences in human races are those of color, nature of the hair, characteristics of the skull, face, eyes and nose, stature, relative lengths of the long bones, and of teeth, especially incisors. Important differences exist in the brain, internal organs and many other parts, but these largely await further investigation.

The main *functional* racial differences, so far as known, are those in pulse, temperature and eruption of the teeth. There are doubtless many others; but here once more a great deal remains to be learned through further research. Demographic differences belong to this section.

Chemical racial differences are manifest in the blood, in sweat, and inferentially in the various immunities. Almost nothing is known as yet of probable differences in the various internal secretions, and elsewhere. Here too remains a great field for future studies.

The *mental* differences between the races, numerous and in some cases important, elude thus far direct and precise specification or determination. Sensory differences exist,

but their exact nature and degrees remain to be established. There are, between the more distinct races at least, apparently substantial differences in the higher psychical processes, but they have not yet been precised; their study is much complicated by what are merely mental habits.

The *pathological* racial differences are in the main those of "predispositions" and immunities. They are mostly environmental, and local rather than racial, in character. They directly correlate but little with other racial features; but in their indirect effects, survival or elimination, range among the basic factors in human evolution. Among pathological conditions largely peculiar to some races may be mentioned the transient nutritional disorder in childhood that leads to the frequent premature occlusion of the sagittal suture, with consequent scaphocephaly, in the negro; the peculiar psychoses of the Malays; the neurasthenias, various skin disorders, etc., among the whites; etc.

The differences in all these lines are in every human group associated with astonishing similarities to identities, pointing strongly to a common derivation of all the existing human varieties.

INSTABILITY

All the racial characters, of whatever order, appear in more or less wide ranges of individual and of group variation, and the extremes of the group variation as a rule largely overlap or interdigitate with those of other racial units.

None of the characters in any group may be regarded as wholly set and stable. A few examples will here suffice.

Color

Color of Skin. In the "white" race the color of the skin ranges from light bluish-white or pinkish, as in the Nordic blond or red-haired, to all shades of tan (many Mediterraneans), or brown (some Arabs, Egyptians, Abyssinians, etc.), to almost black (some Abyssinians, some Hindus).

It varies from almost white to dark brown (solid chocolate) in the Chinese and Japanese, from that of old leather to dark brown in the American Indian.

It is absolutely black in many Australians, whose hair may be nearly straight and features almost like those of a White. It may be brown in an Aino with a physiognomy much like that of a Russian. It may be light tan in a dark-haired Nordic, or resplendently white in a Mediterranean or a Semitic brunette.

It ranges from the blackest through dark brown and red brown to that of old leather, in the Negroes (including the Bushmen).

Color of Eyes. This varies in white races from pale blue, or greenish, or greyish, to dark brown; among the Asiatics, aboriginal Americans, Polynesians and Malays, from medium to very dark brown; and among the negroes from dark brown to black. There are more or less marked age changes in the color of the eyes in every individual.

Color of Hair. The hair varies from almost colorless, or golden, or red, through all shades of brown, to jet black, in whites; from dark reddish brown to jet black, in the yellow-browns; from tow-yellow to coal black in the Australian; from coal- or jet-black to soot- or greyish-black, in the negroes. It may vary from very light to dark brown between the childhood and later adult life in the same individual among the whites, or from sandy to black, as among some of the Melanesians.

Character of Hair

The hair is straight to decidedly curly in whites; it is straight to loosely wavy in yellow-browns; is straight to bushy-curly or frizzly in the Australians; and presents bushy curls to scant spirals, in the negroes. The degree of curliness or wave may differ during the life of the same individual.

In cross-section, on the average, the hair of the white is oval, that of the yellow-browns round, that of the true negro elliptic; but there is much variation and overlapping throughout.

The Skull

The whole gamut of cephalic index, and also that of skull height, is found among the whites; similarly among the

yellow-browns; while general dolicho- to meso-cephaly, but reaching in individuals and in some central tribes to brachycephaly, prevails in the African negro. Even the full-blood Australian reaches from extreme dolichocephaly to the border of brachycephaly, and from low skull to high (see Hrdlička, 1924).

The skull shape changes between birth and the adult stage; differs in the two sexes; is affected slightly by stature; and has within historic times been observed to gradually change in the same people, particularly in the direction of brachycephaly (Austria, Bohemia, Germany, England, etc.), but also in the opposite direction (the Eskimo).

The most distinct and least varied skull, on the whole, is that of the African negro. Yet it also shows some marked differences, as in the "Boskop" type, which may here and there be observed among the living unmixed negroes in South Africa. And individual negro features occur now and then in the crania of all other races, without admixture. In some respects, such as the nose, and prognathy, the African negro skull is on the whole the most primitive; yet it will occasionally be exceeded even in these features by an Australian or Melanesian; and in some points, such as the reduction of the jaws and particularly that of the supraorbital ridges, it, on the average, exceeds these. In the reduction of the brow ridges it surpasses (which means that it is evolutionally more advanced) even the skull of the white man.

Other Racial Differences

Much the same conditions of indefiniteness, or imperfect stability, and overlapping, apply to all other characters, of whatever nature, that are better known in man at large. Nothing is fully set, nothing immutable, nothing wholly apart from the rest. Wherefore the conclusion that man is represented today by but one species, and that his subdivisions deserve no farther reaching designation than that of races, seems the only justifiable conclusion.

Changes in Racial Characters

Races are more or less definite *hereditary* complexes. Their characters may be viewed as so many acquisitions

in the course of the history of each race. These acquisitions, correlated and harmonized with the rest, have become "fixed" and hereditary. The older and more important they are to the system, the greater may, in general, be said to be their fixity. But none are absolutely permanent; so far as perceivable all can change, and probably even be lost, under new conditions favoring or demanding a change or a loss. Races are therefore not permanent but changeable.

Examples of changes in somatic racial characters are more or less clearly perceivable in many cases.

The Aryans who have immigrated into India since perhaps 2000 B.C. now often present color so nearly black that nothing like it exists in any other late branch of the white race. The Ethiopians of semitic derivation stand next in this respect. The unmixed Arabs in Arabia and Egypt show not seldom a rich full reddish brown color of their whole body, fully equaling that of the American Indian; while among higher class Arabs the skin may be practically white. On the other hand the Lapp, the Eskimo and the northwest coast American Indian show more or less depigmentation of the skin, particularly of the body. Without mixture some of these skins approach those of the whites. And a similar phenomenon is manifest here and there among the upper classes of Japan and China.

The cephalic index, as shown by Matiegka, v. Luschan, Parsons, Fleure, has in general been slowly rising during the present millenium in the Slavs, Germans, the English and others. The average stature is increasing in Holland, Denmark, Sweden, Japan, and especially in the United States (See Hrdlička, 1925). The bulk of the supraorbital ridges, the prominence and size of the malars and angles of the lower jaw, the size of the jaws and teeth as a whole, are diminishing in the civilized races. The character of the hair, the nose, orbits, physiognomy, the bulk of the body, the relative proportions of the trunk and the lower limbs, all are changeable, and change appreciably here or there within historic times.

Many physical features are slowly changing now in some peoples as may perhaps best be witnessed among the

American whites, but also among the American Indians, and probably even in the American negroes.

All the changes of racial characters observable in man appear to be essentially of the nature of adaptations and responses to the environment, to altered habits, to abundance of nutrition and to favorable or unfavorable hygienic conditions. The changes as a rule are gradual. There is no record in man of any important sudden mutation.

The changeability of race in accord with conditions, is a fact of much practical importance. It shows that man is still quite plastic, and that he therefore is capable of further favorable evolution; and that it depends largely on the conditions to which he is subjected as to whether he is to advance, and what direction this advance is to take. All of which is of basic value to the social sciences and eugenics, as well as to anthropology.

CLASSIFICATION OF HUMAN RACES

Attempts at a classification of the human races by their physical peculiarities date doutbless to times when men began to be more precisely acquainted with types of humankind different from themselves. The old Egyptians, as shown by Petrie and others, recognized and depicted on their monuments the pygmy and the regular Negro, the Semites, Aryans, and some Mongoloids. The Jews and the Phoenicians, the Greeks of Herodotus and especially Alexander, and surely the Romans of Caesar, Tacitus, Diodore, and Pliny, as well as the Chinese, were acquainted with various races of man and left more or less intelligible accounts of them; while the Negroes, Tartars ("Huns") and Mongols, besides various secondary strains, have been well known, since Roman times, to Europe in general.

The Christian era was not favorable to studies of man; but a fresh impetus to these was given by the reports of various travelers in distant lands, such as Marco Polo, and above all by the discovery of America, particularly when this became known to be a separate continent, occupied by separate people. Yet even then there was nothing like a serious attempt at a scientific classification of the human

races until near the middle of the eighteenth century. There are essays by Bernier (1684), and Bradley (1721), but they are too imperfect to have any real value.

The first effective scientific classification of humankind is that of Linnaeus and appears in his great work "Systema naturae" (10 editions, 1735–60). Man belongs to the class of Mammals, order Primates; he forms but one species, the *Homo sapiens;* and he is divided into the following races:

Homo sapiens	Americanus
	Europaeus
	Asiaticus
	Asser (Negro)

Two other "races" are mentioned, the *H. ferus* (savage) and the *H. monstruosus* (monstrous), which probably connect with some peculiar notions of the past; otherwise the substance of the classification holds true to this day.

The next most important racial classification is that of Blumenbach (1781). This is based on that of Linnaeus, but leaves out the "savage" and the "monstrous" varieties, and adds the Malay. Blumenbach recognized five main races, the Caucasian, Mongoloid, Malay, American, and Negro. His classification prevailed until recent time; it has, in fact, an influence to this day.

Yet even Blumenbach's views did not prove entirely satisfactory, as a result of which there arose in the course of time almost as many schemes of classifications of the races of man as there were students of the question. These schemes differ widely as to the number, names and distinctions of the races. As to number, Virey (1801) recognized but two main races or "species;" for Morton (1839) there were twenty-two, for Huxley (1870) nineteen, for Topinard (1885) nineteen, for Deniker (1901, 1926) twenty-nine, for Burke sixty-three. (See Waitz, 1863; Tuttle, 1866; Darwin, 1871; Topinard, 1885; and Deniker, 1901, 1926.)

PRESENT CLASSIFICATION

The classification to be given here is based wholly on somatology. It is the result of a careful consideration of the

views of others, but also of extensive personal knowledge of peoples, and that of both the living and the skeletal remains. It is restricted to the essentials.

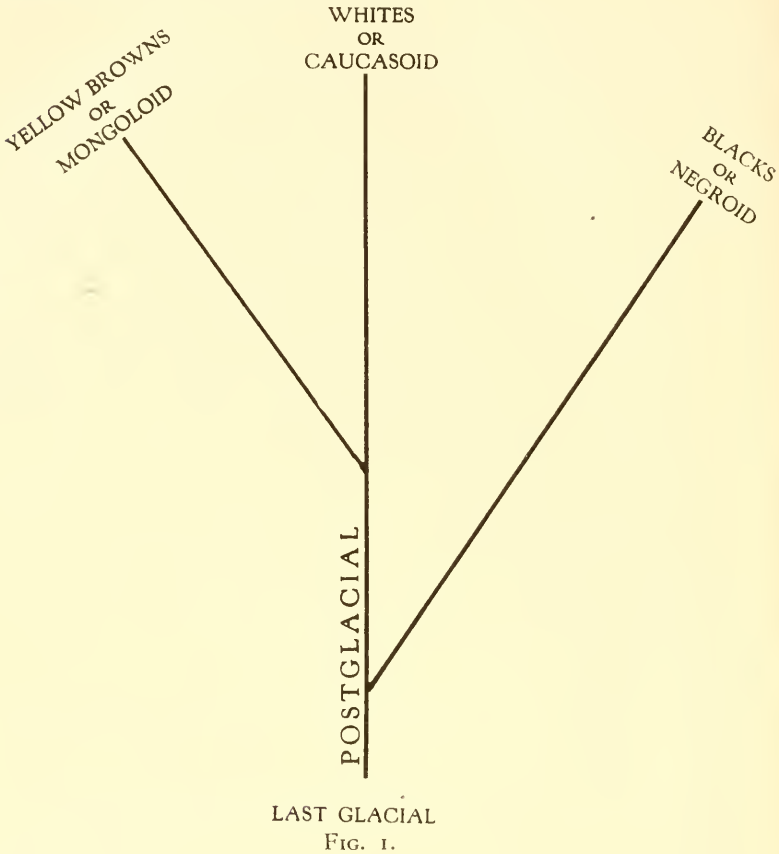

Fig. 1.

The Main Races or Stems

There are three primary *Stems* or *Races* of Man. They are the White, the Yellow-brown, and the Black; or the Caucasoid, the Mongoloid, and the Negroid. The terms are all more or less unsatisfactory, but they are the best we have and the most generally understood. (Fig. 1.)

Characterization. These three primary stems differ from each other in a great number of items, but no feature, except in its advanced development, is the exclusive property

of any one. The whites and the negroes stand in general the farthest apart. The yellow-browns are more or less intermediate, but mostly nearer to the white than to the negro. The more obvious and better known differences of the three stems are given in Table 1:

TABLE 1

PRINCIPAL CHARACTERISTICS OF THE MAIN HUMAN STEMS OR RACES

	Whites (Caucasoid)	Yellow-browns (Mongoloid)	Blacks (Negroid)
Color of skin (in the living)	Essentially "white" (bluish or pinkish white, to tan, brown, and even near black)	Essentially "yellow-brown" (near-white, to leather yellow and all shades of brown)	Essentially "black" (yellowish brown, to various shades of brown to full shiny black)
Color of hair.....	Lightest flax to golden, or red, through all shades of brown, to coal black	Dark reddish black to coal black	Coal black to greyish black
Color of eyes (iris)..	Pale blue to deep blue, greenish, grey, and all grades of brown	Medium to very dark brown	Dark brown to black
Conjunctiva.....	Bluish white to pearly white	Yellowish white to reddish dirty yellow	Yellowish white to very reddish dirty yellow
Hair of the head....	Rich, long, medium to fine, straight to wavy, to curly. Cross-section oval. In males tendency to baldness (under normal conditions). Tendency, both sexes, to early greying, and greyness often extreme (pure white)	Rich, long, medium to somewhat coarse, straight, to slightly wavy. Cross-section roundish. Slight tendency to baldness. Greyness but moderate and later (than in whites), and greyness generally incomplete (yellowish-grey)	Bushy to scant, medium to somewhat coarse, thick curls to scattered spirals. Cross-section elliptic. None or but slight tendency to baldness. Greyness but moderate and later (than in whites), and greyness generally incomplete (iron-grey or yellowish grey)
Beard.....	Moderate to rich and long, slightly wavy to loosely curly, grows plentifully on sides of face	Scanty to moderate, straight to slightly wavy, no beard on sides of face	Moderate to fair, loosely to closely curly, grows moderately on sides of face
Hair over Body.....	Moderate to pronounced	None or slight	Slight to pronounced
Hair in Axillae and on Pubis	Moderate to pronounced	None to moderate	Moderate
Stature.....	Moderate to tall (no pygmies)	Short to tall (occasional approach to pygmies)	Very short to very tall (pygmies)
Head (and skull): Cephalic index	Moderate dolichocephaly to marked brachycephaly	Moderate dolichocephaly to marked brachycephaly	Pronounced dolichocephaly to mesocephaly, rarely brachycephaly
Height of Vault.....	Moderate to high, (rarely low)	Low to high	Low to moderate (rarely above moderate)
Shape (aside of cephalic index)	Great variation	Considerable variation	Form characteristic, variation limited
Size (relatively to Stature)	Small to very large	Small to large (in many groups somewhat smaller than in whites)	Small to moderate (smaller than in whites)

TABLE I (*Continued*)

	Whites (Caucasoid)	Yellow-browns (Mongoloid)	Blacks (Negroid)
Deformities (Pathological)	Rare (mostly various plagio- and acrocephalies)	Very rare (mostly approaching acrocephaly)	Frequent (premature occlusion of sagittal suture, with consequent scaphocephaly)
Forehead	Medium to high	Low to above medium	Low to medium
Frontal eminences	Generally double, lateral	Generally double, lateral, but mostly less marked than in whites	Generally single, median (especially marked in children)
Supraorbital ridges (in males)	Submedium to pronounced	Submedium to pronounced	Slight to medium
Glabellar region	Medium	In large Asian groups characteristically flattened	Medium to beetling
Nasion depression (in males)	None to deep, mostly well defined	Shallow to medium, now and then ill-defined	Submedium to deep "line" depression
Eyes: Fissures	Horizontal to slightly oblique	Slightly to markedly oblique	Horizontal to somewhat oblique
Eyes: Visible part of eye-balls	Oblong, more or less spindle-shaped	Oblong, spindle to almond shaped	More rounded (than in whites or yellow-browns)
Nose: Height (prominence of bridge)	Medium to high	Submedium to above medium	Low to submedium
Nose: Breadth	Medium to narrow	Medium	Broad
Nasal Index	Lepto (mostly) to mesorhine	Mesorhine, in general, Leptorhine occasional (Eskimo)	Platyrhine
In skull: Nasal borders	Sharp	Mostly mildly dull	Mildly dull to very dull, to gutters
In skull: Nasal spine	Well developed (especially in height)	None to submedium (especially in height	Moderate to small
Malars	Subdued to above medium	Above medium to bulky or prominent	Submedium to above medium
Facial prognathism	None	None to slight	Slight to very marked
Alveolar prognathism	None to moderate	Moderate to marked	Above medium to very pronounced
Lips	Medium to thin	Medium to slightly above	Thick to very thick and more or less everted
Teeth	Small to medium	Medium to large	Medium to large
Upper incisors	Hoe-shaped (mildly concave buccally)	Shovel-shaped (deeply concave and laterally bordered buccally)	Hoe- to occasionally shovel-shaped
Chin	Moderate to prominent	Medium	Medium to subdued
Jaws	Light to strongly developed	Medium to very strongly developed	Submedium to medium
Face as a whole	Mostly relatively narrow, with moderate cheek-bones and angles	Mostly relatively broad, with prominent cheek-bones	Breadth and features mostly subdued
Neck	Medium to long	Medium	Medium to long
Body	In prime, shapely	Less shapely	In prime, excellent proportions
Breasts	Hemispherical to semi-conical	Conical to semi-conical, to hemispherical (espec. in Malay)	Conical, to rarely semi-conical
Buttocks	Shapely, to moderate steatopygy	Less shapely, never steatopygy	Shapely, to occasionally pronounced steatopygy

TABLE I (*Continued*)

	Whites (Caucasoid)	Yellow-browns (Mongoloid)	Blacks (Negroid)
Genitals: Male	Medium	Medium	Above medium
Genitals: Female	Nothing special	Nothing special	Occasional hypertrophy of nymphae
Thighs (in females)	Stout and shapely, and in standing are in apposition	Frequently more muscular than stout, less shapely, and will not always come to apposition in standing	Mostly less stout to lanky, and in many of the more slender not, or not fully, in apposition when standing
Legs	Shapely and full	Less shapely and often slender	Mostly moderate, and less shapely than in whites
Hands (relate largely to size of body, length of limbs, and to function)	Small to large	Small to medium	Predominantly large (in the taller negroes)
Feet (do.)	Small to large, well developed arch	Small to medium well developed arch	Tend to large, (in the taller negroes) arch low, tendency to normally flat feet
Bones of the skeleton	Bones of forearm and leg relatively short to medium	Relative length of bones of forearm and leg medium to above medium (as compared with whites)	Bones of forearm and leg relatively long
	Curvatures of long bones in general medium	Curvatures generally medium	Long bones mostly remarkably straight
Special	Platymery and platycnaemy rare	Platymery and platycnaemy frequent (espec. in the American Indian) and pronounced	No platymery or platycnaemy
	All bones, especially in senility, inclined to arthritic exostoses	Less inclination to arthritic exostoses than in whites	Bones marked by freedom from exostoses of all kinds
	Rachitis not rare	Rachitis rare to absent	Rachitis rare in wild, frequent in semi-civilized and mixed
Brain: Size	Medium to large	Submedium to large	Small to medium, rarely above
Brain: Cerebral convolutions	Medium to rich and deep	Submedium to occasionally rich and deep	Relatively simple and shallow, to but fairly complex and deep
Distinguishing Mental Characteristics (to be taken with reservation, ur til more scientifically determined)	Nervous as well as physical vivacity; temperamental	Mostly less vivacious and temperamental	Active and jolly, rather than nervously vivacious; not very temperamental
	Strong ambitions and passions; idealism highly developed	Ambitiousness less developed; emotions and passions less apparent, even when strong; idealism in general moderate to good	Not very ambitious; emotions and passions strong but less rational; idealism rather weak
	Love of all amusement; love of sport, exploration, adventure	Love of sport, less so of exploration and adventure	Love of amusement and sport strong, of exploration weak, of adventure moderate
	Artistic	Artistic	Artistic qualities above moderate in few lines only, mainly pictorial, decorative, and industrial

TABLE I (*Continued*)

	Whites (Caucasoid)	Yellow-browns (Mongoloid)	Blacks (Negroid)
	Music highly developed	Music subdeveloped	Musical ability well represented, but not of high intellectual order
	Poetry highly developed	Poetry subdeveloped	Poetry of low order
	Egoism and individuality strong	Egoism and individuality less pronounced	Egoism and individuality not strong
	Subject to cares and worries	Less, in general, subject to cares and worries	Rather careless and free from lasting worries, but ridden by superstitious fears
	Industrious	Very industrious	Not very or steadily industrious
	Religious life highly varied and developed	Less varied or intense	Little variety or development
	Much subject to psychoses and other brain affections	Moderately subject to psychoses and brain affections	Moderately subject to psychoses

MAIN SECONDARY RACIAL GROUPS

Besides the three main racial stems, there are four large and important racial groups which next demand attention. They are the Australians, the Papuans, the Polynesians and the Finno-Ugrians or Semimongoloids.

The *Australians* (and related Tasmanians) are a fairly well-defined race, which, according to all indications, is an old derivative of the late glacial man of western Asia. Notwithstanding their black color and other important features their basic relation is with the white stem, though in its early and primitive stages. Outside of the mixture with late Papuans and further back possibly even some Negrito, their hair, beard, physiognomy and even their blood are closest to those of whites, particularly perhaps those of the Dravidian type, though often much more primitive somatologically. The Tasmanians may safely be classed now as a moderate variant of the Australians.[1]

The *Papuans* and related *Melanesians* are in all probability of mixed origin. Though at present quite typical, they disclose now and then features which point in two main directions: to an old type such as that of the original Australian, and to the Negrito. There seems to appear in Melanesia also an evidently later, perhaps much more

[1] (See Cat. Crania, U. S. Nat. Mus., No. 3, 1928.)

recent and smaller element of the true tall negro. Anthropological knowledge of the Melanesians is as yet far from as comprehensive or satisfactory as is needed.

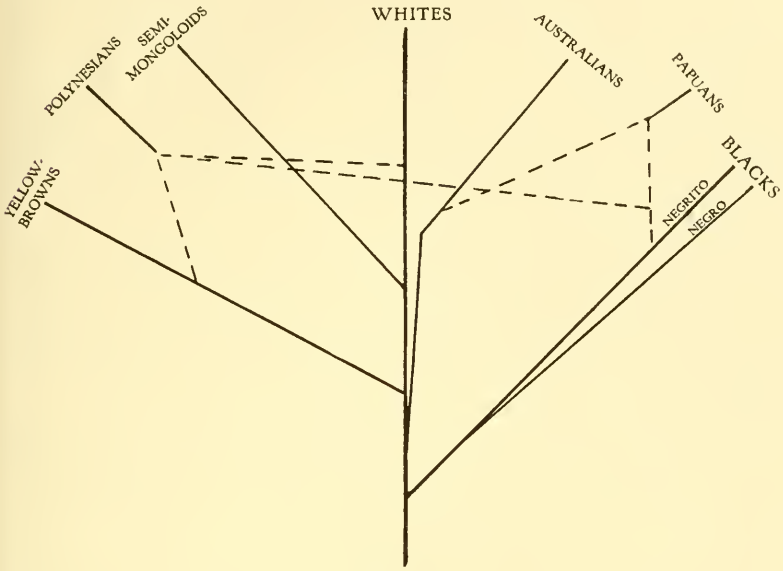

FIG. 2.

The *Polynesians*, though also of a mixed origin, constitute a fairly well-defined secondary race. They show clear marks of a large caucassoid, a small mongoloid (Malay?), and a still smaller negroid (Negrito?) element in their composition. In Hawaii there is also some late admixture with the tall negro, and throughout there is considerable recent introduction of white blood.

The Semimongoloids (*Finno-Ugrian* or *Ural-Altaic* peoples), occupied sparsely, until the tenth century A.D., a vast territory between true whites and the true Mongoloids, taking in most of European Russia and the large parts of Siberia and central Asia. They embraced the original Finnish tribes along the Baltic, the old natives of the Volga, the Huns, possibly the original Bulgars, the Tartars, and various more or less nomadic "Turanian" or "Turcic" units in Siberia and the Turkestans. According to various indications they possibly included, also, the original Koreans,

and may have been related to the pre-Japanese populations of Japan.

This vast stock has never hitherto been segregated as a separate racial unit, yet it appears to necessitate such a separation. Its constituents can neither legitimately be classed as full whites, nor as full mongoloids. They are intermediary, but evidently not mixbloods merely. They may be conceived as later waves of evolving humanity, than those of the truer yellow-browns, advancing from Europe eastward during the late Paleolithic and early Neolithic times.[1]

This vast and loose stock has become greatly thinned out and admixed partly with whites, partly with mongols, until today in many parts, such as the Baltic States, Hungary and Bulgaria, in the interior of Russia, and in many parts of Siberia as well as in central Asia, it shows mere remnants or traces.

The probable relation of these four secondary large racial groups to the main stems or races, is shown in Figure 2.

DAUGHTER-RACES

Each of the three human stems or main races, and in a smaller measure also each of the main secondary groups, has in the course of time differentiated into a number of newer well-established racial units, the daughter-races.

The better established daughter-races of the *White* stem are, in brief: The Hamitic; the Semitic; the Mediterranean; the Alpine; and the Nordic. Besides these truer races there are several additional strains in this large stem, such as the Dinaric, East Baltic, Armenoid, Turcic, etc., but these as yet are not sufficiently well defined and deserve the term of *sub-races* or *types* rather than races. And in each of the larger groups there are a smaller or larger number of nationalistic or local groups that represent more or less advanced *nascent* types or races, races in the process of formation.

The main daughter-races of the *Yellow-Brown* stem are: The Mongolic; the Malay; and the American. There are also a number of subraces and of old mixture-types, such as

[1] See Hrdlička, A. The peopling of Asia, *Trans. Am. Philos. Soc.*, 60 : *525 et. seq*, 1921; 9180. The peopling of the earth, *ibid.*, *65*: 150 *et. seq.*,1926.

the palaeo-Asiatic or Americanoid, the Tungusic, the Aino, the Khmer, etc., in Asia, and the Eskimoan, the Maya-Toltecan, and the Lagoa Santa—Algonquian (or Uto-

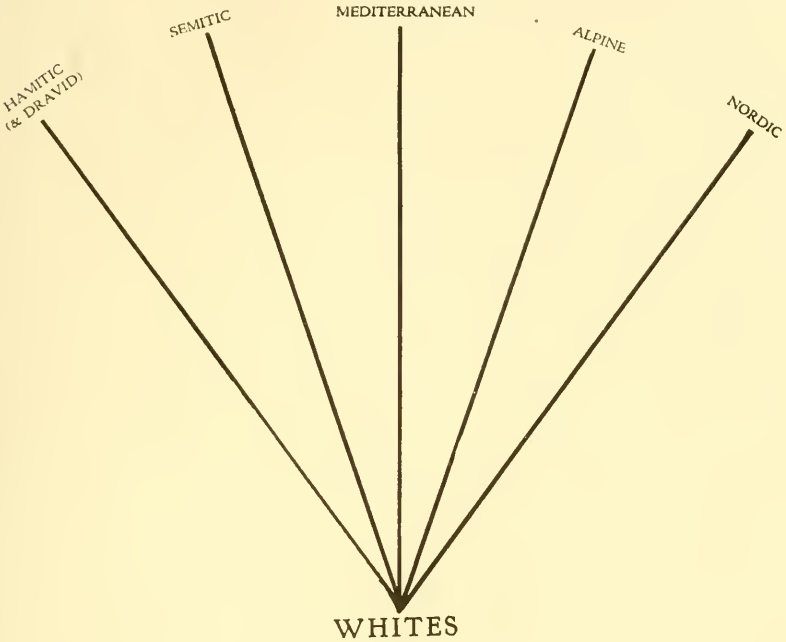

Fig. 3.

Aztecan), etc., in America; and there are important nationalistic types such as that of the Chinese, Japanese, etc. Much here remains to be cleared and defined through further studies.

The *Negro* stem occurs in two main races, the negroes proper, and the pygmies, and the latter are divided into three racial groups, namely the negrito, the negrillo, and the Bushmen-Hottentots.

An interesting question is which one of the two main subdivisions of the negroid stem is the parental one. As there are no indications of pygmies in the human ancestry, it would seem that these short peoples are secondary; on the other hand their marked subdivisions and the greater

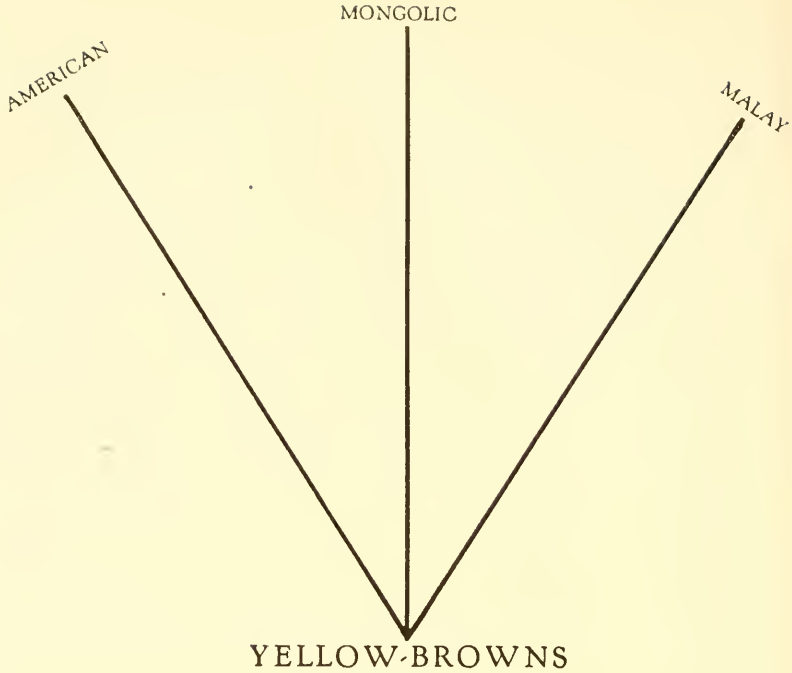
MONGOLIC
AMERICAN
MALAY
YELLOW-BROWNS

Fig. 4.

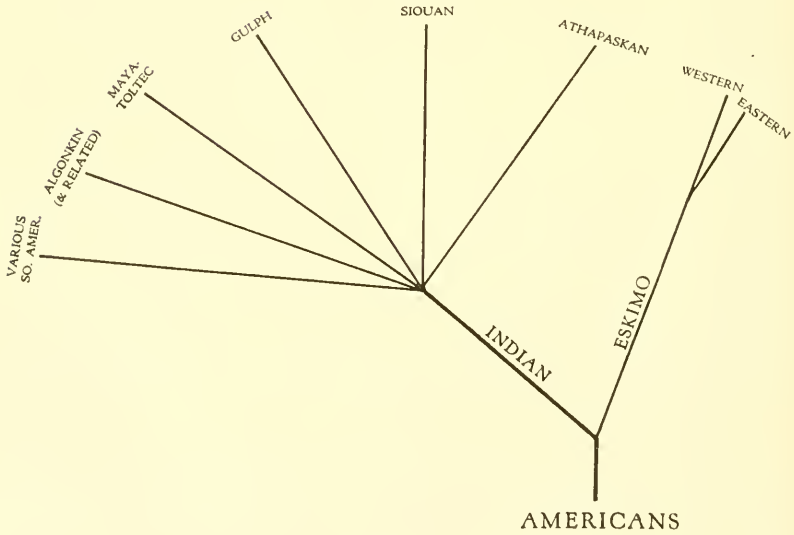
SIOUAN
GULPH
ATHAPASKAN
MAYA-TOLTEC
WESTERN
EASTERN
ALGONKIN (& RELATED)
VARIOUS SO. AMER.
INDIAN
ESKIMO
AMERICANS

Fig. 5.

homogeneity of the regular negroes point to a greater antiquity of the short strains. The probability is, however, that both are developments from an older stock of near

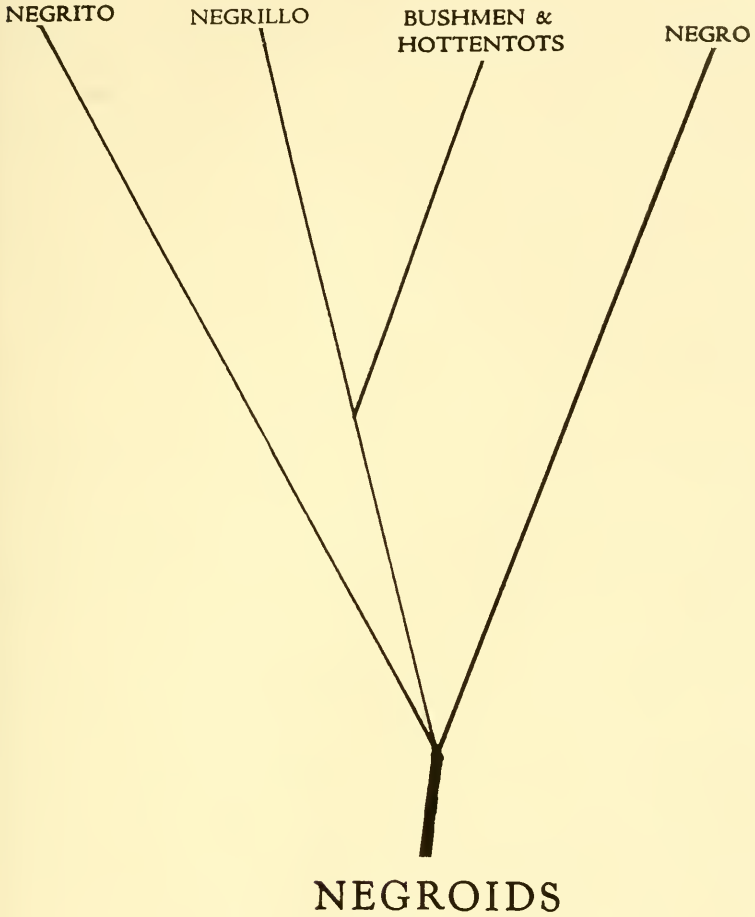

Fig. 6.

medium stature and less pronounced characteristics than either of these specializations.

There are several types distinguishable, but not well defined as yet, among the regular negro.

Concluding Remarks: The foregoing gives the gist of human classification. To go into further details would in this place

be unprofitable, and also more or less uncertain. There is a need of much further study in this field, and that by experts. The subraces and types and nascent racial entities must be determined scientificially country by country, which will take yet a long time to be accomplished. Within late years there was a hope that the agglutinin tests of the blood might be helpful, if not decisive, in racial classification, but that hope has in a large measure failed. Recently new and more thorough chemical tests of the blood (See *Am. J. Phys. Anthrop.*, 1927.) have been devised and may effect more in this direction. Though it must always be remembered that human races are variable and unstable units, much admixed, merging more or less with other racial groups, and without any true lines of demarcation, in blood or any other particular.

MIXTURE OF RACES

Human races without exception are freely miscible, which has always been one of the stronger arguments against their being true species. Human intermarriage has now been observed in all parts of the world, and, barring cases due to purely individual causes, there are no instances of sterility, weakness of the offspring, or eventual extinction of the mixed bloods.

A popular fallacy met with occasionally to this day in the more southern parts of the United States, is that the progeny of the white and the negro will not survive or breed beyond the quadroon or at most the octoroon. Actual observation has completely failed to sustain these opinions. It may be said unreservedly that, except where disease enters into the case, there is no known limit to the fecundity of the white-black progeny. And the same applies apparently to the mixbloods of any other two or more races.

Another widely held view outside of science is that the results of race mixture are generally bad. This view, also, is not sustainable by critical observation. It may be said, as a rule, that the results of a normal union of two healthy units of whatever races, followed by a wholesome care to the children, will result in a normal and healthy progeny. If such a union occurs between two mentally unequal races,

such as the white and black, the children are generally an improvement on the belated parent, though not equaling the more gifted one. But the case is not seldom complicated by prejudice, social ostracism, poverty, and other factors, which may act adversely on the progeny of such a union. In many cases affecting the whites and negroes in the United States, moreover, the union has been a clandestine one, between inferiors of both sides, and frequently aggravated by intoxication; the child is not desired, and whether at home or in an institution is brought up under unfavorable conditions. It is these social and disgenic agencies that frequently affect the negro-white of mixed blood and give him a complex of inferiority.

When the question of mixture of parts of the same main race, such as the White, is approached, it may be said most positively that science has never been able to detect any ill results, except again in individual instances and there through collateral, social and economic, and especially pathological conditions.

All the larger units of the white race are composites. The English have the blood of their neolithic ancestors, of the Bronze Age invaders, of the Mediterraneans, etc., brought in by the legions of Rome, of the western Germanic immigrants, of the Normans, of the Gallic and other French, and of all the later immigration. The Germans are a third Nordic, third Slav and third Alpine. The French are a mixture of Gauls, Alpines, Iberians, Mediterraneans in general, Franks, Brythons, Goths, Basques, etc. The Spanish have Iberian, Gallic, Suabian, Vandal, Moor and Basque blood. Even in Sweden and Norway there is plain evidence of more than one population. A wholesale racial (white) mixture has been going on for centuries in Europe and in many other parts of the world, above all and more recently in America, without any trace of damage. To look upon such mixtures as detrimental, in this or any other country, is scientifically unjustifiable. The biological indications, under normal conditions, are more in favor of than against such mixtures. And what is true in this respect of the whites applies equally to the yellow-browns and the blacks. One of the most mixed of the yellow-brown groups

are the Japanese, yet they are about the most virile people of the Far East.

Extensive and what may be called normal mixture between the negro and various elements of the white race (Egyptians, Arabs, etc.) has taken place in north Africa, from Abyssinia to Morocco and south of the Sahara. In none of these territories is there apparent any degeneration, physical or mental, as a result of the mixture. Mentally the progeny shows a general improvement on the negro, though it does not evidently reach the standard of those who have admixed with him.

"EQUALITY" OF RACES

The sum of the average characters, physical, physiological, and psychological, of a given group of people, whether a family, a nation, or a race, forms the complex standard or general quality of the group. They involve the normal appearance, behavior, and all other manifestations of the group.

These standards differ from race to race, and between some races they are very material. Their study has occupied anthropology from its very beginnings, yet they are not yet clearly and completely determined in any group. Which is especially true of the more subtile differences that are difficult of exact evaluation, the foremost among which are those of mentality.

Due to these defects in our knowledge, it is impossible as yet to exactly weigh the qualities of races and compare them with anything approaching precision. And it is due to this impossibility that wide differences of opinion as to the equivalence of the races exist and can not easily be settled.

The general and most deeply ingrained view is that races are no more equal in mentality than they are in physique. This opinion is partly due to egoism and ignorance, partly to more or less subconscious feelings due to accumulated bias and experiences, and only slightly and exceptionally to actual thorough scientific investigation. Aside from the universal "group spirit" of egoism, the matter is greatly complicated by the social, language, religious and habit differences, through economic factors, and by the universal

distrust of the less known. Nevertheless an "intuitive" feeling of inferiority or superiority, subjective and objective, if generalized and based on a prolonged direct experience of one group with another, deserves careful attention.

The scientific study of the relative values of races has two separate resources. The first is the circumstantial and indirect observations, the second that of direct evidence and examination.

The circumstantial and indirect evidence of a race is that of its origin and antiquity; of its environmental history; of its cultural past and present; and of its relative position in regard to and esteem by other races. The direct evidence is that of the demography, pathology, character, and potentialities of the race, as shown under trained and unbiased observation; while the examinations are those of modern anthropology and psychology.

The indirect evidence leads to suggestive inductions, some of which are already known to be facts.

Races that have been subjected for a long time in their past to malarial or other infections and survive, must have acquired more or less of immunity against these infections which is lacking in other races—and such Medicine has found to be the case. Such races have therefore gained a certain vital advantage, but this only at the cost of prolonged suffering which was adverse to intellectual advance. It is an old truism that a malarial region breeds few talents; and the same may be applied to all chronic blood infections. It could not be expected therefore that two human groups, one living in a wholesome and the other in a malarial region could progress equally and retain the same standards. The affected group would become belated.

The development of intellectual differences would similarly be favored by non-pathological factors which, on one side, would lastingly be of stimulative or favorable nature, while in the other case the stimulation would be largely lacking, to which might be joined unfavorable affects of various nature, such as the development of repressive ideas and habits (superstitions, slavery, cannibalism, etc.).

All these conditions have been realized, particularly as between the races of the northern temperate zone and those

of the tropics; and the results could not possibly be equality, physical, physiological, or intellectual. In broad lines it is legitimate therefore to speak of "advanced" and "belated" human groups or races. And the cultural and other indirect evidence sustains this assumption.

As to direct scientific determination of the differences between races, what has thus far been accomplished is in the physical line. Comparative racial physiology, chemistry and psychology are only in their beginnings. Of the physical studies the most relevant in this connection are those of the brain and the skull, or the head in the living. These researches, too, are far from finished; but enough has already been done for some valid conclusions. These are, in broad lines once more, that within the same stem what differences there are are essentially individual; but that between the moderate zone peoples and those of the tropics, or, more particularly, between the whites and the blacks, there are differences that sustain the conclusions arrived at through other considerations.

The point is raised, now and then, that what differences there are between, for instance, the white and the negro, are differences in accomplishments and education, rather than those of potentialities. Should this mean that the brain of the belated group is capable of development, the proposition could readily be assented to for there is no evidence or probability to the contrary. But there appears to be no possibility of establishing the thesis that the brains of the belated human groups, such as the negro, the negrito, the Bushmen-Hottentot, the Melanesians, the Australo-Tasmanians, the Veddahs, the Fuegians, is of equal potentiality with those of the Old American, the English, Scotch, Irish, French, Germans, etc., and that the only differences are in training, enlightenment and opportunity.

A serious question with which anthropology is frequently confronted, is: What are the indications as to the future of the belated groups? This question involves much more than physical anthropology, more even than anthropology in general. It involves pathology, economics, competition, adaptation. The answers are to be seen wherever the advanced come into direct contact with the really belated.

RACE DEGENERATION

Races do not live forever. Just as the whole so the parts of humankind change. They differentiate into newer, or daughter-races; they end through exhaustion by wars, famine, disease, the remnant merging with some stronger group; or they assimilate so much of other blood as to be changed into a new unit; or they degenerate mentally and sink into long dormant states in which they may perish, or from which they may revive for a further course of active existence.

In human history, "race" after "race" has risen to power and cultural prominence, only sooner or later to go down before some stronger group. This up-linger-and-down phenomenon has in fact up to the recent time been the invariable rule. Its principal cause has often been believed to be "race degeneracy."

If mentality be excluded, no such degeneracy in any instance can be detected by anthropologists. The physique of the purer remnants of the Old Egyptians, Syrians, Arabs, Persians, Greeks, Romans, Gauls, Mongols and Mayas, is seen on direct examination into the matter to be as good as it ever was. There has been no perceptible physical degeneracy in any of these cases. Even the mixtures left by these peoples fail as a rule to show degeneracy.

This unexpected realization leads to the search for somatic degeneracy in man elsewhere, which leads to interesting results. Physical deterioration appears to be rare and limited to localized groups. It seems to affect mainly the stature and bulk of the body, occasionally also the strength.

The foremost examples of stature and bulk diminution, though without relative weakening, are probably the various pygmy groups, particularly the negrillo and the negrito. As no dwarfs are known in human ancestry the pygmy condition may be looked upon as secondary. But, while its origin may have lain in disgenic influences, the result, that is the pygmy status of the body, may perhaps be conceived more properly as adaptation or specialization, than degeneration. There are many analogies to this in the animal kingdom. And the same principle applies probably

to other dwarf or shortened-stature groups, such as those of America (Mexico, Venezuela, Brazil). For outside of their smaller stature and mass these groups are quite fecund, and able to cope with their special environments.

Nevertheless deterioration proper may occasionally be observed, as for example among the native populations of Java, in the southern Bushmen and Hottentots, in some of the Alpine and Appalachian populations in Europe and America, in parts of China and especially of central and southern India, among some of the American Indian tribes in transitional stage, such as the Osage, southern Ute, and others and among some at least of the negro communities in America.

In all these instances the deterioration is seen not to be "racial" or general, but to apply only to such groups and families as have become subject to unfavorable, physically and otherwise degrading conditions.

Race deterioration is therefore a conception that is not sustained by science. Deterioration, where present, is seen to be a phenomenon of locality and of conditions, but not of a race. It may extend to a geographic group, a social class, a tribe perhaps, but never as far as discoverable now, to a whole race.

A temporary deterioration of human groups, as that of individuals, is moreover, mostly "curable," and is often cured, on the one hand, through natural elimination of those affected most seriously, and, on the other, through restitution and new adaptations of the remainder. The beneficial *vis mediatrix naturae* acts evidently on groups as it does on individuals, and where deterioration does not surpass the limit of the curable it slowly restores and strengthens, until a "normal" status is reached once more, adapted to and mastering the particular place and conditions.

One of the peoples in whom such restitution under more favorable conditions may best be studied, and that in various parts of the world, are the Jews.

A physical degeneration of a race is therefore a notion for which it is difficult to find a substantial foundation. If traced closely the supposed degeneracy resolves itself generally into mental affects and states, which in cases may

amount, without physical concomitants, to actual generalized deterioration.

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PART III. MAN AS A PHYSIOLOGICAL UNIT

Chapter VIII

THE VITAL UNITS CALLED CELLS

E. V. Cowdry

THE human body is made up of a mass of living units, which are known as *cells*. The term, cell, is a misnomer and a relic of the past, yet it is sanctioned by usage. Vital units are not empty spaces, as the word suggests, but filled with a fluid substance called *protoplasm*, which is the basis of all vital activity. Recognition of their existence dates back almost one hundred years. The *cell theory* introduced by Schleiden and Schwann (1838), according to which all living things are built up of cells, has played a fundamental rôle in biology and medicine comparable in importance only to the conception of the existence of organic evolution.

SIZE AND SHAPE OF CELLS

In size, the cells of our bodies are very small. Among the most minute are the white blood cells, or leucocytes, about $\frac{1}{120}$ of an inch in diameter and altogether too tiny to be seen with the naked eye. Human eggs are the largest ($\frac{1}{70}$ inch) and are just visible when artificially stained. Since they are so minute the number of these vital units which make up the body of a man weighing about 155 pounds is legion. It has been calculated (Donaldson) that there are about 26,500,000,000,000.

The shape of cells is highly variable. We can study their form in several ways. One method is to examine them with the microscope in the still living state. A red blood cell which carries the respiratory pigment called hemoglobin, and a leucocyte, viewed in this way, are represented diagrammatically in Figure 1 (A and B). The former is rather lens shaped but looks circular. Within the leucocyte may be seen an irregular lobated structure, known as the nucleus, which will be referred to again. Some cells are much elongated, like the muscle cell (D), and the nerve

cell (E). If the conductile process of the latter were likewise magnified 700 times it would extend downward beyond the limits of the page, a distance of 1568 feet.

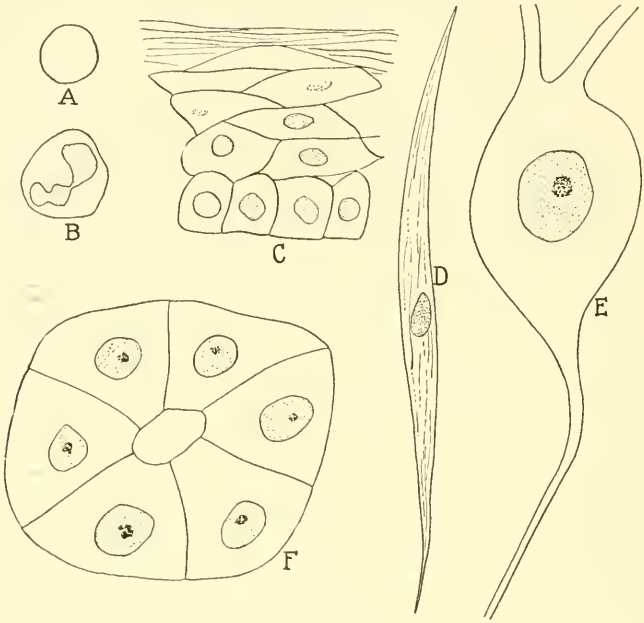

FIG. 1. Diagrams to illustrate the shape of different kinds of cells.
A. Red blood corpuscle. B. Leucocyte. C. Flattened cells of skin. D. Muscle cell. E. Nerve cell. F. Group of pancreatic cells. (Magnified 700 times.)

Another method is to preserve the cells, cut them into very thin slices, or sections, and stain them. Such sections can be made 1/25,000 inch in thickness. A section through the skin is illustrated at C in Figure 1. It shows how the cells become flattened as the surface is approached. Diagram F illustrates the grouping of secreting cells in the pancreas.

CELLS BEHAVE LIKE INDIVIDUALS IN A LARGE COMMUNITY

Despite their microscopic dimensions, the cells of the body have a certain measure of independence like individuals in a large community, a comparison originally made by Virchow (1858). While they are members of this community they grow, reproduce their kind, die and are destroyed by

their neighbors or by the fluids surrounding them. Some by virtue of their occupations have a shorter life than others. There is reason to believe that the life of leucocytes in the blood stream is limited to a few days, perhaps even to a few hours. The average age of red blood cells is placed at between fifteen and forty days, while nerve cells usually remain alive during the whole life of the individual.

During the life of any man or woman a continual replacement of dead cells by living cells is provided for. The rate of this replacement is naturally conditioned by the length of life of the cells in question. Since, as we have said, the nerve cells may remain functionally active as long as the individual lives no arrangement is normally necessary for this replacement, which explains the lasting injury resulting from the death of nerve cells in various forms of paralysis and in organic diseases of the nervous system. The expectation of life of blood cells being short they are replaced relatively quickly by the production of new cells, chiefly in the bone marrow and lymph glands.

But one of the most interesting reservoirs of new life (or rather of more life) in the body is found in the deeper layers of the epidermis. Here the cells multiply rapidly and new cells are supplied from within to take the place of the dying and dead cells on the surface which are continually being cast off. It is a true saying that "while we are in life we are in death" because this protective investment of dead cells is held like a shield between the living delicate tissues beneath and the environment outside. It is a kind of shock absorber.

This insulation, however, if it were complete, would make us totally inert and unresponsive. We may regard the cells of our sense organs as sentinals looking out through specially constructed windows in our skin so that they may perceive what occurs without, and signal the results to the entire body through the activity of certain nerve cells, devoted to conduction, which group themselves in series like the relay stations in a telegraph system. The analogy is a close one, for, with the passage of each nervous impulse, slight electrical variations take place. Happily for our peace of mind the receptive cells are only attuned to certain changes in our

environment. Sounds occur which we do not hear, and light waves, notably the ultraviolet, strike us which we cannot see, yet influence us profoundly.

The cells of our lungs are adapted to the taking-up of oxygen and the giving-off of carbon dioxide. The cells of the alimentary tract take in foods and those of the kidney throw out waste products. Muscle cells enable us to move and work. As we have intimated, some cells are stationary and others highly motile. Sperms in search of eggs to fertilize may travel relatively long distances. Leucocytes in the blood stream are washed hither and thither but may actively migrate through the vessel walls to attack invading bacteria and other harmful agencies. They may be likened to the policemen; the fat cells (which store potential energy), to the bankers; the muscle cells, to the laborers; the gland cells to the manufacturers; and so on, while the nerve cells form an hereditary ruling class.

Cells, like individuals, through their special temperamental activities affect their surroundings. In the body they are bathed in fluids the character of which they modify. These fluids are comparable to the atmosphere, often polluted, in which we live. Important physiological changes take place in this watery environment so that the activity of the body cannot be regarded merely as the unrelated sum total of those of the component cells. An element of integration is added through which elements, themselves different, by association may produce something wholly new, the character of which could not have been forseen, just as oxygen and hydrogen, two gases, on combination make a different substance, water. The medium about the cells may not remain fluid, but may be converted by the cells into various substances, among which is bone, without which we would be spineless creatures indeed. Cells of like character are grouped into what we call *tissues*, such as cartilage. The tissues, in turn, are often combined to form *organs*, as, for example, the thyroid gland, which on enlargement produces a goiter.

The behavior of cells is dependent upon their ancestry, their environment (or training) and their age. Thus the blood-forming organs produce blood cells and the deeper

layers of the epidermis, skin cells, not muscle cells or sex cells. But to explain all the differences existing between fully developed cells on the basis of what is known of their heredity is difficult because all of them, except the sex cells, are known to inherit the same chromosome complex. Here, as in the case of individuals, it is customary to fall back upon the environment to which the cells must become adapted if they are to survive. Young cells are more adaptable than older ones and are immune to a lot of degenerative changes by which the older ones are afflicted; they are also better behaved; fewer of them become criminals.

It is a kingdom rather than a democracy because the nerve cells, though dependent for their position and all their worldly goods upon the others, are born to this station, not elected to it. They also control. The arrangement is in many respects almost utopian.

The division of labor leaves nothing to be desired. There is always an excess of willing hands (or cells) for every basic industry, which we call the "physiological reserve." This is exemplified by the observation that we can live with one lung, one kidney or a third of our liver substance. Yet normally there is no unemployment. The labor is equally spread among the cells in each organ. To live, the cells must work; otherwise like individuals they atrophy from disuse and die as, for example, when labor is denied them by the ruling class of nerve cells. When the task becomes harder they increase in size and power, again like individuals. But this happy state of affairs does not last forever. Inevitably the kingdoms rise and wane. Death for the individual, made up of the kingdom of cells, is a normal process.

Internal disintegration may come in different ways which we cannot discuss here. Reference may be made, however, to the fact that the cells do not always attend to their duties as they should do. When the kingdom has attained the height of its efficiency and is on the downward path (middle life and old age) some of the cells show an alarming tendency to shake off the community control which has been molded by nature during millions of years, as laws have been formulated by the experience of the race.

Like criminals (see Chapter xv) they become antisocial. They grow unrestrictedly, invade the territory belonging to the other cells, pilfer their food, which they can ill afford to lose, and so completely disrupt established conditions that community life is no longer possible. But, again like criminals, the cells do not embark upon this mad career merely out of perversity. Beforehand they are injured in some way which we do not at all understand. They are the victims of some intangible kind of misfortune. They have been designated "anarchists" by tumor specialists. As a result of their activity one in every seven of us dies of cancer (see Chap. xviii).

It is a curious fact that although death in one way or another is thus inevitable for the individual, there is reason to suppose that it is apparently not so for special groups of cells removed from the body. Carrel has found that when cells known as fibroblasts are taken from the body and cultivated in appropriate media, which are changed at stated intervals, they will live as far as we can tell at present forever.

MICROSCOPIC STRUCTURE OF CELLS

The properties of living cells are so challenging that it is not surprising that many attempts have been made to ascertain the structural basis of life. The problem is obviously a difficult one. Thus far a beginning has hardly been made, although it has been possible to recognize certain elements within the cell.

A gland cell of the stomach, for example, when magnified about 4000 times, is represented in Figure 2. It possesses a very flexible and delicate *cell membrane* by which is enclosed a mass of watery material. In it may always be seen a large oval or spherical structure, the *nucleus*, which we mentioned at the beginning of the chapter. It was discovered by the Englishman, Robert Brown, in 1831. The fluid contents of the cell, other than the nucleus, are known as the *cytoplasm*. In addition, one may observe various granules in this case consisting of *mucus*, or slime, which is about to be poured into the cavity of the stomach.

All other cells present the same structural pattern in so far that a cell wall enclosing liquid material may be distinguished. The nucleus and the mitochondria are likewise

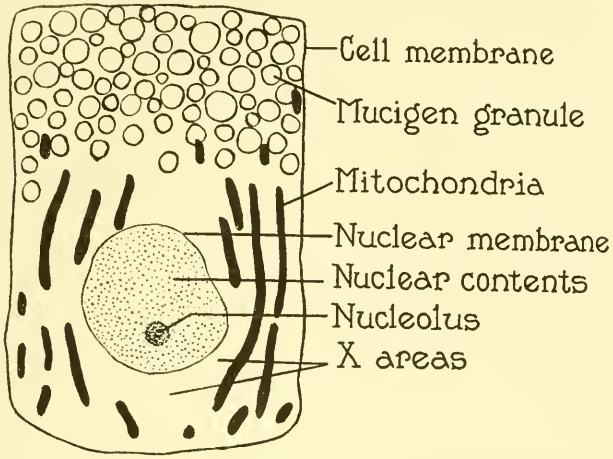

FIG. 2. Diagram of mucus-secreting cell of stomach. (Magnified about 1500 times.)

invariably present. Various special components are found, in certain kinds of cells. Among these may be mentioned secretion in gland cells, droplets of fat, contractile fibrils in muscle cells, and pigment in the cells of the eye and often in those of the skin.

THE CELL IS BUILT LIKE AN ENGINE

We can liken the cell to an engine although it is in every respect a more efficient mechanism. Despite its small size it is able to bring about chemical and physical changes, the majority of which it is impossible to repeat outside the body even with the aid of the most delicate and complicated apparatus.

The cell takes in crude materials and makes them into finished products (e.g. adrenalin) which influence other industries or tissues, themselves composed of cells. As a great engine is organized in space so is the cell. Gland cells, for instance, devote a special part of their circumference to the reception of substances from the blood stream, just as

an engine has a mechanism for the intake of materials to be used in it. Gland cells discharge from their opposite extremities the products which they make (see Fig. 2). Engines have attachments for the utilization of the power generated. This polar organization of the cell, providing for intake and output and other attributes which it is unnecessary to mention here, is referred to as *polarity*.

The motive power for the cell and the engine is derived from the combustion, or burning, of material coming from without. Both of them are transformers, for energy is not "created" anywhere in the known universe, it is merely changed from one form to another. Sunlight acting upon the green coloring matter of plants causes in some mysterious way the liberation of oxygen and the formation of compounds high in carbon and hydrogen. These substances are the fuel. They are present in abundance in food and wood, coal and oil. Combustion is brought about by the addition of oxygen from the air. The energy developed through this process of oxidation is much more economically used in the cell than in the engine, for in the latter a large part of it is lost by heat radiation. An impulse passing along a nerve fiber generates heat, but only to about 1/1,000,000 of a degree.

Waste is discharged from the cells into the surrounding body fluids (see Chap. XI) and is finally eliminated through the lungs, kidneys, digestive tract and skin. In the engine it is carried away in smoke and disposed of as ashes. If such products accumulate instead of being removed in an orderly way both machines become clogged and cease to function.

Electrical forces are harnessed in the cell and by the engine. Without them life would be impossible. In cells they are usually barely detectable, but in rare instances these vital units are grouped together to form organs which are highly charged and are capable of giving a dangerous electrical shock, or when appropriately connected up, to ring a bell vigorously. This can be done by the electrical organs of some fishes. Though most cells are rhythmical or periodic in their action they are, as we have intimated, never electrically at rest. By rest is here meant complete

inactivity, which would be death. In the same way an engine, or any mechanical contrivance, must be used or it will deteriorate and become unworkable.

Cells compare favorably with engines, especially chemical ones, in still another respect, namely, the much greater speed at which they perform their duties. Like so many things connected with the cell we understand this quality but imperfectly. It is known, however, that the rate of chemical reactions is hastened by peculiar substances termed *enzymes*, which are of many kinds and are widely distributed in living matter. While they accelerate chemical changes they have the property of maintaining their integrity so that they are not lost in the process, but may play their part again and again. Catalysts are widely used in industry.

Obviously some internal mechanism for the separation and integration of chemical changes is essential for the cell and the engine. If the contents of a cell are stirred up and mixed together it dies, just as the efficiency of any engine would be destroyed if all parts of it were thrown together into one vast heap. Although such organization undoubtedly exists in the cell, how it is brought about in a space so small that we cannot see it with the naked eye is a mystery.

A certain amount of localization and separation of chemical reactions is, however, made possible by the elements which are microscopically visible in the cell. Some results of recent investigations point to the conclusion that chemical and physical changes of great variety are prone to occur at surfaces of separation between materials of different character. Referring back to Figure 2, it will be seen that we have to consider in this connection: (1) the surface of the cell itself; (2) the surface of the mitochondria; and (3) the surface of the nucleus. The contents of the nucleus are, in addition, shut off from the surrounding fluid cytoplasm in which it is embedded. It is within the nucleus that the physical basis of inheritance is mainly concentrated. This feature of segregation and protection is very important in the preservation, without continual modification, of hereditary characteristics (see Chap. 11). The nucleus is the most acquisitive living element known to us. It "hoards like a raven." This will be briefly considered later.

But this measure of organization is very inadequate to explain even in a halting way the capability of the cell to manufacture materials and to live. It will be noted that comparatively large stretches of the cytoplasm occur between the components which we have enumerated in which no trace of structure can be made out, notwithstanding the fact that great improvements have recently been made in our microscopes. These parts are marked "x" in Figure 2 and constitute what is known as the *ground substance.* It is made up largely of materials in the colloidal, or glue-like, state. They are of gelatinous consistency and hold a great deal of water. Indeed living material contains about 85 per cent of water.

LIMITS OF MICROSCOPIC VISIBILITY

With ordinary white light and direct illumination we can distinguish particles about 1/250,000 of an inch in diameter provided that they are colored; or that the light rays when passing through them are slightly deflected, in other words, that they exhibit a different refractive index from the *ground substance* of the cell in which they are observed. We can push back the limits of visibility a little further (to approximately 1/11,000,000 of an inch) by employing an ultramicroscope. The principle of this piece of apparatus is that the light is so arranged that it strikes the cell at an angle to the direction of observation. We recall how particles of dust, otherwise invisible, flash out in the presence of a beam of light entering a darkened room.

The ultramicroscope often permits us to detect in these "x" areas the reflections of many extremely tiny bodies which often dance about actively, like little twinkling stars, in the field of vision. But there remain regions of the ground substance in which even these particles are not seen. Methods of ultraviolet photography, now in their infancy, may eventually help us, but it seems unlikely. Thus, the ground substance in which these various structural differentiations are formed is quite beyond our ken. Basically it must be structurally organized, also, but we have only nebulous and ill-conceived theories concerning it which it is unprofitable

to mention here. This much, however, we do know: that the cell itself is a complete and indivisible unit. Attempts to distinguish living and non-living elements in it are futile and irrational.

MULTICELLULAR AND UNICELLULAR ORGANISMS CONTRASTED

Thus far we have stressed one of the principal tenets of the cell theory, which is indeed an established fact, namely, that the body is a sort of kingdom of cellular units. This applies not only to man but to almost all living animals and plants. The word *almost* is inserted because forms of life exist which are themselves single cells, not combinations of cells. We at once think of the bacteria and of certain unicellular animals, the Protozoa. As an example of the latter, the parasite of malaria is cited. There is a distinct difference between the life of a unicellular organism and a cell inhabiting our own body.

Perhaps this may be made clear by reference to Figure 3. A unicellular organism like an ameba (A) has to adjust itself only in respect to its own environment (E). A cell of the intestine (I), on the other hand, must shape its behavior not only in response to the character of the contents of the intestine (E) but also in respect to neighboring cells (C) and the fluids of the body (F). In the case of epithelial cells of the skin the contact with adjacent cells is often not merely the close approximation of like surfaces. There may be continuity of living substance across specially developed bridges which pass from one cell to another. Cellular activity may also be governed by nerve fibers terminating on their surfaces so that stimuli originating in other parts of the body impinge upon them. The association with the body fluids is a complex matter involving the transport of substances of many kinds to and from the cell. It is interesting to note that we have among these the so-called *chemical messengers*, or hormones, produced by the ductless glands, and probably by other cells not recognized as glandular in nature. Through their action one cell may influence another far removed from it. A free living protozoan or a bacterium is, therefore, not strictly homologous

to a cell existing in a multicellular aggregate. It has more individuality and is less bound down by the conventions under which it lives.

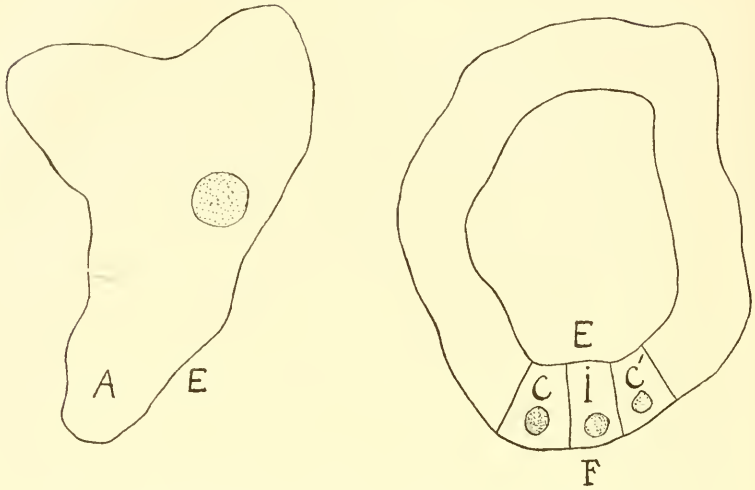

FIG. 3. Comparison of ameba and cell of intestine.

An ameba (A) must adjust itself to its environment (E). A cell of intestine (I) must react to its environment (E), neighboring cells (C and C′) and fluids of body (F).

ALL CELLS ARE SAID TO DEVELOP FROM PRE-EXISTING CELLS

Another postulate of the cell theory is that all cells originate, or develop, only from preexisting cells. No exception to this generalization has ever been observed. But its unqualified acceptance involves the further assumption that life commenced at some very remote epoch when the primordial cell was first built up from presumably lifeless components and that cells do not arise in this way at the present time. As Wilson has clearly said life "is a *continuum*, a never ending stream of protoplasm in the form of cells, maintained by assimilation, growth and division. The individual is but a passing eddy in the flow which vanishes and leaves no trace, while the general stream of life goes forward." Though this is what is always observed, it is conceivable that exceptions, quite unsuspected, may in

rare cases occur. If it is literally true that life once "evolved" and that the process of creation has never been repeated the most primitive cells now known to us or their descendants must have persisted without evolutionary change for a very long time. This would mean that they constitute a self-perpetuating reservoir of living forms arising from others like them which is not replenished by the creation of new forms from inanimate material.

It is interesting to note that certain disease-provoking agents exist which are not cellular in structure. Some investigators believe them to be living, while others think them to be dead. In this category are placed the *iruses* (literally poisons) of chicken pox, rabies, common warts and certain other infective diseases. They are too small to be seen, yet like living cells they are capable of unlimited multiplication, or more correctly, of increase in amount, if each ultimate particle is not an individual unit susceptible of division to form two others like it. The viruses have never thus far been found to develop *de novo*, that is to say in the absence of preexisting viruses. They can only increase in intimate association with living cells, from which they may have arisen in the first place. To determine just what they really are is one of the most captivating problems in cytology.

CELLULAR BASIS OF INHERITANCE

But it is in cell multiplication, and in the associated phenomena of inheritance, that we have one of our greatest riddles. It would seem a simple matter to ascertain why a cell divides to form two others like it, but it is not so. Some of the changes that occur we can observe though we cannot begin to explain them. They are not always alike and there is still some difference of opinion in regard to details but the general process is represented very diagramatically in Figure 4.

A. A cell just before division is represented. In it the distinctive nuclear material, *chromatin*, is illustrated distributed in the space within the nuclear membrane. Just above the nucleus two granules may be seen, usually referred

to together as a *diplosome*. The cytoplasmic material tends to be radially arranged about the diplosome which must be a dynamic center of some kind.

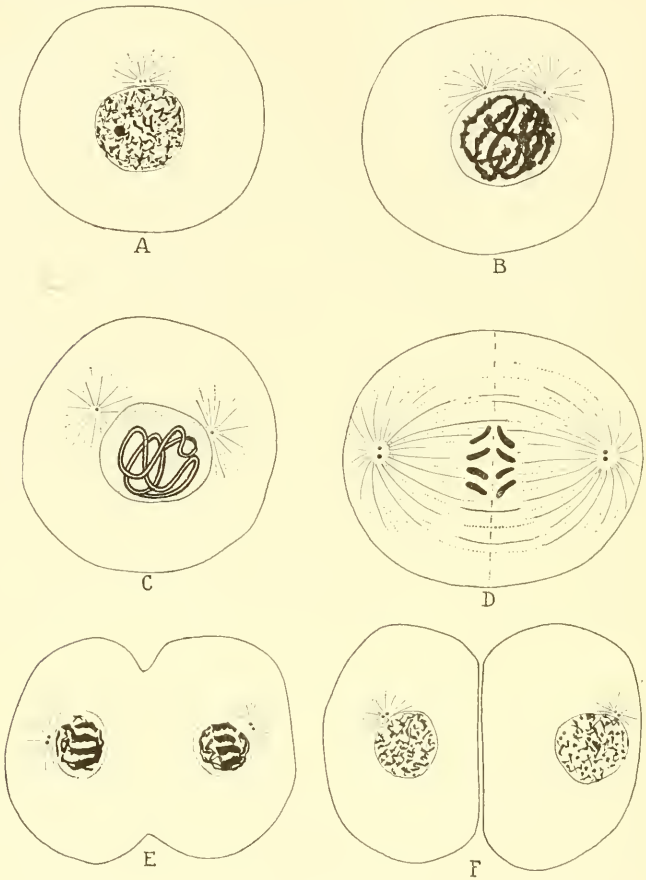

FIG. 4. Schematic representation of cell division.

A. Resting cell with diplosome just above nucleus. B. Separation of two centrosomes of diplosome. Spireme formation within nucleus. C. Longitudinal division of spireme. D. Chromosomes formed from each half of spireme arranged on opposite sides of equator. E. Groups of chromosomes migrate apart and lose their distinct outlines. Groove appears about equator of cell. F. Groove deepens and pinches originally single cell into two.

B. The first change consists of a concentration of the chromatic substance into a long and tortuous thread or

spireme. At the same time the diplosome divides giving rise to two centrosomes which separate and migrate in opposite directions.

C. The spireme splits longitudinally throughout its length. This is important because, if the hereditary determinants occupy a definite linear arrangement in the substance of the spireme, as they appear to do, it provides for their qualitatively equal separation into two parts.

D. The double spireme now becomes segmented into a series of pairs of rod-like bodies called *chromosomes.* The nuclear membrane disappears; the centrosomes move further apart. The chromosomes become disposed in such a way that those formed from each half of the spireme are placed on opposite sides of a plane known as the equator of the cell and represented by a dotted line.

E. The groups of chromosomes separate and then fuse together losing their discrete outlines. A circular groove appears around the equator of the cell and gradually deepens.

F. Finally the masses formed from the chromosomes become enclosed in nuclear membranes and the groove pinches the originally single cell into two cells which are qualitatively similar as far as their nuclear components are concerned.

DETERMINATION OF SEX

A fundamental difference has been discovered in the chromosomes of male and female sex cells. The former originally contain one X, or sex, chromosome which is often larger than the others and easily identified; while the latter possess two of them. As the sperms and eggs mature the number of chromosomes in each is reduced by one half, because they are later to combine to produce tissue cells with the whole number. This means that half of the males contain an X chromosome and that the other half do not, further, that each and every female has now one, in place of the original two. On fertilization there are two possibilities expressed by the following equations.

1. Egg X + Sperm X = individual 2X, a female
2. Egg X + Sperm = individual 1X, a male

The first is that the egg is fertilized by a sperm carrying one x chromosome so that an individual results which has two x chromosomes and is a female. The second is that the egg is fertilized by a sperm with no x chromosome, so that the resulting individual possesses only the one x chromosome contained in the egg and is therefore a male.

The determination of sex is, however, not so simple as it appears to be from these equations. Many factors enter in to modify the process which we do not understand. Some of them may be environmental and nutritional. Gradations between maleness and femaleness occur and some individuals may be both, that is hermaphrodites. Though the chromosomes may contain the physical basis of heredity we are profoundly ignorant as to what it actually is. Modern chemistry does not enlighten us on this point. Inheritance of some characters through the cytoplasm of the egg is a possibility that has been much discussed.

THE SCIENCE OF CYTOLOGY

The science which deals with cells is called appropriately *cytology*. The cytologist is concerned with the smallest visible things, the astronomer with the largest. Yet in a sense this science stands at the head of the list because it is a kind of superstructure built upon the other sciences, which are said to be more fundamental. The cytologist must avail himself of advances in the more easily studied fields of physics and chemistry, but in doing so he has to be very cautious because there is always the question as to how far discoveries in these sciences may be applied in the interpretation of vital processes occurring largely out of his reach in living cells. But the reverse does not hold; the physicist and the chemist may, and often do, forge right ahead in their researches without taking into consideration in the least the activities of *living* matter. It is almost invariably *dead* material, the reactions of which are more definitely predictable, to which they give exclusive attention.

Cytology is also the meeting place or the center of integration of related sciences. The biologist and the bacteriologist, the physiologist and the pathologist all contribute material of the utmost importance to our knowledge of cells. Evidently

the cytologist must be broadminded and friendly cooperation is essential for his success. He is obliged to invoke assistance on all sides. Through experience he usually acquires a profound respect for the capabilities of these vital units and an appreciation of the saying that "Nature moves in mysterious ways her wonders to perform." He is distrustful of the simple cut and dried explanations sometimes offered by his colleagues in other branches of science. It is a curious paradox that those investigating vital phenomena, faced as they always are by the unknown and unpredictable, are much less ready to accept blindly the existence of supernatural deities or controlling powers than are the astronomers, physicists and mathematicians. When committees are appointed to report on the relation of science and religion it is almost invariably workers in the exact sciences who take the lead in assuring the laity that the two lines of thought and action are fully compatible and reconcilable.

For those who would understand, even in a halting way, what life is, enough has perhaps been said to indicate the interest which attaches to these elementary vital units which are the highly adaptable building stones of the bodies of all plants and animals. To the practical minded it may be worth while to cite a few examples of how profoundly the study of cytology has influenced human welfare.

Of all the cells of the body the most easily examined are those of the blood. Reference was made at the beginning of this chapter to the white blood cells, or leucocytes. A few minutes devoted to their study is often sufficient to return a definite verdict as to whether an operation for appendicitis should be undertaken. Similarly observation of the red blood cells gives information which helps to tell whether a patient is suffering from a simple secondary anemia or from the dreaded disease known as pernicious anemia, which latter is now happily greatly improved by the administration of liver extract. When a tumor is discovered and the surgeon while operating comes to suspect that it may be a cancer, all he has to do is to arrange for the cytological examination of a small fragment. In a few minutes, while the patient remains under anesthesia, he is told with considerable accuracy, from the appearance

of the cells, whether the overgrowth is benign or malignant. In the latter case he is dealing with a cancer and he must remove in addition to the mass itself a large amount of the surrounding tissue to prevent recurrences if at all possible. Cytological studies on certain parts of the pancreas, termed the islands of Langerhans, in human diabetes and particularly in the same disease experimentally produced in animals led directly to the recent discovery of insulin, a substance which has given a new lease of life and usefulness to thousands of sufferers whose future otherwise would have been hopeless. In fact nothing further need be said in favor of well-regulated animal experimentation. Persons who really desire to influence human reactions for the better both in health and disease will readily understand how important it is not to study the body as a whole vaguely, but rather to base the investigations upon the behavior of the constituent vital units of which the body is built, in other words to get down to fundamentals.

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Chapter IX

THE RELATION OF CELLS TO ONE ANOTHER

Alexis Carrel

BIOLOGY deals with problems of a far more complex nature than those of any other natural science. The solution of some of these problems is not yet in sight. As their subject matter lies on difficult and dangerous grounds at the frontier of science and philosophy, it cannot easily be brought into the experimental field. Such is the question of the manifoldness and the unity of the organism. We know that every human being is composed of billions of cells aggregated into tissues and organs, and that each cell is constituted of an immense number of smaller elements. As the number of permutations possible between the minute components of the cells and between the cells themselves is practically infinite, every individual differs from any other individual who has ever lived, and is an unique event in nature. In spite of his extreme complexity, the human individual is an harmonious whole. His specific characteristics come from the enormous development of the cerebral system and the appearance of the mind. Memory, conscience, and personality are the ultimate expressions of the highest organization that a cell community has ever evolved. It is through the association of myriads upon myriads of nervous cells that the most prodigious form of energy existing in the world manifests itself.

The processes which bring about and maintain the wholeness of the organism seem to be purposeful. This characteristic is apparent, not only in the formation of the body from the ovum, but also in the regenerative mechanisms which cause a lost part of an organ to grow again or a wound to heal. It is also present in the processes which reestablish the equilibrium of the body after it has been disturbed. These adaptive mechanisms are numerous. For instance, if one kidney is removed, the other enlarges. When the axis of a limb is modified by the defective repair of a fracture,

the architecture of the bone itself becomes changed, and the trabeculae orient themselves according to the new lines of stress. Through a more complex process, the bacterial invasion of the body is opposed by substances which develop within the tissues and lead to the destruction of the foreign elements. It appears that any factor tending to disturb the physiological equilibrium determines a reaction which opposes this factor, as happens in the inorganic world, according to the Le Chatelier principle. Formative, regenerative and adaptive processes bring about or maintain the wholeness of the organism, as if the building-up and preservation of this wholeness were their end. They are probably the different aspects of a single principle. This principle seems to group and direct in a purposeful way the processes which are instrumental in producing the unity of the organism. Each event is mechanically related to an antecedent event which we may call its cause. But the causal events themselves appear to be linked together in a teleological manner. The Aristotelian conception of efficient and final causes satisfactorily expresses what seemingly happens in the organism.

It is obvious, however, that this conception does not help us to understand the mechanism of the simultaneous plurality and unity of the organism. The nature of the purposeful processes, at which students of nature have wondered for ages, has remained utterly unknown. In spite of the great difficulty of the problem, we are irresistibly compelled to delve into the mystery of the constitution of the body and the semblance of a driving intellect within a community of tissue cells. So far, this search has been in vain. But it will never cease, because human beings will again and again attempt to unveil the secrets of their nature. Even if the ultimate goal is never reached, such a study may become of practical significance. It is well known that the quality of a human being depends largely on the perfection with which his component parts are coordinated. If the factors that control the building-up of organs and tissues during embryological development and also those that determine the hereditary characteristics were discovered, it would become possible artificially to improve the quality

of human beings. Such knowledge would be still more important for the future progress of medicine. Today, the cure of disease depends almost entirely on the spontaneous power of the organism to repair itself. The object of therapeutics is chiefly to set in motion by appropriate means some of these natural mechanisms. Should we discover the nature of the factors which are instrumental in the repair of a diseased body, we could probably activate the cicatrization of wounds, the healing of fractures, and the cure of any disease. For these reasons, it appears to be not only of philosophical but also of practical significance to look into the mechanisms that make a unity from the cell aggregates composing the body of the higher animals.

However, it should be clearly understood that for the biologist the problem is purely scientific and should be dealt with exclusively by the experimental method. The temptation is great, in the presence of a very complex problem, to build up hypotheses and to assume that they are the expressions of reality. In this manner, almost everything can be explained and, in fact, has been explained. But each succeeding generation has to demolish the systems created by the preceding one, and no real progress in knowledge is made. On the contrary, if we realized that natural truth can be apprehended only in fragments and by the strict application of the scientific method, we would not try to develop a formula disposing of the more complex biological problems in a logical manner. In the course of investigation, philosophy and biology should not be mixed. Biology is in one realm and philosophy in another. Scientific explanation and philosophic explanation, as Needham said, are two distinct foods of the soul, and they are confused only at great peril. Biology is full of such confusions, and has suffered markedly from them. It is obvious that hypotheses are necessary. But only hypotheses susceptible of experimental verification must be constructed. We have to be purely empirical. It is time to discard mere logical concepts. The concepts required for the building-up of an experimental science must be such that they remain true, whatever future experience may be in store. Modern physicists widely use concepts which are equivalent to a set of

operations. In his remarkable essay on the logic of physics, Bridgman shows that a concept must involve as much as, and nothing more than, the set of operations by which it is determined. Concepts can be defined only in the range of actual experiments, and when they cannot be so defined, they are meaningless.

If meaningless and useless questions were banished from natural sciences, the road to progress would be freer. Biologists have more or less entangled themselves in philosophic and scientific systems. Those who belong to the vitalistic school believe that the integrating principle that makes a whole of the organism cannot be expressed in physicochemical terms. The mechanisms responsible for the organic unity would be directed by an independent agent, a governing idea, analogous to that of an architect in the construction of a building. The more eminent exponent of vitalism, Driesch, teaches that certain classes of natural facts are not of the physicochemical type, but possess an autonomy of their own. The autonomous agent at work in the vital processes, called entelechy by Driesch, is something that is non-physicochemical. However, it is not psychical. It is of a non-energetic character and cannot create energy. It is concerned only with the arrangement of the manifoldness. This definition of entelechy shows that it is quite outside of the realm of positive investigation. The hypothesis of a non-physicochemical force within the organism and at the same time independent of the organism cannot inspire any new line of research. It is a pure mental construct, impossible to reach and to measure. It will contribute no more to the finding of new biological laws than the belief in Naiads presiding over the fate of springs has helped in the discovery of the laws of hydrodynamics. Although it may be of real philosophical interest, such a concept should be discarded by biologists as being meaningless. The classical mechanisticism that has superseded vitalism does not express a sounder intellectual attitude. It claims that the application of the scientific method exhausts the content of natural phenomena, and that all physiological processes can be explained in terms of the present laws of physicochemistry. These pretensions are obviously unwarranted.

It is impossible to know whether the phenomena that take place at a given scale of magnitude will occur at a very much smaller scale. Can the second law of thermodynamics express what is going on in cell organs less than 0.1 micron in diameter? Helmholtz doubted it, and Guye, in his remarkable essay on physicochemical evolution, has discussed how, at such a magnitude, the statistical laws of physics are possibly replaced by the laws of the individual action of molecules, atoms and electrons. As long as the phenomena that take place in minute cell structures have not been investigated, they cannot be assumed to follow the known laws of physical chemistry. The affirmations of mechanisticists on this subject must be considered as useless and meaningless. The neomechanistic school has assumed a more sensible attitude. It makes almost no philosophical claims, but merely asserts the universal dominion of scientific method over natural phenomena. However, it is still unsound as it limits science to the realm of phenomena which can be studied quantitatively and expressed mathematically. Science should not be identified with measurement and, as Gilbert Lewis said, one must have no patience with any definition of the scientist that would exclude a Darwin, a Pasteur, and a Kekule. After all, it seems that the best possible intellectual attitude for biologists is to follow the advice of Claude Bernard and "reject all scientific and philosophical systems in the same manner as they would break the chains of intellectual bondage."

The problem of the unity and manifoldness of the organism has then to be attacked with only the help of the experimental method. Our concepts of the integrating principle must not be logical constructs, but the mere expression of the manner through which they are acquired. How can we bring into the field of experimental analysis the purposeful processes of the living organism? It is obvious that such an attempt would be unthinkable if the teleological agent were an entelechy independent of the body. In that case, the subject should be dismissed from the laboratory and entrusted to the philosopher. However, we may reasonably assume that the purposeful factors reside within the units themselves, and not within the organism as a whole. While

no experiment can be made on a non-physicochemical agent distinct from the body, it is entirely feasible to measure an impulse toward organization present in a small group of cells. It has recently been discovered that cells removed from their normal surroundings and caused to live as independent units begin at once to manifest their innate properties. The analysis of these properties, which remain hidden in normal life, may explain the mechanism of some of the formative and regenerative processes. Such an investigation can be made on embryonic as well as on adult organisms. It is well known that the prospective value of any group of embryonic cells is far greater than its real value. When a blastula is cut into two parts, each develops an embryo. This experiment indicates that the fate of a cell is a function of its position. The egg is an equipotential harmonious system, as Driesch has named it. Each element appears to be able to play different parts equally well in the formation of the totality. What factors are responsible for the actualization or non-actualization of its potentialities? Probably certain chemical substances set free by the cells themselves. The epidermis of amphibia produces the lens of the eye under the influence of a formative stimulus from the primary optic vesicles. The analysis of the nature of such a stimulus is impossible when the tissues are parts of a living organism. But it would become feasible if the physicochemical conditions that may determine the transparency of epidermis were ascertained *in vitro*, and if the substances set free by optical vesicles were studied under the same conditions.

Should the principles determining organization reside within the elements composing the body, they would become apparent if tissue cells of various types were isolated and maintained *in vitro* in a condition of active and free life. With this object in view, we have developed elaborate physiological techniques during the last few years by which tissues and blood cells can be separated from the body and caused to show their natural tendencies toward organization and the elemental properties underlying formative, regenerative and adaptive stimuli. The application of the method of tissue culture in its modern form to embryonic and adult

tissues of birds and mammals has revealed some of their fundamental properties.

1. *Unlimited Proliferative Potentialities of Tissue Cells.* When fibroblasts or epithelial cells are removed from the body of an animal and kept in a nutrient medium under proper conditions, their multiplication goes on indefinitely at the same rate. As long as waste products are eliminated and food material is supplied, they synthesize new protoplasm from the constituents of their medium. A strain of tissue cells is immortal, if maintained in a proper state outside of the body. Within the organism, tissue cells actualize only a small part of their potentialities. But the proliferative capacity always remains present, even in old age, when the cells are still capable of unlimited multiplication *in vitro.*

2. *Dependence of Cell Activity on the Composition of the Medium.* Tissues taken from an embryo or from a pure culture of embryonic cells and placed in a medium containing inorganic salts and glucose, but no nitrogenous substances, stop growing after a few days and die. In a medium containing inorganic salts and lacking glucose, death occurs almost immediately. On the contrary, fibroblasts or epithelial cells cultivated in embryonic proteins immediately increase their rate of multiplication. After a few days, the mass of the tissue doubles in size every forty-eight hours and the velocity of proliferation remains stationary. Under such conditions, the cells accumulate reserves. Then, if they are deprived of food, they go on multiplying for several days. Connective tissue cells removed from an adult animal rejuvenate at once and begin to multiply again when they are placed in embryonic proteins, although they may have been in a dormant condition for several years. After a few weeks, they cannot be distinguished from embryonic cells. These experiments led to the important conclusion that the proliferation of a cell depends on the composition of the fluid in which it is placed. The state of rest or of proliferation of a tissue in the adult animal is a function of the quality and quantity of the food material at its disposal. A tissue cell has no spontaneous activity or energy. It is like a motor which does not run when it lacks fuel. The reason for cell

multiplication must always be sought in the nature of the surrounding fluid. The growth energy of a cell at a given instant is a function of its inherent growth energy at the preceding instant and of the concentration of growth-promoting and growth-inhibiting substances in its medium.

3. *Diversity of Growth-Promoting Factors According to Cell Types.* Pure strains of epithelial cells or fibroblasts, when placed in a medium composed of embryonic proteins, or of proteoses, peptones, and peptides, begin at once to multiply. Adult as well as embryonic cells respond in identical ways to the presence of these substances. The rate of growth depends both on their nature and their concentration. But fibroblasts, epithelial cells, and macrophages do not behave in the same manner toward a given substance. In embryonic proteins, the rate of proliferation of epithelium is always slower than that of connective tissue. Thyroid cells, and iris or Malpighian epithelium in pure cultures grow much less actively than fibroblasts. Moreover, these cell types do not utilize serum proteins. When cultivated in such a medium, they die within a few weeks while, on the other hand, blood and tissue macrophages proliferate rapidly in serum. The latter also multiply when fed on muscle fragments or protein precipitates. They remain in the localities where these particles are present and increase in size, as well as in number. But in digests from proteins and in concentrated solutions of embryonic proteins, they do not multiply, and often die. If such an investigation were extended to other cell types, differences doubtless would be discovered also in the nature and concentration of the substances which promote their growth. The innate properties of the various cell types account for the specific response of the tissues within the organism toward a given nutrient substance. Their activity is automatically and differentially determined by the quantity and the quality of the food supply.

Some nutrient substances may be manufactured by the tissues themselves. For instance, tissue cells cultivated in a flask set free in their fluid medium growth-activating substances. When leucocytes are multiplying actively in a plasma coagulum, the medium acquires the power of pro-

moting the multiplication of fibroblasts and of epithelial cells. This phenomenon must be attributed to the production of either embryonic proteins, or of proteoses and peptones.

4. *Specific Growth-Inhibiting Factors for Various Cell Types.* When fibroblasts and epithelial cells are placed in a medium composed of diluted plasma, they go on multiplying for a few days, but their rate of multiplication is less active than in Tyrode solution. The significant fact is thus brought to light that not only is plasma not a nutrient substance for these cells, but that it inhibits their multiplication. This effect increases progressively with the age of the animal that supplies the blood. It is not due to a special condition of the proteins during adult and old age. Once isolated, these proteins have no inhibiting or activating effect on cell proliferation. But quite the reverse, the lipoids that can be extracted from plasma possess a very marked inhibiting effect on the growth of fibroblasts. The plasma of an old animal contains a large amount of lipoids, and they are more toxic for tissue cells. However, the substances exerting such a marked effect on fibroblasts and epithelial cells do not prevent the multiplication of macrophages. Macrophages proliferate in the blood of an old animal, although the multiplication is slower than when they are cultivated in the plasma of a young animal.

5. *Morphological Effect of Nutritional Changes.* When cells endowed with definite morphological characteristics are placed in a medium where their nutrition becomes modified, marked changes occur in their appearance. Blood monocytes cultivated in a medium containing some red blood corpuscles, or particles of protein precipitate, or fragments of muscle killed by heat, increase rapidly in size. After a few days, they may be ten times longer than they were originally, and closely resemble tissue macrophages. In fact, they cannot be distinguished from them by any known morphological criteria. Inversely, tissue macrophages cultivated in a medium containing only a minute amount of nutrient substances decrease progressively in size and lose their large neutral red vesicles. The mitochondria shrink and the nucleus itself becomes smaller. The cells assume an appearance analogous to that of blood monocytes. A similar

phenomenon is observed when the food supply of fibroblasts is modified. It is known that such cells growing from fragments of adult connective tissue contain a small segregation apparatus and a few slender mitochrondria. After they have been fed well for a few days on embryonic proteins, the segregation apparatus grows much larger and the nucleus and mitochondria become similar to those of embryonic fibroblasts.

It is obvious that the anatomic constitution of a cell is modified by its nutritional state. Cell morphology depends, in some respects, on the nature and the concentration of the substances which are free in the surrounding medium. Moreover, the effect of the medium may be more radical and lead to a transformation of the cell type itself. When blood monocytes become crowded in a plasma coagulum, they die or transform themselves into fibroblasts, that is, into a type whose physiological properties are very different. Secretory activity also depends on the nature of the pericellular fluid. A pure culture of iris epithelium in embryonic proteins gives rise to rapidly developing cells which contain very few dark granulations. On the contrary, when the rate of growth is decreased by the presence of blood serum, a large amount of pigment is produced and the cultures become almost entirely black.

6. *Effort toward Organization of Isolated Tissue Cells.* Tissue cells isolated from the body for several years retain certain habits in the formation of colonies. They attempt to join together by building up tissues of the same architecture as were found within the parent organism. Fibroblasts never scatter through the medium of the flask, but rather pack themselves closely together in an intricate manner, forming a felt-like tissue which resembles young embryonic tissue. Epithelial cells, on the other hand, practically always unite by their edges and form a kind of pavement. If fibroblasts are placed close to a pure culture of iris epithelium, they quickly surround the epithelial cells which congregate in acinus-like formation, as indeed Fischer has shown. Although living far removed from the body in artificial media, epithelial cells have a tendency to unite as they are wont to do in the organism. A pure strain of Ehrlich car-

cinoma sends forth into the medium buds and sinuous branches composed of densely packed cells and grows to resemble an alveolar carcinoma, without any connective tissue to fill the spaces between the alveoli. Thyroid cells may also form alveoli in which secretory substance is observed. Evidently, therefore, cells isolated from the body show a blind tendency to form organs even when there is no organism and no object for such formation. This purposeless organization is clearly the expression of certain fundamental properties of the cells. Blood monocytes, on the contrary, never congregate as a tissue. When they are cultivated in a flask, they scatter all over the coagulum. It is only when they have reached its edges that they begin to grow in a denser formation. But the cells never come in contact on their sides. Sometimes they unite in a chain, but it is never a constant and definitive structure. If compelled to aggregate in a mass, they generally die. Their scattering through the body is the expression of an elementary property and not of an impulse to protect the organism against the invasion of bacteria or the accumulation of dead cells or foreign bodies.

7. *Production by the Cells Themselves of Certain Conditions of their Environment.* It is very probable that the fluids of the body, such as interstitial lymph and blood serum, are entirely the result of cell activity. But the mechanisms governing the formation of interstitial lymph by the tissues, and the effect of the lymph on the tissues are still unknown. Nevertheless, it has become possible to investigate the manner in which groups of cells may modify their immediate environment. When a fragment of pure culture of fibroblasts is placed in a coagulum stained with phenol red, it quickly surrounds itself with an orange-yellow crown, and a piece of spleen creates for itself a still more acid atmosphere. Colonies of blood monocytes do not produce any local change in the color of the medium, but they progressively modify the hydrogen ion concentration of the entire coagulum. When fragments of spleen are being transformed into sarcoma by Rous virus, the production of acid becomes more active. In composite tissues made of normal and sarcomatous fibroblasts living in symbiosis, golden-yellow spots on an

orange background characterize the presence of malignant islands within the normal tissue. Cells also modify their medium by the production of larger or smaller amounts of proteolytic ferment, growth-activating substances, etc. A fragment of leucocytic film placed beside a pure culture of fibroblasts causes an increase in the rate of proliferation of the latter. This effect is due to the setting free of a growth-activating substance in the medium. Certain malignant fibroblasts attract wandering cells and receive from those cells the substances which determine cell multiplication. The substances may belong to the class of embryonic proteins, such as are contained in very young cells. They may also be protein split products. It is evident that tissues possess, in some measure, the power to manufacture the medium in which they live.

The application of such a new method to a very old problem has brought to light some of the hitherto unsuspected properties of living tissues which are instrumental in building up unity from manifoldness. These properties until recently have remained hidden because cells had always been studied as independent units without consideration of their environment. It is imperative, on the other hand, to apprehend the concrete event of a living cell and not merely the abstractions on which classical cytology is based. Tissue and blood cells never escape the influence of their environment without, as well as within, the organism. When removed from the body of the embryonic or adult animal, they manifest almost at once their latent potentialities. They are seen to be endowed with attributes which compel them to respond in a certain manner to given chemical substances. Even when they have been separated from the organism for several years, they keep elementary characteristics which induce them to organize, despite the fact that there is no organism to be formed. They are apparently endowed with instincts which continue to manifest themselves, even when they have become purposeless.

The elements of the body, therefore, do not appear to be integrated by a central principle. Ontogenic or regenerative stimuli cannot be likened to the driving impulse of the mind of a sculptor carving a statue. There is no need of an

architect to direct the execution of the plan, because the living units themselves understand the requirements of the whole and act according to it, through a process which has no analogy in nature. Cells can be compared to stones which might have the magical power of setting themselves in order and making a wall, even when there is no house to be erected and no mason to build it. Possibly there is some remote analogy between the behavior of tissue elements and that of ants or bees which blindly work for the interest of the community. But the manner in which final causes seem to act upon efficient causes is as mysterious in the case of insects as in that of cells. Biology is not at present in a position to give any general explanation of organization and of the teleological processes responsible for it. We must patiently bring into the experimental field the mechanisms which cause, partly at least, the unity of the body. After an extensive analysis of the elementary processes, the horizon may broaden, and the veil may be lifted. But all is still very dark. Even if the ultimate mystery of organic unity should never be understood, this investigation of the integrating principles will be far from useless. It is bound to supply medicine with most important information about the mechanisms which are involved in the formation and maintenance of the wholeness of the body, and to increase its power for curing diseases and improving the quality of human beings.

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Chapter X

THE INTEGRATIVE ACTION OF THE VASCULAR SYSTEM

W. B. Cannon

A FLOWING stream of water brings to the simple organisms fixed on the rocks of the stream bed the food and oxygen needed for existence and carries away the waste. These single-celled creatures can live only in watery surroundings; if the stream dries they die or enter a dormant state. The same conditions prevail for the incalculable myriads of cells which constitute our bodies. We ordinarily think of ourselves as inhabitants of the air. In fact, however, every part of us that is alive is in contact with fluid. The surfaces of the body are either dead, as the horny layer of the skin, or are covered with moisture, as the eyes and the nose and mouth. Within these surfaces are the vast multitudes of minute living elements or cells which compose our muscles, glands, brain, nerves and other parts. Each cell has needs similar to those of the single cell in the flowing stream. But the body cells are shut away from any chances to obtain food, water and oxygen from the environment or to discharge the waste materials resulting from activity. To provide these necessities moving streams of fluid have been developed to take from the moist surfaces of the body food, water and oxygen which they deliver to the cells in the remotest nooks of the organism, and from the cells they bring back to the moist surfaces the useless waste to be discharged. The streams which form a fluid matrix for our body cells are the blood and the tissue fluid or lymph. They are related to each other somewhat as the water in a rivulet is related to the more stagnant water in the swamp through which it flows. The blood passes rapidly along fixed courses in tubular vessels; the tissue fluid, which fills the chinks and crannies outside the vessels until it too is gathered in its own channels, is shifted slowly from place to place. We are to examine the nature of these fluids and the

ways in which the internal environment of the cell is made favorable by keeping them on the move and constantly fresh and uniform.

The Nature of Blood and Tissue Fluid. The blood, constituting about 8 per cent of the body weight, is a remarkable substance consisting of immense numbers of red corpuscles (a drop of blood contains millions of them) and also minute motile white corpuscles, floating in a thickish watery solution of salts, sugar and albuminous material, the plasma. The plasma constitutes somewhat more than half of the total blood mass. The red corpuscles are able to take on very quickly in the lungs a load of oxygen, which is more or less unloaded in other parts of the body where the cells are in need of it. On the way back from these cells to the lungs the red corpuscles carry one of the waste products of activity, the carbon dioxide which results from oxidation or burning, a process that yields heat and mechanical work in the activities of the organism. The motile white corpuscles serve as scavengers and protectors against inert foreign particles and invading germs which, if they should accumulate, would pollute the stream. The plasma is a conveyor of all manner of food materials provided by the final digestive processes in the intestines. These materials are carried, like oxygen, to the remote cells for use in case of need or to special places where they are stored for future use. The plasma also carries from the cells the waste materials, apart from carbon dioxide, which result from the wear and tear of activity, and delivers them to the kidneys through which they are discharged from the body.

The plasma also has the extraordinary capacity to change from a fluid to a jelly when it comes into contact with an injured region. If the blood vessels are damaged, for example, and there is danger of loss of blood through the opening, the jellifying or clotting of the plasma forms a plug which more or less promptly closes the opening and prevents what might be a serious bleeding.

The tissue fluid differs from blood chiefly in containing no red corpuscles and less albuminous material than the plasma. It does contain, however, white corpuscles, and

also sugar and salts. And it is capable of clotting, though the clot is less firm than that formed by the blood itself.

Since the tissue fluid lies between the blood vessels and

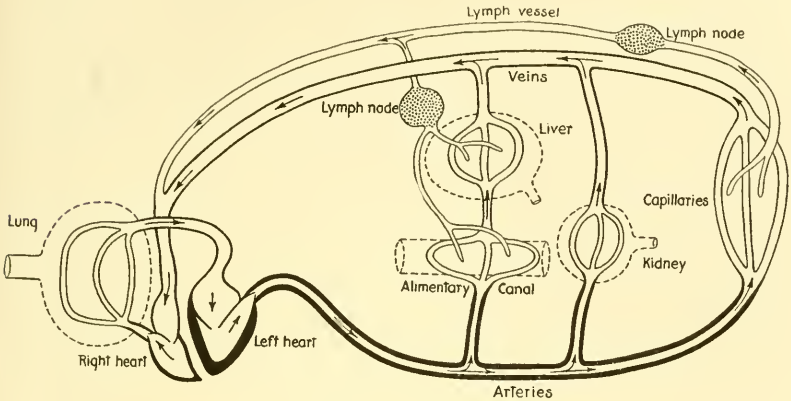

FIG. 1. Diagram of circulation.

Left heart chamber pumps blood out into arteries which distribute it to capillaries. Venous blood is collected from capillaries and returned to right heart chamber by veins. Thence it is pumped to lungs and onward to left heart chamber. Tissue fluid, exuded through capillary walls, is collected in lymph vessels and returned to veins near heart.

(Modified from Paton.)

the tissue cells, all the materials exchanged between the cells and the flowing blood must pass through it. It is, therefore, the direct intermediator for that exchange.

The Circulation of Blood and Tissue Fluid. Because these fluids are limited, the only way for them to serve continuously as carriers between the secluded cells and the body surfaces is by being used over and over again. They must circulate (see Fig. 1). The blood is forced through the vessels by the contractions or "beats" of the heart—essentially a powerful hollow muscle with two chambers, right and left. Each chamber has inlet and outlet valves. The nature of the muscle requires it to rest after each beat before it can beat again. During the rest period blood flows into the chambers of the muscle through the inlet valves, into the right chamber from all the remote parts of the body, into the left chamber from the lungs. When the muscle contracts on its contents, these valves close,

preventing a back-flow; the pressure on the contents rises until it opens the outlet valves, whereupon the blood is driven forth through these valves into the outleading vessels, from the right chamber into vessels distributing to the lungs, from the left chamber into the great main vascular trunk of the body, the aorta. The heart then relaxes, and when the pressure within it becomes less than that in the vessels, the outlet valves close. Thus the heart is emptied, and made ready for being recharged.

The vessels leading away from the heart are like the elaborate branchings of a thickly growing tree. The major trunk is the aorta. Large minor trunks reach out to the arms and legs, to the head and to the organs of the abdomen, e.g. the stomach, the liver and the intestines. In each of these regions the minor trunks ramify again and again into smaller and smaller twigs until every part of the body is supplied. The vessels leading away from the heart are the arteries, and this intricate branching system is sometimes called the "arterial tree." The arteries have relatively thick elastic walls, and because provided with muscle their capacity can be varied. When the heart discharges its load into the arteries it starts a distending wave along their contents, which can be felt in any superficial branch, e.g. in the wrist at the base of the thumb, as a "pulse."

We must remember always that the virtue of the circulating blood is to serve the cells which are far removed from the sources of supply and from the conveniencies for voiding their rubbish. It is clear that this service must be performed through the walls of the vessels. The arterial walls are too thick to permit the passage of material to and fro. The process of exchange occurs through the walls of capillaries, extremely minute tubules with walls so exceedingly tenuous that gases, such as oxygen and carbon dioxide, and sugar and salts in solution, pass readily through them. The capillaries, about 1/4000 of an inch in diameter, form a rich and intricate network, intimately insinuated between the layers and masses of the cells everywhere in the body. Into this network the fine twigs of the arterial tree, the arterioles, pour the blood; and from it the blood is gathered into the fine twigs of another tree, the tree of veins. From

the venules the blood passes to larger and larger veins with thicker and stronger walls until the main trunks are reached which pour the blood accumulated from all parts of the body into the right chamber of the heart.

Many of the veins lie just beneath the skin where they may be so prominent at times that they are clearly seen. On the back of the hand, for example, they are usually evident as a coarse network. By pressing on one with the tip of a finger and sweeping out the blood toward the wrist with the thumb, a valve (a cup-shaped sac attached at the side of the vein) can be demonstrated which does not permit a back flow. Wherever the veins are rhythmically pressed upon, as by the muscles in walking, the valves require the blood within them to be forced towards the heart. This pumping action on the veins may aid greatly in hastening the circulation.

A similar system of arteries and veins connects the capillaries of the lungs with the heart. It is important to note that in the lungs, as in all other parts, the flow of blood through the capillaries is the essential process. Only in the capillary region do the necessary exchanges occur. All of the rest of the circulatory system exists to maintain the flow in that region where it is serviceable.

Tissue fluid is produced by the filtering of a portion of the plasma through the capillary wall. In some parts of the body, e.g. in the liver, the capillaries are so "permeable" that the process of filtration occurs continuously; in other parts, e.g. in the limbs, it occurs only when the parts are active. Under such conditions the fluid may be formed more rapidly than it can be carried away, and therefore the part may become perceptibly larger.

The tissue fluid is returned to the blood in two ways. It may pass back in part through the capillary wall when the activity of the part ceases, or it may enter a definite system of thin-walled tubes, the so-called "lymphatics," and be conducted through them to a large vein near the heart where the lymph is delivered as a stream into the blood. The larger lymphatic vessels, like the veins, are provided with valves and in consequence every little pressure exerted on them pushes the lymph onward to the exit.

In their course the lymphatics are interrupted by nodes or "glands," which act as sieves and hold back small particles, e.g. bacteria and cancer cells, and keep them from being widely spread through the rest of the body. When protecting the body in this way they become enlarged and can then be felt. Thus, when the tonsils are inflamed the lymph glands of the neck may be swollen and tender.

The multitudes of finely branched arterioles which the blood must pass through on its way to the capillaries offer a considerable frictional resistance. When the heart beats and discharges its contents, it must develop a pressure which will drive the blood not only past this resistance, but also through the capillary net and the veins. With each fresh delivery of blood from the heart the elastic arteries stretch to accommodate the extra contents, and while the heart is resting and filling behind the outlet valves the elastic recoil of the arterial walls presses the blood continuously onward. Measurements show that the blood in the arteries is under a high head of pressure, equal (in young adults) to a column of about 120 millimeters of mercury (about 5 inches) at the peak of the cardiac discharge into them, and to about 80 millimeters (about 3 inches) just before the next discharge. In the capillaries the pressure has fallen to about 25 millimeters (about 1 inch), and it falls progressively in the veins until its lowest point is found as the blood enters the right chamber of the heart.

Clearly the same amount of blood must pass through the heart, the lungs, arteries, capillaries and veins at the same time, or otherwise the circulation could not continue. Since the total bed of the capillaries is much greater than the cross-area of the aorta or the large veins, the blood moves much more slowly in the capillaries than in either the arterial or venous trunks. This slow flow in the capillaries provides time for the important exchanges which occur in this region.

As we shall soon see, the circulation must vary greatly in its service to the needy cells, according to their degree of activity. The adjustments are brought about through nervous control of the heart and blood vessels. The heart can be made to beat rapidly or slowly by action of two

sets of nerves, the vagus nerves which hold the heart rate in constant check and the sympathetic nerves which make the rate faster. Interestingly, the constant moderate action of the vagus nerves can be used to speed up the heart; it is only necessary to remove the check which they exert. The blood vessels, especially the arterioles, can be made smaller here and larger there, also by action of the sympathetic nerves, thus limiting the flow to one part and distributing a larger volume to another part as need arises; indeed, the mass of the blood can be largely shifted from one region of the body to other regions in special emergencies.

The Constancy of the Internal Environment. One of the most striking features of the more highly developed organisms is their independence of their surroundings. They can go long without water and food, they can endure extremes of outer temperature, they can live equally well at the seashore or on the mountain tops. Lower organisms have not these capacities. They have been developed by remarkable automatic arrangements whereby, in spite of external changes and in spite of bodily activities which tend to disturb the internal conditions, the fluid matrix of the body is kept constant. The great French physiologist, Claude Bernard, stated fifty years ago that it is the fixity of the *milieu interieur* which is the condition of free and independent life. "All the vital mechanisms," he wrote, "however varied they may be, have only one object, that of preserving constant the conditions of life in the internal environment." We shall now examine some of the ways in which this constancy is maintained.

The Constancy of Blood Sugar. Grape sugar or glucose is the form into which starchy food is changed for use in the body. Of all energy-yielding materials supplied by the food, glucose is the most readily serviceable. When it is provided in abundance it is preferably utilized; the burning of fat is almost completely stopped. Furthermore, according to present views, glucose or its storage precursor, glycogen, is essential for muscular contraction. The substance is continually being used, therefore (even during sleep the heart muscle and the muscles of respiration are consuming glycogen) and it can be renewed only periodically. How is

the problem met of delivering a continuous supply of this important material to the active cells?

The problem is more complex than at first appears. Ordinarily the concentration of circulating glucose is 100 milligrams in 100 cubic centimeters of blood (commonly expressed as 100 mg. per cent). If the concentration rises to about 180 mg., the glucose will be lost by escape through the kidneys; if it falls to about 45 mg., convulsions are likely to occur, which may be followed by coma and death. The sugar supply, consequently, must not only be continuous, but cannot vary beyond certain limits without danger of loss or serious disturbance.

The problem of constancy of sugar in the blood is solved by storage. When food containing much starch and sugar is eaten, the glucose which results from digestion is stored locally in the muscles and for general use in the cells of the liver, as glycogen. The general reserve in the liver can be built up, however, only by collaboration of the pancreas. In that organ are groups or "islands" of cells that elaborate a peculiar substance which they discharge into the blood stream as an internal secretion. When it is lacking, sugar is not stored in the liver, is not normally used by the tissues, and may accumulate in the blood until it has a concentration there of 300 mg. per cent or higher. If under these circumstances an extract of the island cells (insulin) is injected into a vein, the blood sugar is promptly reduced both by storage and by use. There is evidence that normally an increase of blood sugar causes impulses to be discharged through the vagus nerves to the island cells; they then secrete natural insulin into the circulating blood, and this substance carried about the body induces both the building-up of the glycogen reserves and the more efficient utilization of glucose.

The stored glucose is needed when extra combustion or special muscular activity is demanded in the organism, for example, on exposure to cold or in severe and prolonged physical struggle. Under these circumstances the glycogen in the liver cells is changed to soluble glucose, is discharged into the blood, and is distributed to all parts of the body. The mechanism by which glucose is thus increased in the

circulation is similar to that operating when it is stored; it is a combination of nervous action and an internal secretion. Just above each kidney is an organ about the size of the end of the thumb, the adrenal gland. The mid-portion of this gland is called the medulla, the outer portion, the cortex. The cells of the adrenal medulla are controlled by sympathetic nerves, i.e., nerves which are excited by exposure to cold, by strenuous muscular efforts and by strong emotions, such as fear and rage. The substance which these cells pour into the blood stream, when they are stimulated by the nerve impulses, has the remarkable power of producing in all parts of the body the same effects that are produced by the sympathetic nerve impulses themselves. These impulses not only cause a discharge of adrenin into the circulating blood, they also call forth glucose from the stores in the liver. But the secreted adrenin can do likewise. Thus the sympathetic impulses and the secreted adrenin cooperate to mobilize the reserves of energy-yielding material when the cells are likely to be in need of it.

Fat is stored in fat cells, and there is evidence that protein is stored in liver cells. After a considerable period of fasting the blood still has a normal fat and protein content; the fat and protein reserves have been reduced, however, and yet organs of prime importance, e.g. the heart and the brain, show no signs of any weakness or decrease of weight. They are maintained at the expense of the reserves and of less important structures. The conditions which govern the laying-by of fat and protein reserves and which bring them out for use when they are needed are still largely unknown.

The Constancy of the Water Content of the Blood. As we have seen, the blood plasma and the tissue fluids are watery solutions of salts, sugar and albuminous materials. The sap of cells is also a watery solution of like materials. Between this sap and the tissue fluid everywhere is the cell membrane through which water and certain of the dissolved substances can readily pass. Ordinarily the water of the plasma is balanced against that in the tissue fluid, and that in turn is balanced against the water in the cells. If the water of the plasma is increased it disturbs the balance, and, when

excessive, results in headache, nausea, dizziness and other effects attributable to an altered state of the brain. On the other hand, if the water of the plasma is decreased the blood becomes thickened, the blood pressure falls, fluid passes out of the cells and the temperature of the body rises in a fever. The constancy of the water content of the plasma, therefore, is of primary importance for the normal life of the organism.

Water is being continuously lost from the body. It floats away as vapor in every breath we expel. Even when we are quiet it is lost through the skin at the rate of about a quart a day. And it goes out through the kidneys with waste products which must be kept in solution. To replace this continuous loss water can be taken only periodically and then it may be taken in excess of the immediate requirement. Under the circumstances how does the plasma fare?

Experiments have shown that its consistency is kept constant in spite of most exacting tests. Over five quarts of water have been drunk in six hours (indeed, the volume of water exceeded by one-third the estimated volume of the blood in the man who performed the feat) and yet it was absorbed into the body, was carried to the kidneys and by them discharged, without at any time causing a dilution of the blood which could be detected by studying a change of its color. On the other hand, total deprivation of water for as long as three days may be endured without any detectable change in the concentration of the plasma

The remarkable uniformity of the water content of the blood is maintained by storage and overflow. When much water is introduced into the body it is stored in muscles and other organs and in the skin. Since muscles constitute nearly half of the body weight only a very small accumulation in each muscle cell results in a large reserve. And in the skin is a peculiar form of tissue, with innumerable miteuo spaces, in which water and the substances dissolved in it (sugar and salts) can be retained. If the water intake is not great or too rapid to be accommodated in these stores it pours over the dam in the kidneys and is discharged from the body. The kidneys must be remarkably sensitive to a slight change in the concentration of the blood or there

would be easily detected alterations after the drinking of large volumes of water such as described.

When need arises water is withdrawn from the stores. After bleeding there is a sudden demand. The largest amount of the released fluid comes from the muscles (though they lose only ½ of 1 per cent of their weight) and the next largest amount comes from the skin. Other parts give up their reserve as well. Among the other organs are the salivary glands. The saliva which they produce is more than 98 per cent water. When the water supply fails, therefore, they cannot provide an adequate amount of saliva to keep the throat moist. In consequence disagreeable sensations of dryness and stickiness arise from that region, sensations which we call thirst. This leads to the drinking of water and thus to restoration of the normal supplies in the body and to resumption of the normal service of the salivary glands.

The Constancy of Temperature. One of the most striking and easily observed constants of the internal environment is that of the temperature in the "warm-blooded" animals. Although there is a daily swing from a low point about 4 A.M. to a high point about 4 P.M., the variation is hardly more than a degree in the Fahrenheit scale. The constancy is so reliable that the thermometer makers can stamp 98.6° on the scale with assurance that it will mark closely the temperature of the normal person everywhere. The value of uniform temperature is demonstrated by comparing the influence of cold on ourselves and on lower animals without a regulatory mechanism. As the weather becomes cold the frog, for example, becomes more and more sluggish, until finally he sinks inactive to the bottom of his pool and thus remains unless he is warmed again. This behavior is determined by the direct dependence of the speed of chemical processes in the body on the degree of heat. The "cold-blooded" animals, having the temperature of their surroundings, can act with speed only when the weather is warm; the warm-blooded, maintaining a fairly fixed high temperature in spite of external cold, can act with speed at all times. There is no better illustration than this of the value of the even tenor of our internal environment as a condition for

freedom from changes in the external environment. How is this valuable independence achieved?

To understand regulation of temperature we must realize first that heat is continuously being produced in the body by every variety of activity that occurs. All the energy of the heart is turned to heat inside us, about three-fourths of the energy of our muscles appears necessarily as heat, the processes in the liver are accompanied by large heat production. As the circulating blood passes through the specially active regions, heat flows from the warmed cells to the cooler blood and is thus distributed to other regions. An important service which the circulation performs, therefore, is that of equalizing the temperature in different parts of the body. It also plays an essential rôle in the management of heat loss through the skin.

Let us suppose that there is a tendency for the body temperature to rise because a large amount of heat has been produced by muscular work. The heat will go to the colder outer air by radiation and conduction if it is brought to the skin, which is in contact with the air. Under these circumstances the nerves governing the size of the surface arterioles relax their grip, the vessels dilate, and the blood flows through them and through the capillaries to which they contribute, in much greater abundance. In consequence the skin becomes red. Thus the extra heat is delivered to the surroundings and a rise of body temperature is prevented. If the outer air is too warm to permit the heat to pass to it, however, another process is resorted to; heat is lost by evaporation. When water evaporates, as much heat is taken from the surroundings as would be required to cause the water to evaporate. The greater delivery of warm blood to the skin can be combined with pouring of sweat on the skin surface. As the sweat evaporates the surface is cooled and likewise the flowing blood. If the air is dry, large amounts of heat may be lost in this way, and thereby high external temperatures may be withstood (e.g., by stokers and foundry workers). Occasionally the sweat glands fail to develop or they degenerate. Persons thus afflicted may have to wet their garments in order to endure hot weather, or they may pant, as a dog does (having inefficient sweat glands),

and lose moisture from the surfaces of the respiratory passages. The highly uncomfortable experience which we have on a day which is not only hot but muggy is due to the interference with free evaporation by the moisture already in the air.

If the body temperature tends to fall, an interesting series of adjustments occurs, all directed towards preservation of the steady state. First, heat which is being lost is conserved: perspiration is reduced to a minimum, the surface vessels are contracted and thus the warm blood from the interior is not exposed to the cold surroundings, and in animals provided with hair or feathers these appendages of the skin are elevated so that a thicker layer than usual of insulating air is enclosed in their meshes. In us only futile "gooseflesh" remains of this last protective reaction, and we resort therefore to extra clothing to prevent too great heat loss.

If the check on the outflow of heat is not sufficient to protect against a fall of body temperature, more heat must be produced. The first step in that direction is a discharge of adrenin from the adrenal medulla. This remarkable substance not only collaborates with the sympathetic impulses which are constricting the surface vessels, but it has the power to accelerate the processes of combustion in all parts of the organism. Its discharge is like opening the dampers of a furnace: burning goes on more rapidly and the heat production quickly mounts. But even this extra heat may not be enough to match the losses. In that event muscular activity is automatically started, i.e., shivering occurs. The greater production of heat with which we are familiar when we run or play vigorous games then results; indeed, shivering may more than double the rate of heat development in the body. And if shivering does not suffice to keep up the normal temperature we are likely to be impelled to engage in such strenuous physical exertion that heat flows to the blood from many large muscle masses engaged in the effort and is delivered promptly to all parts of the body by the streaming blood.

It is noteworthy that not only are there arrangements which check a shift of body temperature in one direction

or the other, but that there are successive lines of defense set up against the shift. If dilatation of the skin vessels does not stop the rise of body temperature, sweating supervenes; if conservation of heat is not enough to stop the fall of temperature, a second line of defense appears in the action of the sympathico-adrenal mechanism, and a third in shivering. Of course extreme conditions can break down these defenses, and a person may die of heat stroke or of freezing. Within a wide range of temperature variations in the external environment, however, we maintain the temperature of the internal environment at an astonishingly uniform level.

The delicate control of the body temperature indicates the operation of a sensitive thermostat. The location of this part of the regulatory apparatus is in the base of the brain, in the so-called thalamic region. If the blood going to that region is warmed, the surface vessels are relaxed and sweating takes place; if the blood is cooled, shivering results. When that region is destroyed, regulation is lost and the animal is changed to the cold-blooded type, i.e., its temperature now follows the changes of its surroundings. Anesthetics, such as ether and chloroform, and also excessive amounts of alcohol, have similar effects. In fever the thermostat is set for a higher temperature level.

Adjustments for Maintaining an Adequate Oxygen Supply. The cells of the body are more closely dependent on oxygen than on any other substance obtained from the outer world. We can live without food for weeks, and without water for days, but there are important nerve cells in the brain which cannot live without oxygen for longer than about eight minutes. These differences appear to be due to differences of storage of these substances in the organism. Food and water are stored, as we have seen, but since oxygen is present all about us, as one-fifth part of the atmosphere, there is no need for storage and to a noteworthy degree there is none. The problem in times of need, therefore, is that of conveying the oxygen to the cells from the surrounding supply.

Although such need arises after profuse hemorrhage, for example, or in poisoning by illuminating gas or auto-

mobile exhaust, these may be regarded as unnatural states. The problem is best presented and is best met during vigorous muscular exertion. The oxygen requirement of a man of average size may be only 0.25 to 0.30 liter (quart) per minute when he is at rest; but very rigorous exertion may raise the requirement to 15 liters per minute or more. Even in most favorable circumstances however, the maximal intake of oxygen is at a rate less than 4 liters per minute. Thus during highly strenuous effort the intake may be from 10 to 12 times what it is during rest and yet be far short of what is needed. When this situation arises the lactic acid which attends muscular contraction is not burned to carbon dioxide and it accumulates in the muscles. Contraction can continue, but with decreasing efficiency because of increasing concentration of the acid. Thus an "oxygen debt" is incurred; and even though activity ceases, extra oxygen must be delivered to the muscles to burn in part the lactic acid, until the debt is paid and the resting state is restored. Various and complex adjustments of the respiratory and circulatory systems are made, each tending to supply an amount of oxygen sufficient to meet the need of the laboring parts or to pay the oxygen debt if the need has not been met during the period of labor.

The respirations, first of all, are deeper and more frequent. This change occurs at the very start of a muscular effort, too soon to be caused by any other agency than the nerve impulses which initiate the effort itself. Thereafter the greater volume of breathing, which we have all noted when exercising vigorously, is due to an increase of carbon dioxide (and perhaps lactic acid in addition) in the blood. As this increase develops, the portion of the brain which governs the respiratory movements becomes more active and by amplifying and accelerating these movements it brings about a much greater pulmonary ventilation than before. This carries away the carbon dioxide which is given off from the circulating blood into the myriads of little sacs or alveoli of the lungs. At the same time the greater ventilation maintains the percentage of oxygen in these alveoli. By this double process the blood unloads its volatile waste (carbon dioxide) and is promptly loaded with oxygen for

delivery to the active organs. The respiratory adjustments, therefore, maintain in the lungs an adequate supply of oxygen in spite of the extra demand, and they minimize the accumulation of carbon dioxide there in spite of the larger deposit from the blood.

To understand the circulatory adjustments we must remember that the carriage of oxygen and carbon dioxide is dependent on the red blood corpuscles of the blood and that, although their number can be increased in emergencies, it is nevertheless limited. In such conditions the only way to increase the carriage of these gases is to increase the use of the carriers; in other words, to multiply the number of trips which the carriers make between the lungs and the active parts. This in fact takes place, but in addition the processes of loading and unloading are facilitated at the two stations. We shall now consider these adjustments in detail.

First, in order that there shall be a larger output of blood from the heart there must be a larger return of blood to the heart through the veins. This effect is achieved by a variety of actions when we engage in muscular effort. The nerves governing the size of the blood vessels in the capacious vascular area of the stomach and intestines cause these vessels to contract. In consequence much of the blood is driven out of them and into the vessels of the muscles, which, as we shall see, have a greatly enlarged capacity when the muscles are at work. Now the contracting muscles press more or less rhythmically on the vessels, especially on the small veins, and since there are valves which permit only an onward flow of the blood towards the heart, the rhythmic pressure necessarily promotes that flow. If the left wrist is grasped firmly by the right hand, and the left hand is then rapidly and repeatedly clenched and relaxed, the quick filling of the veins, as seen on the back of the hand, can be readily demonstrated. Another type of pumping action on the veins occurs in the functioning of the great dome-shaped muscle of respiration, the diaphragm, which separates the chest from the abdomen. When it contracts, it flattens, and thereby it somewhat increases the pressure on the great vein which leads the

blood upward through the abdomen from the legs. Since valves prevent the backward flow of the blood into the legs the pressure favors the onward flow. At the same time that the pressure in the abdomen is increased by contraction of the diaphragm, the pressure on the veins in the chest is decreased. The result is that with each inspiratory act conditions are established which promote the flow of a larger volume of blood into the heart. During expiration the returning venous blood accumulates in the veins outside the chest, in the arms, neck and abdomen. At the next inspiration, however, the conditions just described recur and the accumulated blood is driven to the heart. Thus to the pumping action of the limb muscles is added the pumping action of the diaphragm as a factor favoring the greater utilization of the blood. Note that the bodily organization is such that the contracting muscles, which need extra oxygen because of their contractions, automatically favor the securing of the needed oxygen by returning the blood which carries it; and that the diaphragm, which is made to pump more vigorously during exercise, not only maintains the oxygen supply for loading the oxygen carriers, but also aids to speed up the circulation of the carriers.

Although the capacity of the heart chambers can be enlarged, that adaptation is limited. The greater return of blood to the heart in a given time resulting from the pump-like actions just described must be received and sent forth, therefore, by a heart that beats faster. As with the red corpuscles, limitation is compensated for by more rapid service. The faster heart beat is brought about and maintained by a variety of agencies. We have noted that the very act of making a motion is accompanied by increase of respiration, because nerve impulses, attending the act, excite the respiratory center in the brain. Similarly when we start to move, the heart beats faster because vagus nervous influences, which are continuously holding the heart in check, are more or less suppressed. These are devices for prompt adjustment to need, that appear in two different systems which are, however, clearly related in their cooperative functions. The pump-like action of the limb muscles and of the diaphragm, that drives onward the venous

blood, causes an increase of pressure in the veins (note the prominence of the veins beneath the skin during exertion). This increased pressure continues and accentuates the nervous effects just mentioned, for when it is applied to the right side of the heart, it starts a reflex which suppresses still more the vagus check on the heart rate and thereby the beat becomes still faster. The sympathetic nerves, also, which are known to be excited when muscular exertion is very strenuous and especially when emotional excitement accompanies the effort, as in competitive games, may play an important part in making the heart contract more rapidly. All these influences working in harmony provide for adequate reception of the greater volume of blood flowing back through the veins, for adequate delivery of the blood to the lungs where the deeper ventilation cares for the larger exchange of the respiratory gases (oxygen and carbon dioxide), and for adequate driving of the oxygen-laden blood into the great "arterial tree."

The more ample discharge from the heart into the arteries is attended by a rise of pressure in the arteries. In tests made on a man riding a stationary bicycle the arterial blood pressure rose at the start from 130 millimeters of mercury to 180, and during the continuation of the exercise it remained high, between 165 and 170 millimeters (i.e. at about 7 inches instead of the resting level, about 5 inches). The value of the increased pressure we can best appreciate when we consider that there is a dilation of the arterioles and capillaries in the active muscles. If the arterial pressure were barely sufficient to keep the blood in circulation, a widening of the vessels in one region would provide such a way of escape for the blood from the arteries into the veins that it would run through them and thus would leave other regions without an adequate supply. The increased arterial pressure not only prevents any such failure of the delivery of blood to quiet regions, but it also assures rapid flow through the dilated vessels of active regions, i.e. where the need for the materials which the blood carries is greatest.

The dilation of the blood vessels, arterioles and capillaries in active muscles is one of the most remarkable adjustments for bringing supplies to the cells and for carrying away

their waste in an emergency. Careful studies have shown that when a muscle is at rest many of its capillaries are not in use or that they have shifts of service, one opening here for a time and then closing down so that no blood runs through it, while another near-by capillary opens and serves its neighborhood. Only the capillaries which contain blood are visible. When an active muscle from one side of the body is compared with the corresponding muscle, inactive, of the other side, the astonishing fact appears that the number of open capillaries in the muscle at work may range from 40 to 100 times the number in the muscle at rest. What causes the capillaries to dilate is not yet clear; lack of oxygen, increase of carbon dioxide, or possibly some subtle substance resulting from the wear and tear of the muscle as it pulls, may open the vessels. However they may be opened, the great importance of their being open should not be overlooked. It is in the capillary region of the circulatory system that the exchanges between the blood and the fixed cells occur. Here all the adjustments of that system during physical work that we have been considering have their significance. The blood is bearing sugar and oxygen which the laboring muscles require, it can bear away the carbon dioxide and water which result from the burning that attends contraction. The nearer the flowing blood can be brought to the muscle cells in their need for both these services, the more efficiently will the muscular work be performed. The extraordinary unfolding of the unused capillaries assures intimate relations between the cells and the blood stream.

We may now complete the circuit of adaptive changes in the circulatory system. It is clear that when the muscles are rhythmically contracting and massaging the vessels within and between them they are pressing on a greater volume of blood than is present when the muscles are at rest. In other words the laboring muscles act as if they were outlying hearts, receiving more blood when they work and pumping that blood back to the central heart and to the lungs for a new service.

Still another remarkable relation remains to be mentioned: that of the facilitation of the gas exchanges in the capillaries

of the lungs and of the muscles. We have seen that the adjustments in the circulation when work is being done are all directed towards increasing the number of trips of the red blood corpuscles from lungs to muscles and from muscles to lungs again in a given time. Although the blood flow in the capillaries is slower than anywhere else in the circuit, when the rate is increased it is increased in the capillaries as well as elsewhere. That means, of course, that less time is allowed for the carriers to unload carbon dioxide in the lungs and take on oxygen and to perform the reverse processes in the muscles. The beautiful fact has been discovered that excess of carbon dioxide hastens the unloading of oxygen from the corpuscles and that excess of oxygen hastens the unloading of carbon dioxide. When the muscles work, therefore, and produce extra carbon dioxide and need more oxygen, the extra carbon dioxide forces the unloading of oxygen from the corpuscles more rapidly at a time when the faster flow through the muscle capillaries requires a more rapid unloading. And when the corpuscles, laden with carbon dioxide, reach the lungs, the higher concentration of oxygen there drives out the carbon dioxide more rapidly when the faster flow through the pulmonary capillaries requires a more rapid unloading. In each place the gas which drives the other out seizes the vacated place in the carrier for itself and holds it until it in turn is driven out. There is no more fascinating interplay of processes than this in any part of the organism.

One more striking provision for assuring an adequate delivery of oxygen in case of need is seen in the sudden rise in the number of red blood corpuscles when muscular exertion is vigorous. This is the only aspect of the adaptation of the organism to oxygen want that resembles a resort to the supply depots. As we have seen, when muscular exertion is severe and prolonged, glucose is mobilized from the liver stores and distributed by the blood for use wherever required. There is a store of red blood corpuscles in the spleen; the concentration of the corpuscles there may be as much as twice that in the general circulation. In strenuous exercise the spleen is made to contract by sympathetic nerve impulses and squeeze out its contents. The addition of the con-

centrated blood thus made to that in the vessels may increase the number of circulating corpuscles by 20 per cent or more. These corpuscles, of course, promptly become carriers of oxygen and carbon dioxide, at a time when their services are in demand.

It is of interest to note that many of the changes in the circulation described are a part of the bodily changes occurring in profound emotional excitement. Respiration deepens, the heart beats more rapidly, the arterial pressure rises, the blood is shifted away from the stomach and intestines to the heart and central nervous system and the muscles, sugar is freed from the reserves in the liver, the spleen contracts and adrenin is discharged from the adrenal medulla. The key to these marvelous transformations in the body is found in relating them to the natural accompaniments of fear and rage: running away in order to escape and attacking in order to be dominant. Whichever the action, a life-or-death struggle may ensue. The emotional responses may be regarded as preparatory for that struggle, adjustments which so far as possible put the organism in readiness for meeting the demands which will be made upon it. The secreted adrenin not only collaborates with the sympathetic impulses, to the degree that they are engaged in the adjustments, but it has the property of extending the ability of fatigued muscle to continue at work. All these wonderful arrangements which operate when we engage in hard muscular exercise, and particularly when there is attendant excitement, we can best understand by reference to racial history. For myriads of generations our ancestors have had to meet the exigencies of existence by physical effort, perhaps in supreme effort. The struggle for existence has been a nerve and muscle struggle. The organisms in which the adjustments were most rapid and most perfect had advantages over their opponents in which the adjustments were less so. The functional perfections had survival value, and we may regard the remarkable arrangements for mobilizing the body forces, which are displayed when intense muscular activity is required or anticipated, as the natural consequences of a natural selection.

The Constancy of the Neutrality of the Blood. The foregoing edscription has repeatedly called attention to the release of lactic acid and carbon dioxide (which in watery solution forms carbonic acid) during muscular work. Besides these and other acids which may be developed in the body, acid foods may be eaten and absorbed and they also tend to render the blood acid. On the other hand, the food may be alkaline in reaction, or there may be a loss of acid from the body by its secretion in the gastric juice, or the carbon dioxide may be "pumped out" of the blood to a considerable degree by prolonged deep breathing; each of these conditions tends to render the blood alkaline. It is of the greatest importance to the existence and proper action of the cells that the reaction of the blood and tissue fluid shall not become either acid or alkaline. If the blood becomes too acid, coma, or unconsciousness, is likely to occur; if too alkaline, convulsions may take place. If the fluid supplied to the heart is too acid, the muscle relaxes and ceases to beat; if too alkaline, it again ceases to beat, but usually stops in the contracted state. These are only two examples out of many that could be cited to show the dangers of a shift of the chemical reaction of the blood too far away from the neutral point between acidity and alkalinity. Within a narrow range of variation the nervous system will operate perfectly, with no signs of coma or spasmodic discharges, and the heart will go on beating continuously. But the reaction must be kept within that narrow range.

The complete account of the mechanisms by which the reaction of the blood is kept close to neutrality, in spite of external and internal conditions which are constantly acting to push the reaction away from that point, would require elaborate and detailed consideration of highly involved processes. We shall regard only the simpler aspects of the mechanisms. Dissolved in the blood plasma is a compound of the elements sodium (symbolized by the letters Na), hydrogen (H), carbon (C) and oxygen (O) in three parts (ordinary cooking soda). This compound is known chemically as sodium bicarbonate ($NaHCO_3$). The symbol of carbonic acid, which results from dissolving carbon dioxide (CO_2) in water (H_2O), is H_2CO_3. Now the

reaction of the blood is determined by the relation of H_2CO_3 to $NaHCO_3$ existing in the blood. If the carbonic acid is increased the blood is more acid; if the carbonic acid is decreased, as it may be by excessive voluntary ventilation of the lungs and consequent removal of carbon dioxide from the blood, the blood is more alkaline. If a non-volatile acid, such as hydrochloric acid (HCl) is added to the blood, it unites with the sodium of some of the sodium bicarbonate and drives off carbon dioxide, according to the following equation:

$$HCl + NaHCO_3 = NaCl + H_2O + CO_2$$

The NaCl is common salt, a neutral harmless substance. The H_2O and CO_2 form the familiar carbonic acid, which is volatile. The addition of the strong acid (HCl) has, to be sure, made the blood more acid by increasing the H_2CO_3, but, as we have seen, this stimulates the respiratory mechanism and thus the extra carbon dioxide is quickly and readily reduced. And when it is reduced the normal ratio of H_2CO_3 to $NaHCO_3$ returns, the neutrality of the blood is restored, and the deeper breathing stops.

The sodium bicarbonate has served to protect the blood from becoming acid in the circumstances just described, and because of its capacity to perform that function it is called a "buffer" salt. Another buffer salt existing in the blood, especially in the red blood corpuscles, is alkaline sodium phosphate (Na_2HPO_4). When acid is added to blood, not only is it "buffered" by sodium bicarbonate but also by the alkaline sodium phosphate, according to the following equation:

$$Na_2HPO_4 + HCl = NaH_2PO_4 + NaCl$$

Again note that common salt (NaCl) is formed and acid sodium phosphate. It happens that both "alkaline" and "acid" sodium phosphate are almost neutral substances. The strong hydrochloric acid (HCl) has, therefore, not altered the reaction of the blood to an important degree by changing the alkaline to the acid form of the sodium phosphate. The acid phosphate has, however, a slightly acid reaction and it must not be permitted to accumulate in the

blood. Unlike carbonic acid it cannot be breathed away. It is eliminated by being discharged, along with excess of NaCl, by way of the kidneys. If large amounts of non-respirable acid appear in the blood, ammonia, which is alkaline and which is ordinarily changed to a neutral product, urea, is utilized to render the acid harmless and to carry it away in the urine.

A modification of these processes occurs when the blood tends to become alkaline. Let us suppose that a sharp pain has caused unusually deep breathing. The carbon dioxide percentage in the lungs is thereby reduced and in consequence it is reduced also in the blood. The ratio of H_2CO_3 to $NaHCO_3$ is lowered, i.e. the reaction shifts towards the alkaline side of neutrality. Under these conditions respiration may cease altogether for a time. In the absence of breathing the carbon dioxide, which is continuously being produced by the beating heart and other persistent activities, accumulates in the blood until the normal ratio of H_2CO_3 to $NaHCO_3$ returns, whereupon the rhythmic ventilation of the lungs begins again. And if the reaction of the blood is for some time shifted towards alkalinity, alkaline sodium phosphate is excreted by the kidneys until neutrality is assured.

In the main the delicate balance between a dangerous acid and an almost equally dangerous alkaline reaction is maintained by the extraordinary sensitiveness of the respiratory center in the brain and of the kidneys to even slight alterations in the blood. We may think of these sentinels as being continuously on the alert, ready at the first indications of a change to act in such a way as to prevent a harmful swing away from the normal steady state of neutrality.

Other Integrative Services of the Circulating Blood. We have been considering the blood and lymph as the fluid matrix of the body and noting the various devices which work towards the maintenance of constancy of the supplies and of the working conditions which it provides for the living cells. Among the devices for regulating the storage and mobilization of sugar, it will be recalled, the adrenal medulla and the islands of the pancreas were mentioned. These are examples of glands of internal secretion, or endocrine glands, organs which elaborate special substances

and on occasion discharge their products into the blood stream for distribution to all parts of the body. The profound influence which these internal secretions have on the organism cannot be overemphasized. In general they affect the rate and nature of the chemical changes in the body, sex functions and characteristics, and the processes of growth.

We have seen that adrenin produced by the adrenal medulla, when discharged in extra amount, is capable of accelerating heat production. Another gland which affects the speed of combustion is the thyroid, which is located in the neck. When it is deficient, the processes of burning in the body may be so slow that the heat output may be reduced 30 per cent or more below the normal level. Naturally enough persons afflicted with this condition are especially sensitive to cold weather. When the substance produced by the thyroid is delivered to the blood in excess, the heat production may be doubled in rate. More food must be eaten in order to keep up the normal weight, the skin is flushed, and sweating is prominent, for the extra heat must be eliminated if normal temperature is to be maintained. It is possible that the thyroid plays a rôle in adjusting the body to alterations in the external temperature, acting like the adrenal medulla but in a less ready and a more persistent manner.

The sex glands, the testes and ovary, produce substances which, given into the blood stream, bring forth the typical features of the male and female respectively. The influence of the testes in this respect has long been known. The striking transformations which occur in the boy at puberty: the growth of hair on the face and other parts of the body, the deeper voice, the development of physical vigor, the assertiveness and sense of power, all these fail if the testes are absent. Analogous changes occur in the young girl at puberty and are lacking if the ovaries are removed. The outer part (the cortex) of the adrenal gland also has a remarkable relation to the development of superficial sex appearances. If tumors of this portion of the adrenal gland appear in young boys, maturing occurs at an early age; the phenomenon is sometimes referred to as the

"infant Hercules" type. In woman such tumors have the extraordinary effect of giving the female some of the male characters, e.g. a deep voice and a beard, and removing a number of the typical features of the female.

The endocrine glands which especially influence growth are the thyroid and the pituitary which is at the base of the brain. If the thyroid is deficient from birth the condition of cretinism results. Unless treated the child remains a dwarf, hideous in appearance, and furthermore an idiot. Such monsters are now rare, for it is commonly known that by giving a preparation of the thyroid gland it is possible to bring about a natural development of body stature and of the nervous system. The transformations thus wrought seem nothing short of miraculous. If there is deficiency of the front part of the pituitary gland, dwarfism results, but the dwarf is not idiotic. He is unusually fat, especially about the hips, he has an infantile body form, and there is failure of development of the reproductive organs. When this portion of the pituitary gland is over-developed and overactive in youth, growth, especially of the long bones, is excessive. The result is a giant. The large growth of the pituitary body enlarges the bony pocket in which it rests, and with the *x*-rays it is possible to see in the skulls of living giants the evidence of the cause of their abnormality. Recent experiments indicate that the growth-principle of this gland has been isolated and can be used effectively in promoting growth during adolescence.

The foregoing references to the functions of the endocrine glands should be regarded as merely illustrative. In each instance it is clear that an organ in one part of the body has remote effects on parts far removed from it. The connecting agency is not the nervous system, but the other great integrating system of the organism, the circulating blood and tissue fluids.

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Chapter XI

NERVOUS INTEGRATIONS IN MAN

J. F. Fulton and C. S. Sherrington

IT has to be remembered that of the cells, which in their multitudes compose the body, whether animal or human, each one leads its individual life, is individually born, feeds and breathes for itself, and is destined for individual death. This book has described already these microscopic living units, and their arrangement and combination into differentiated systems and aggregates called tissues and organs. These pages have also told how from those systems and organs is constructed the unified individual, for instance the human being. With the differentiation of the cell systems have gone division of labor and specialization of function, and a crowning part in the integration of the total individual is played by the system of differentiated nerve cells, the nervous system.

NERVOUS INTEGRATION

The system provides speedy communication between one part of the body and another part, by message sending. One of its main offices is to "operate" the muscles. It has been commonly and permissibly likened to an electric installation with connected central exchanges whither run wires from receiving stations and whence issue wires to outlying motor machines. Through it a single receiving station has touch with many of the motor machines. The exchanges are the nerve centers in spinal cord and brain; the motor machines are the muscles, the receiving stations are the sense organs, and the wires are the nerve fibers connecting all these into a system. The central exchanges are so contrived that a wire from a receiving station can put these or those motor machines into action and likewise stop or restrain others which would impede or conflict with them.

The receiving stations are commonly called sense organs; through them light, sound, or other external stimuli excite

in the central exchanges a reaction which often documents itself to the mind as a perceptual experience. But that sensual result accrues only when the central reaction involves certain *sets* of the central exchanges. The central reaction taken as a whole consists of much that does not document itself to the mind. Therefore it is better in speaking of the receiving station to replace the term "sense organ" by the broader and simpler term "*receptor*." This latter is suitable for the receiving station in respect of both of its two central results, the non-mental "reflex" and the sensual or other mental result; whereas "sense organ" is a misnomer for the receiving station in respect of its purely reflex and non-mental function. This distinction is the more important because the pure reflex central reaction occurs sometimes by itself, and can in experiment be cut off from the mental by taking advantage of the partial separateness of the central exchanges for the two, although the nerve from the receptor leads to both. The conducting paths to the "mental" nerve centers run for the most part through the "reflex" nerve centers.

The "exchanges" or "centers" consist of extensively branched nerve cells "holding hands" with each other in many, but precisely restricted, directions, these communications being for the most part capable of being opened or closed as circumstances may require. The "lines" entering and leaving the exchanges, and traversing them *en route* for others, are built of long living threads (nerve fibers) each one an extension from some nerve cell, and by it kept alive. The cells and their fibers when followed in the direction of their linkage can be traced as chains of which each link is a living nerve cell with its nerve fibers. Along these living chains travel, when a stimulus excites them at any point, "nervous impulses," transient waves of physicochemical change. A receptor acting on the nerve fibers which connect it with its next nerve centers thus excites, when it is stimulated, nervous impulses which run into, and in various directions along, the central nervous system. Everywhere and whatever the receptor, whether the retina reacting to light, the ear to sound, or the skin to touch, the nervous impulses generated seem to be alike. Each is a brief disturbance

lasting about $\frac{1}{500}$ of a second, and travelling about 88 yards a second along the conducting paths. Each impulse leaves the conductor behind it in a state incapable of transmitting another impulse for about the same period.

Similarly the messages issuing from a nervous center whatever they have to effect, whether to cause a gland to secrete, a muscle to contract, or the heart to slacken, consist solely of nerve impulses like those generated by the receptors at the beginnings of their entrant paths. Some of the nerve fibers are thicker than others, and in these their impulses travel slightly faster than those of the smaller. Otherwise the only difference observed between impulses, wherever occurring in the nervous system, lies not in the individual impulse itself but in the time-grouping of the impulses, so that concomitant with intensity of actions go impulse trains of higher frequency (although each impulse in each train is still quite discrete), so that the number of successive impulses arriving or leaving by a particular path is per second greater.

But impulses are not the sole form of functional reaction exhibited by the nervous system. Consisting as it does of chains of conducting cells laid end to end, the impulse after propagating itself along one cell has then to excite the next. All points of linkage between cell and cell in the system are confined to nerve centers. It is in nerve centers that functional study finds evidence of forms of reaction which summate, that is can add themselves together both in space and in time, which nervous impulses cannot do. These reactions which can show summation do so chiefly in regard to the excitation of one cell by the next cell or cells down stream from or collateral to it in the cell chain as followed in its functional direction. Further at these neurone junctions (synapses), which always lie within the nervous centers, a process which is the polar opposite of *excitation* is found, i.e., *inhibition*. It, like excitation just mentioned, gives evidence of summation, but has for result the prevention or diminution or suppression of excitation. There is, however, no evidence that it can suppress impulses once started to traverse the nerve fiber. These processes of excitation and inhibition can much exceed in duration the brief nervous impulse itself.

Speed of communication and of reaction of one part of the body to happenings at another seems to be part of the "purpose" of this living telephone system. Although its microscopic structure and its elemental unit reactions exhibit an almost monotonous uniformity and process, the results which are their outcome are strikingly various and bear, as do so many of the body's reactions (but these even more obviously than most) the feature of "purpose." Thus, by their means a speck of dust in the eye sends messages thence far and wide over the body, all of them conducive to an obvious purpose. Its messages evoke (1) protective movement of the eyelids, (2) protective secretion of tears, (3) protective coming of the hand to the assistance of the eye and indeed a whole train of motor acts toward relief of the situation. Finally (4) that situation is reinforced and therefore protectively accentuated, until relief has come, by superadded mental experience, i.e., pain; the pain we note is likewise and no less than the rest of the train of reactions a sequel to, a product and accompaniment of, the neural reaction, mysterious though the relation between it and the material processes still remains.

The nervous system throughout the whole great class of animals known as vertebrate exhibits the same broad plan of construction, the same character of unit cells or neurones arranged in chains and with conductive thread-like fibers, and the same fundamental reactions, namely impulse conduction and the two opposed processes of excitation and inhibition. In man it does not depart from that plan or from those characters but merely offers the highest and most complex example of them.

It was said above that a main function of the nervous system is to enable quick appropriate reaction, by movement for the most part, to environmental events significant for the organism, for example escape from being made a prey, or the securing of prey or other food. The primitive nervous system of the more primitive vertebrates secures this end, within usually a more restricted range of circumstances than in the higher vertebrates, and so far as we can judge by little else than pure reflex action.

INTEGRATION BY PURE REFLEX ACTION

In the lower vertebrates the spinal cord forms relatively to the brain a much larger portion of the whole central nervous organ. Spinal reactions unaided by the brain operate a much larger part of the acts of the animal than in higher forms. There is no evidence that mental experience enters into any of this spinal operation; its reactions appear to follow mechanically and automatically, and for that very reason are termed reflex. This "spinal" life concerns itself in these animals with attitude, locomotion, breathing movements, movements for grooming the skin, and defending it from parasites, movements of escape from local injury, the actual swallowing of food, and so on. The reflex actions thus exhibited are themselves of various grades of complexity. Reflex actions of various grades such as obtain in animals make up also a large part of the functioning of the nervous system of man. Integration by reflex action is a part of the integration which his nervous system effects for man, and an important part. His reflexes perform many sorts of useful acts for him throughout his waking day, not to speak of some, such as his reflex breathing, which continue during his profoundest sleep. This "reflex" life of man is sufficiently many-sided to relieve the mental portion of his nervous system from much that, were matters not so, would occupy it and preclude his attention, one would suppose, from higher things.

Of this reflex life one field which is particularly primitive is that concerned with the viscera, particularly the digestive, and their movements. Such movements, though rather complex, occur with digestive periodicity, largely regulated by lower and primitive centers of the nervous system, and during health they pass practically unperceived, indeed the mind cannot by any effort of attention attain perception of them. Another related primitive reflex or set of reflexes concerns the movements which, ventilating the lungs, are indispensable for breathing. These, although themselves in essence purely automatic, illustrate the close touch which can obtain between the "reflex" and the "mental." We can hardly think about our respiratory movements without

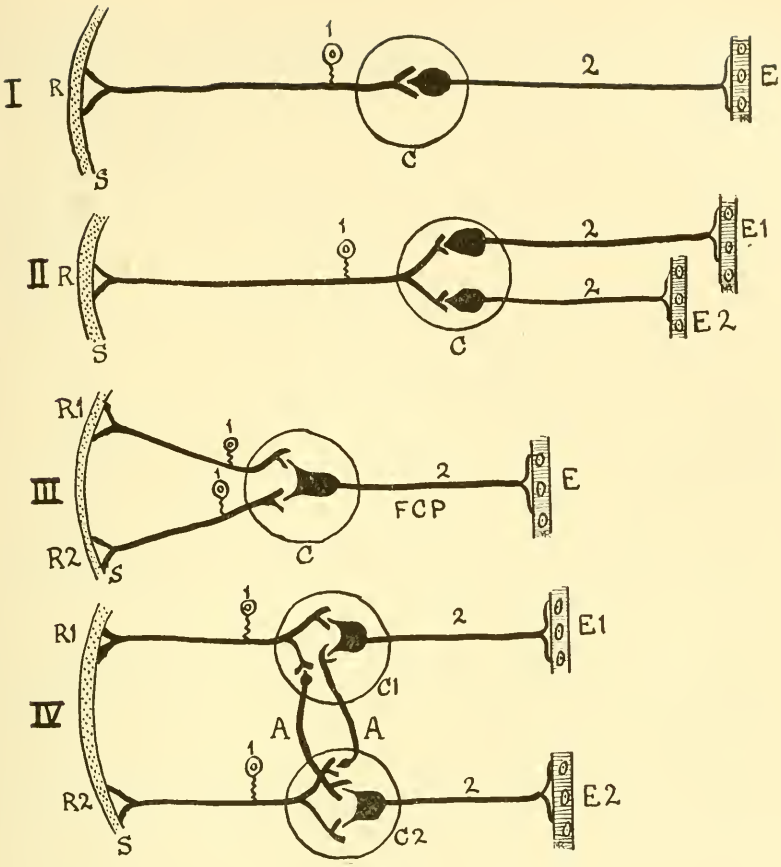

FIG. 1.

I. Reflex arc with two elements, receptor and effector.

II. Reflex arc with one receptor and two effectors, illustrating how, through branching in center, one sensory neurone may influence more than one motor neurone.

III. Reflex arc consisting of two receptors and one effector, illustrating principle of convergence; axone of motor neurone is referred to as final common path.

IV. Diagram showing interaction of two separate reflex arcs through association neurones A.

In all four figures letters indicate following: R, receptor; S, surface of body; E, effector (skeletal muscle); 1, ganglion cell of receptor; 2, axone of effector; C, central nervous system, e.g., center in spinal cord; FCP, final common path; A, association neurone in central nervous system.

altering them, although they are reflex. This touch attains its closest in instances where as in man the expiratory movement is regulable by the higher and so-called volitional

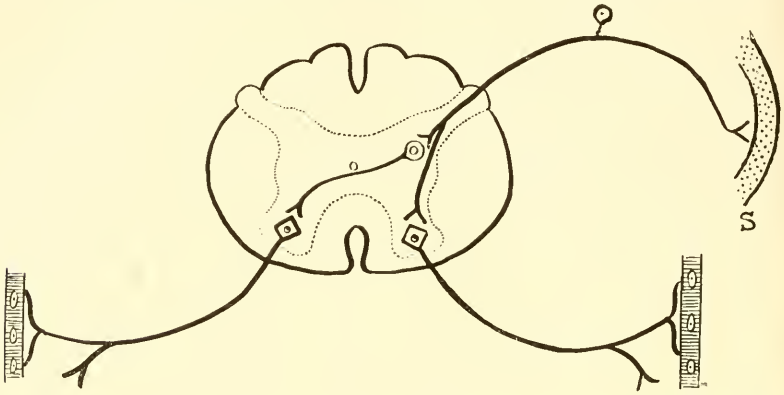

FIG. 2. Schematic cross section of spinal cord, illustrating control which may be exerted by a receptor over effectors on two sides of body. One motor neurone may, through peripheral branching, supply many muscle fibers.

centers in order to serve the vocal organ for speech, man's language having become a supreme mode of expression for his mental experience.

Turning next to acts in which we employ the muscles which are familiar to us as moving our bony frame in trunk and limbs, much of the reflex activity of the nervous system is devoted to exploiting this field for many purposes of life. Regarding these muscles it is to be noted that although we have already likened them to motor machines at the disposal of nerve centers driving them from without, they are in fact instruments not purely passive under that drive, for they possess receptors of their own intrinsic within themselves, and can report and send messages on their own behalf into the central exchanges. They have some voice in their own conditions of service, and the messages by which they thus express themselves are termed proprioceptive. The proprioceptive reflexes are peculiarly remote from mental experience and lie quite beyond our self-examination by any effort of introspection. But they habitually exert a self-regulation upon the muscular activity not only during

purely reflex acts initiated from receptive sources outside the active muscles themselves, but during the execution of even highly volitional acts. One set of the proprioceptive reflexes arising intrinsically in muscle reinforces the muscular contraction. A pull upon a muscle, whether passively given or occasioned by the active contraction of the muscle itself stimulates tension organs in the muscle and its tendon and these receptors tend to excite reflex contraction of the muscle and can reinforce contraction already present. Active contraction itself stimulates certain other end-organs within the muscle connected with the muscle fibers themselves, and these again exert a reflex influence on the driving nervous center. The intrinsic reflex (proprioceptive) influence developed by the muscle itself on the nerve center immediately driving it consists probably of opposed influences of excitation and inhibition in various degrees of balance. This is a fundamental factor in the normal behavior of our muscles and its loss by disease may cause grave impairment of posture and movement, and especially of skilled acts.

Among the acts which, using these partially self-regulated muscles, the nervous system of man, like that of many lowlier organized beings, integrates essentially reflexly, is that of maintenance of the erect position. How essentially reflex this act is becomes evident from the competent way in which in its two habitual forms of standing and stepping it goes on without making any continuous demand upon our mental attention. Conversation may seem to engross the mind wholly while we stand or walk. Aristotle and his peripatetics promenaded while discussing philosophy. In the reflex basis of standing and stepping the nervous reactions of man resemble fundamentally those of the animals, save for the important detail that in man the vertebral column is balanced vertically and the forelimbs are free of the ground. The essence of the reaction seems to be that the superincumbent weight of the body tends to put tension upon and thus to stretch certain of the muscles, so exciting them through their own reflex arcs to reflex contraction. A widely distributed set of muscles so placed as to antagonize gravity in the erect attitude of the body is found to be

especially sensitive to this proprioceptive stimulation by passive stretch. This antigravity reaction of the muscles themselves is reinforced by adjuvant reflexes operated by pressure of the foot upon the ground. The whole many-muscled reflex is further modified by reflexes originated by two tiny gravity organs lying in the bony wall of the skull, and forming part of the inner ear, though not themselves auditory. These little sacs contain small crystalline "stones" loosely attached to sensitive nerve patches. According to the position of the head the stones press or drag upon the nerve bed in this or that direction and to this or that degree. These cranial gravity sacs have through their nerves and the lower nervous centers the power of modifying the gravity reflexes of the antigravity muscles.

It is abundantly shown by experiment in the higher animals that the standing posture and stepping, walking or running can be executed after destruction of all the higher parts of the brain and certainly after removal of all that part which may be termed the "mental organ." Not only does the purely reflex animal stand and step, but it can when displaced from the erect position reflexly regain it and restore itself, head, body and limbs and all to that posture. A remarkable manoeuvre exhibited by the cat is that when inverted and let fall from a short height, it rights itself in the air and alights on its feet. This manoeuvre is executed perfectly by reflex action after removal of the animal's entire higher brain; cinematograph analysis of the act shows that it is then performed exactly in the same way. Observations upon human infants with congenital non-development of the higher brain have revealed in them also righting reflexes resembling those of animals.

To these reflexes of habitual attitude and locomotion can be added a number which bear the purpose of self-protection. Thus the reflex quadruped will, if it hurts one foot, go on three legs with the hurt foot held up out of further harm's way. The ear of the purely reflex cat will flick and throw off the fly which settles there, not less promptly than does that of a normal cat. So too the dog scratches itself, grooming its coat by a rhythmic movement

of the hind foot, and this occurs after severance of the spinal cord. The shoulder-skin irritated by parasites then evokes still the same scratching movement of the hind limb, although both the skin and the muscles are beyond means of appeal to any portion of the brain. The scratching thus performed as a pure spinal reflex does however often lack the precision of direction which higher and cerebral control can give it. Instances in normal man of simple protective reflexes are, besides the closure of the eyelids against a blow, the expiratory movements, cough and sneeze, which remove irritants from the respiratory passage; also the involuntary holding of the breath against an irritant vapor. The purposive character of reflexes is evident.

In man severance of the spinal cord is followed immediately by a period of depression of function in that part of the cord cut off from connection with the brain. This period of shock lasts for weeks or months. It is as though in man the higher nervous centers so greatly contribute to the driving of the spinal (lower) mechanisms that the removal of that drive upsets the spinal mechanisms for a long time. In most animals this is far less so, e.g. dog; but the monkey in this respect resembles man. In man the spinal reflexes released from higher control tend to be mainly flexor in type. There is a spread from one spinal center to another, so that contraction of the bladder, and profuse sweating may accompany flexion of both legs; this generalized spinal reflex response is termed the "mass reflex."

The Decerebrate Animal. We may now pass from the spinal condition in man to a more highly integrated state, usually referred to as the decerebrate condition. The condition, which is brought on by removal of the nervous organ anterior mid-brain is well recognized in animals and has been thoroughly investigated. (See Chapter IV.) A decerebrate animal is capable of standing albeit the posture is an exaggerated caricature. Movements are well coordinated and graded so long as the cerebellum remains intact. The decerebrate condition is also characterized by a series of striking reactions known as the neck and labyrinthine reflexes. Rotation of the head to the left, for example, causes increase in tonus of the extensor muscles

on the left side, so that if the animal chooses to seize an object to the left of him the limbs on that side are ready to support his weight when he takes off with his right foot. The same reactions are exhibited by human beings when in a decerebrate condition. Indeed, to the neurologist the occurrence of neck and labyrinthine reflexes in man is an important diagnostic sign. These reactions offer still another instance of the more complicated field of integration which one encounters on examining the higher levels of the brain stem.

The Cerebellum and Bulb. Lying over the bulb in intimate anatomical association with it is the large convoluted organ known as the cerebellum. If this is removed, the rest of the brain stem being allowed to remain intact, orderly locomotion and delicately adjusted skilled movements become forever impossible. Extirpation of the cerebellum, however, produces no effect upon the mind. The wildly incoordinated character of the movements which result from a cerebellar lesion is usually referred to as "cerebellar ataxia." The way in which the cerebellum operates to secure delicate adjustments of the voluntary muscles is still to some extent a mystery. No reflex, for instance, is known to occur in normal animals which does not also take place after the cerebellum is removed. The anatomical relations of the cerebellum, however, provide important information as to its probable mode of action. It is known that the great proprioceptive system of sensory nerves arising within the skeletal muscles (tendon organs and muscle spindles) send large fiber tracts which pass up the spinal cord and into the cerebellum, eventually terminating within the cerebellar cortex as do other large groups of fibers which descend from the cerebral hemispheres. Emerging from the cerebellum are other fiber tracts which descend via the red nucleus to the motor neurones of the spinal cord, immediately subserving the skeletal muscle fibers. Electrical stimulation of the cerebellum sometimes causes excitation, and sometimes inhibition of the voluntary musculature, but more often a mixture of both in the musculature as a whole. Consequently, one may conclude that the cerebellum can bring to bear both excitatory and

inhibitory influence and that by virtue of its rich receipts from the sensory endings in muscle it exerts an influence appropriate to the particular reaction in progress, so securing

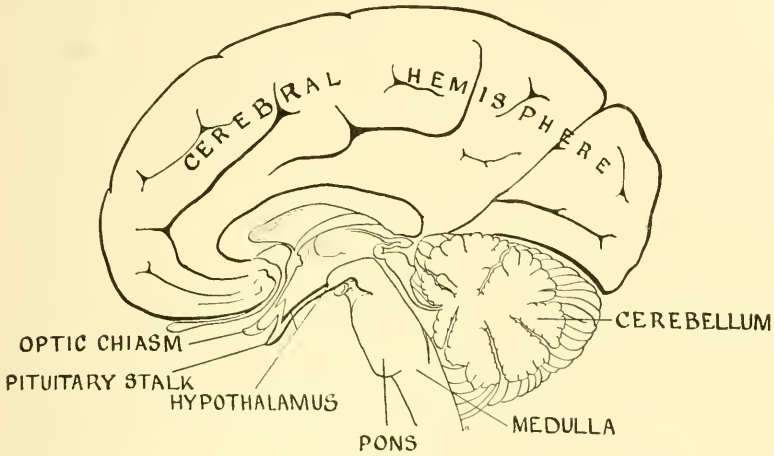

FIG. 3. Median sagittal section of human brain, showing position beneath cerebral hemispheres of cerebellum, medulla and hypothalamus.

an orderly adjustment of the movement. When movements are initiated through activity of the cerebral hemispheres, the cerebellum, through its cerebro-ponto-cerebellar connections, is notified of the intended act, and adjustments are automatically made to bring about its harmonious execution. The adjustments facilitated by the cerebellum involve regulation of the reciprocal activity of antagonistic muscle groups as well as of the so-called synergic muscles.

The activity of the cerebellum is not confined to the skeletal muscles; it exerts also a regulatory influence over the eye muscles, the vocal cords, and the muscles of deglutition. Destruction of the cerebellum causes, for example, characteristic changes in the voice, the speech becoming thick, monotonous and slurring (ataxia of the laryngeal muscles), and swallowing usually becomes to some extent impaired though not impossible. It may be, however, that the dysphagia of cerebellar lesions is due, not to destruction of the cerebellum, but to injury of the subjacent centers of the medulla (bulb).

The nervous organ (the bulb) which immediately directs and executes swallowing is a lower non-mental center like the cerebellum and the spinal cord. The mental organ, however, is able to get into touch with the bulbar organ. The swallow, moreover, is unlike the previous steps in the train of behavior directed toward obtaining food, since it cannot be initiated by the mental organ *per se*. We cannot swallow unless we have something to swallow; the act is essentially a reflex and requires a local stimulus. Further, when once initiated it cannot be arrested by the mental organ; it must take its course, hence the bitter powder once placed at the back of the child's tongue is safe from refusal if the swallow starts. And the final step of transit down the gullet is so wholly reflex, and the nervous system which it involves is so remote from mentality that ordinarily we cannot sense it at all, let alone voluntarily initiate or arrest it. The swallow is thus a reaction which, dealing with an object (food) which has formed the aim and goal of a whole train of mentally operated and supervised acts involving the central nervous organs, finally takes the object thus acquired and dismisses it abruptly from all commerce with mind. Although within the body, it will under normal circumstances never again come within the ambit of cognizance of the mental organs. A dog comes to the platter, and seizes the food; or in the case of man, he serves himself with his hand and some tool to pass the food to his mouth. Experiment shows that this stage of the act is impossible to the dog after destruction of that part of the brain, the cortex cerebri, which is the mental organ; similarly with man where lesions (e.g. tumors) of the cerebral hemispheres may, if extensive, cause a state of apraxia in which the individual, though unparalyzed, is quite unable to feed himself or to do so simple an act as to strike a match. A further phase in the chain of nervous reactions associated with feeding is the treatment of the food within the mouth by tongue and teeth, its mastication and its mixing with saliva. Experiment teaches that after removal of the whole "mental organ" these processes still occur. This, as a preliminary act to the swallow, an elaborately adjusted movement which transfers the food from the mouth across the entrance to the windpipe

to the gullet, and so to the stomach, this despite its complexity, can go forward after removal of all of the higher parts of the brain and the whole of that portion which we have termed mental.

The Hypothalamus. If the brain stem is transected so as to leave intact a few millimeters of the base of the brain, known as the hypothalamus, the preparation being otherwise the same as that used for study of the decerebrate condition, one observes a most striking series of phenomena. The animal is restless and exhibits periodic outbursts which have been appropriately termed "sham rage." The pupils become dilated, eyes protruded, fur erect and the animal may snarl, growl and show his teeth, and exhibit in addition periodic running movements. Occasionally, if gently patted the animal may purr and wag its tail inordinately and show other evidence of intense pleasure. In the small area of the hypothalamus there lie the centers for emotional expression, and when these are released from higher control the threshold for elicitation of emotional responses is lowered.

In man one sees the direct counterpart of such a state under the influence of certain drugs, notably ether, alcohol and "laughing" gas, when vigorous expressions of rage or of exceptional delight may alternate with surprising rapidity. Symptoms of acute mania associated with outbursts of activity of the sympathetic nervous system akin to the sham rage or to the expression of pleasure seen in hypothalamic animals have been observed in man after injuries to the base of the brain. From this and other evidence the hypothalamus has come to be looked upon as the chief ganglion of the sympathetic system, and the region of the brain chiefly concerned with emotional expression.[1]

HIGHEST NERVOUS CENTERS

The supreme outcome of nervous integration is mind, and in man mind dominates the organism. Could we look quite naïvely at the body as indwelt by mind we might perhaps suppose mind diffused throughout it, not localized in any one particular portion at all. That it *is* localized and

[1] The relation of the hypothalamus to emotional expression has lately been dealt with at length by W. B. Cannon (1927) and by his pupil P. Bard (1928).

that its localization is in the nervous system—can we attach meaning to that fact?

Taking as manifestations of mind those ordinarily received as such, mind does not seem to attach to life, however complex, where there is *no* nervous system, nor even where that system though present is quite scantily developed. The nervous system is that system whose special office from its earlier appearance onward throughout evolutionary history has been more and more to weld the body into one consolidated mechanism reacting as a unity to the changeful world about it. Mind becomes more recognizable the more developed the nervous system. Hence one difficulty in tracing mind to its origin is the twilit emergence of mind from no mind, which is repeated even in the individual life-history. But that in this system mind as we know it has had its beginning and has progressively with it step by step developed, is significant of the system. In the nervous system itself there is localization of function, relegation of different work to the system's different parts. This localization shows mentality not distributed broadcast throughout the nervous system, but restricted to a certain portion of it. And this particular portion to which mind transcendently attaches is exactly that where are carried to their highest pitch the nerve actions which manage the individual as a whole, especially in his reactions to the external world, animate and inanimate, outside himself. This part moreover is a comparatively modern structure superposed on the non-mental and more ancient other nervous parts. The mental portion is so placed that its commerce with the body and with the external world can occur only through the medium of the archaic non-mental nervous parts. This perhaps makes more intelligible the common and well-recognized experience that acts essentially reflex, such as standing and walking, are initiated and controlled by processess with mental accompaniments although not actually run by them. Thus, just as plants, for instance the pine tree on the rock side, orientate themselves to the line of gravity (geotropism) so, with greater speed and nicety of movement, does the animal, for instance the dog as it stands, runs, and so forth. It maintains the erect attitude; and as mentioned earlier

it does so essentially by a pure reflex, a geotropic reflex. The erect posture is the normal basis both in ourselves and in the dog for much of all the active reaction to the world that life and its behavior demand. Its observance and maintenance are therefore of eminent and fundamental importance to the organism. Maintaining the erect attitude is indeed nothing less than keeping right side up to the world in which it lives. What is the relation of the highest centers, the mental organ proper, to this great basic act of animal life of keeping itself right side up? As already stated the animal without its mental organ still stands and walks, runs and even jumps, and further can, if its erect attitude be disturbed, regain it. It is therefore less true to say that the animal under direction of its mind keeps itself right side up than to say that the animal body by automatic mechanism is kept right side up. From the animal's point of view, as a sentient being, for itself to be right side up to the world is, of course, for the world to be right side up to it. In other words, the body's automatism ensures that the mind looking, so to speak, out from the body, finds the world right side up. This relation is maintained by physiological reflex processes seemingly as non-mental as is the digestive secretion of the bile. Hence, this right-side-upness being settled without mind, and indeed prior to mind, and naïve mind being, whatever else it is, utilitarian, the situation has not invited and not had consideration from naïve mind. Mind has not troubled because it has not *needed*, so to say, to think about a relation already established and given it from the outset. This enables us therefore to trace how, in the make-up of mind, right-side-upness of the world comes as an innate unargued dictum, an immediate intuition, largely eluding mental analysis because there is wanting direct sense experience of its origin and of its elemental processes, although confusion in mental space results when its elements conflict. William James, with characteristic picturesqueness, wrote that "our prehistoric ancestors discovered the common-sense concepts," among them as he says "one-space." With that latter we may set "world right-side-upness;" but we must date its discovery further back than to our prehistoric ancestors. It is an immediate intuition and must

date back not merely to the prehistoric but to the entirely prehuman.

The portion of the human brain which on account of much and well-established evidence must be regarded as the material seat of man's mind is that great surface structure rooted in the forebrain and a relatively new excrescence from it known as the *cortex* and its fibers; and, probably subsidiarily to that, the *thalamus* deep underlying the cortex, and of far older evolutionary history. The thalamus forms a relay station for practically all of the nerve paths ascending to the cortex. The cortex itself is for the most part of comparatively late evolutionary history. The pre-mammalian vertebrates possessed merely a trace of it or none at all. The higher mammals, especially the monkey, possess it in large proportions. In man it is so greatly developed that even in brute bulk it dwarfs the whole of the rest of the nervous system. From the biological point of view it represents the very culmination of integration of the animal organism. It consists of two broadly symmetrical hemispheres, one right and one left. The relation with the voluntary muscles is for each hemisphere a crossed one, so that it is the left hemisphere which is concerned with the skilled acts of the right hand. A curious fact is that in right-handed persons the left hemisphere is functionally the more important mentally. Medical experience shows that small lesions of certain parts of the left hemisphere destroy speech and even memory, while similar lesions of the right hemisphere may pass for years unnoticed because productive of no obvious defect or symptoms. In fact the recent experience of brain-surgeons dealing with malignant growths indicates that the entire right cerebral hemisphere of a right-handed human being may be removed without there ensuing mental defects that are recognizable (Dandy), though of course the patient becomes in result of such an operation paralyzed on the left side.

This supreme development of the brain, the cerebral cortex, has the property of relatively quickly adjusting its reactions to meet various conditions. It can establish new functional habits requiring new functional connections. A dog secretes saliva when food is placed in its mouth;

that is a reflex innate and characteristic of the species. But a dog customarily fed by the same person may secrete sal va when it sees that person come at the accustomed time. This latter is a reaction for which it has been shown the cortex is needful. The cortex has the means of attaching the reactive act, e.g. salivation, innately resulting from a particular stimulus, e.g. food in the mouth, to another stimulus, e.g. visual image of a platter, if this latter stimulus has occurred for even a few times closely precurrent to the innately effective one. Individual experience with its repetitions during daily life of stimuli habitually closely associated in time finds the cortex therefore an educable nervous organ, by which the organism acquires numbers of adapted reactions meeting the vicissitudes of the environment. Man experiencing these reactions in himself is aware that accompanying these adapted and adaptable trains of acts and behavior there occur in him mental events which he distinguishes in some measure one from another as memorial, affective, conative, etc. This mental activity is so important to man that from our point of view it would seem the coping stone of the integration of the individual. It is therefore to the psychologist we must turn for fuller study of the final contribution made by the nervous system to the integration of man.

But to pass from a nerve impulse to a psychical event is to step as it were from one world to another. We might expect then that at the places of transition from its non-mental to its mental regions the brain would exhibit some striking change of structures. But no; in the mental parts of the brain still nothing but the same old structural elements, with essentially the same old features, set end-to-end in neurone chains as elsewhere, and evidently just as before serving as lines for travel of nerve impulses, and nodal points for their convergence and irradiation, their further launching by excitation, and their restriction by inhibition. We are here faced in perhaps its sharpest form with the age-old ever unsolved problem of the nexus between matter and life and mind.

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Chapter XII

THE INTEGRATION OF THE SEXES—MARRIAGE

Clark Wissler

ONE of the most difficult problems man faces is the understanding of his own community life. Modern society has proved so baffling that, in despair, many have turned to the study of primitive life, assuming that there the fundamentals may be found in high relief. Something has been gained by such study of primitive communities, but the result is rather disappointing, since experience proves it little less difficult to penetrate the complexity of a savage community than to comprehend a present-day town. Nevertheless, a little has been gained in the way of perspective, and looking at human community life in the large, the integration of the sexes is seen as the core of the structure. In the social science of the past, stress was laid upon the family, or the biological pair, which was considered the fundamental social unit. According to this conception, a community is an aggregation of mated pairs, engaged even in reproduction and the rearing of their offspring. In time, however, students of society came to feel that this was too narrow a view; there is still universal agreement that the rearing of children is the chief business of these mated pairs, but it nevertheless appears that a community is something more than a mere aggregation of such pairs. Everything we know of primitive man indicates that he is by nature a camp dweller, which is to say, that he lives in communities, or groups. Further, these communities are, in constitution, groups of cooperating mated pairs, with their children. One often meets the statement that in primitive communities there is no specialization in labor or social function, that each individual does everything for himself. This is contrary to the observed facts, because we encounter individual specialization in handicraft and organized team work, a savage camp presenting in outline a replica of a civilized community. So we can feel on safe

ground in assuming that one of the distinguishing characteristics of the species *Homo sapiens* is his biological equipment for group life. We may also agree with those who regard human community life as an expression of man's original nature. Of course, it is not the mere matter of living in a community that distinguished man, since some other living forms maintain such group life; rather should we bear in mind that the human community is in many respects unique, at least, easily distinguishable from others.

Looked at from the outside a savage community is an inbreeding, self-contained, group of human beings. The number of males rarely differs markedly from the number of females, on the average scarcely at all. In the discussion of the sex ratio, the relatively small differences between the number of males and females is given its due, but considered from the standpoint of our problem, we are justified in ignoring these smaller constant and local differences, at least for the present. So, one of the primordial biological conditions in group life is the division of the community into halves, one of which is male and the other female. It is now quite the fashion to insist that rationalization is something unreal and that it plays no part in the shaping of social affairs; so we shall not say that savage man rationalized on this matter. What we do propose is that there is in anatomy, physiology, and behavior, such an objective cleavage between the sexes, that human beings, being what they are, could not help responding to it. Nor could they well ignore what was always present and observable. It appears, then, that sex is one of the most natural objective lines of cleavage in a community. Consistent with this are the sharply defined distinctions between what women and men may or may not do. The line of sex cleavage cross-sections the life of the community, and, whether rationalized or not, it functions. In one way, it seems that man has improved upon nature by widening the gap between the sexes, by such secondary developments as costume, division of labor, and social procedure. On the other hand, there are evidences everywhere of more or less successful integration of function within the group. One form of such integration is marriage, the mated pair, and it is the knitting

of these pairs into a cooperating group that forms a community.

FORMS OF MARRIAGE

We are often told that society has but two alternatives: marriage or promiscuity. We are also told that promiscuity would prevail if it were not for the restraining hand of society. These statements do not reveal the true status of the human sex problem, but they do bring before us points of regard in contemporary thought. Taking up, first, the matter of marriage, we may select for study any one of several aspects of the subject, confining our discussion to it alone. Thus, we may look upon marriage as a biological phenomenon, solely. On the other hand, we may regard it as a social institution; again, as an economic adjustment to living conditions. Shifting our interest, we may take the ethnography of marriage as our task and so concern ourselves with describing existing forms of marriage and stating in what parts of the world they occur. This can be narrowed somewhat, by making it an anthropological investigation, and thus limiting the study to primitive peoples. Finally, one may consider only the history of marriage, and with the data available, attempt to discover the time order in which each form of marriage appeared. Also one may specialize in the history of divorce in Europe and America, the history of legislation regarding marriage, the rights of property in the marriage relation, etc. All of which shows how complex marriage is and how deeply rooted in society. It is not a simple phenomenon and there is no ground for expecting its cause to lie in a single controlling factor.

Naturally, a great deal has been written and said on the subject, too much to be summarized here, but, for purposes of orientation, we may enumerate a few of the important contributions so far made. Turning first to marriage as a social institution, we cite Westermarck's definition: "a relation of one or more men to one or more women which is recognized by custom or law and involves certain rights and duties both in the case of the parties entering the union and in case of the children born of it." While no definition can fully cover all examples of marriage, this one does meet

the situation with respect to the sex and number of the persons concerned. If, on the other hand, we consider the whole marriage complex, all its ramifications in society, then varieties may be discovered that fall outside the range of this definition, but at that it is a good working definition of marriage as a social institution. Yet, before we go far afield, it may be advantageous to consider the number of possible ways in which it is conceived the sexes be paired in marriage; these possibilities of union are as follows:

1. One man to one woman at a time—monogamy.
2. One man and two or more women simultaneously—polygyny.
3. One woman and two or more men simultaneously—polyandry.
4. Two or more men and two or more women simultaneously—group marriage.

So, taking marriage to mean matings of appreciable duration, formally sanctioned by the community, this list exhausts the possibilities. That is, if the group maintains a definite marriage system, that system must, in general outline, conform to one of these four types of matings. Now, as everyone knows, these four forms of marriage do occur in the world of today; an important fact to bear in mind, for those who contend that marriage is something invented by man, will give great weight to this exhaustion of the possibilities. They will say that here is proof that the form of marriage adopted is a choice on the part of the community. There are, however, certain relations between these four forms of marriage that discourage so simple an explanation.

It is sometimes assumed that these four marriage systems are mutually exclusive, which in practice would mean that when a community adopts one, it frowns upon the other. To some extent this is the case. Highly organized governments legislate the national form of marriage, which, in case of Christian nations, is monogamy. The other three forms of marriage are thus made illegal and punishments are provided for those who attempt such unions. On the other hand, certain non-Christian nations legalize polygyny and so outlaw polyandry and group marriage, but curiously

enough, they do not outlaw monogamy. This is consistent in one way, because it is the woman who is restricted to a union with one man, not the man who is limited to one woman. Long ago, Westermarck demonstrated that monogamy was tolerated everywhere, which he considered proof that monogamy was the original natural union of mankind. That this does prove it may be doubted, because a man usually marries one woman at a time; so he would first be monogamous, even though later polygynous. In the same way the first step in polyandry, the form of marriage in which a woman marries several men, may be monogamous, later polyandry and eventually group marriage. It appears then that the forms of marriage are not mutually exclusive in community practice, and that in dealing with the subject it would be fairer to regard the ideal of the community or nation rather than to count all the forms of union observed at a given time. A monogamous tribe would then be one in which other forms of marriage were frowned upon; a polygynous tribe one in which that form of marriage was the objective, even though a number of men had but one wife each. Looked at in this way, a census of the world may be taken to see what form of marriage prevails.

First, we may inquire as to what peoples live, or have been observed to live, without marriage of any kind. For such examples the records of explorers have been searched without success. Everywhere, marriage as a social institution is recognized and enforced, so we can say, with confidence, that marriage is universal. Westermarck and others made this clear long ago. It would seem then that marriage as a social institution is very old, probably the oldest surviving social complex. Not a few social philosophers and historians, as well, have regarded it as the foundation to the whole social structure. Whether this is a justifiable hypothesis or not, we need not pause to consider, but may return to the question of universality. As we have stated, there are four forms of marriage, all of which exist at the present time and that a savage community or a nation consistently approves one of these and frowns upon the antagonistic forms. In a world survey of marriage forms monogamy may appear dominant because it is the form followed by Christian

nations whose civilization is spreading over the world, and the tendency for all nations taking over this type of civilization, whether Christianized or not, is to adopt monogamy, for example, Turkey. So it is clear that monogamy is associated with a dominant contemporary world culture, and is being carried along with it. If we disregard this recent phenomenon and review the pagan and non-Christian peoples of the world, a different picture greets us. Polygyny now far exceeds other forms. Monogamy is next, however, after which come polyandry and group marriage. It is difficult to be exact, because of the varying nature of our information, but there seems little doubt that polygyny leads by a wide margin. On this ground, the views of Westermarck are opposed by some authorities who claim that not monogamy, but polygyny, was the original and is still the natural form of marriage. They say that "by nature man is a polygynous animal." Yet, origins to human customs are for the most part past finding out. Some have sought the answer in man's mammalian background, but some animals are monogamous, some polygynous, and some promiscuous. Our knowledge of the gorilla and other primates is not very specific on family matters, but there is reason to suspect them to be polygynous when conditions permit.

The one thing we can be sure of is that marriage is universal. Each nation and primitive community not only works toward the standardization of a marriage system, but gives its sanction to each marriage in a fixed procedure. This is the marriage rite or ceremony. It occurs in the presence of the relatives of the contracting parties, at least those of the bride, who have given their assent to the procedure. It is the business of those present to see that the requirements of the group as to eligibility have been met by the candidates. Marriage is so intricately meshed into the life of the community that the situation is always complex, but one function the ceremony serves is to give notice to the community that a marriage has been entered into.

PROMISCUITY

At the outset we cited promiscuity as the antithesis of marriage. True promiscuity implies no union other than the

most casual, the sexes remaining absolutely free. The group form of marriage, previously noted, would approach promiscuity, provided every woman in the community was married to every man; but group marriages as found do not include the whole tribe, instead a small number of men and women constitute a family. So, as previously stated, no where in the world do we find a community living in absolute promiscuity. Yet, there was a time when the view prevailed that a state of promiscuity preceded marriage; that one of the important steps in the evolution of society was taken when marriage appeared. Everyone assumes that marriage, like other social institutions, had a beginning, or that marriage was preceded by a state of no-marriage. But we have seen that marriage as a social institution may have been preceded by restricted mating similar to what is observed among many other mammals. The weakness of the promiscuity theory lies in the assumption that promiscuity is the only possible antecedent to marriage as a social institution. There is every reason to believe that the biological family functioned a long time before the form of society we now know came into existence. However, one of the strongest supporters of original promiscuity was Lewis H. Morgan, who arrived at this interpretation, not by free speculation, but by empirical observation. Discovering that primitive peoples had peculiar methods of reckoning relationship which took the mother into account, but did not distinguish between the father and other men of similar age, Morgan believed this to be a survival of an earlier form of human society in which the father was unknown and so indicated an antecedent stage of promiscuity. It is now believed that there are other interpretations to this phenomenon more consistent with the observed facts. However, Morgan seems to have been the only student of marriage offering a theory of promiscuity based upon objective observations, and since this theory has not stood the test of time, we may consider the case as not proved.

MARRIAGE AS A REGULATOR OF SEX LIFE

Our own social viewpoint encourages the inference that the primary function of marriage is to regulate sex life.

For one thing, we place a high value on the virginity of the bride, the chastity of the groom, and the strict observance of the marriage tie. All other peoples seem to put equal stress upon the fidelity of the married woman, but many, if not most, primitive peoples, care little for pre-nuptial abstinence. In fact, not a few primitive peoples look upon virginity among the unmarried as abnormal, or at least antisocial; whereas the irregularities of a married woman are vigorously condemned. There is then some justification in the notion that marriage, of whatever form, is a regulator of sex life, though often preceded by an initial period of approved license, and accompanied by varying degrees of laxity.

Among advanced nations a belief prevails that early sex activity and, naturally, early marriage, is injurious to the mother, as well as the child. This tends to postpone marriage several years after puberty. On the other hand, primitive people regard the appearance of the menses as evidence that the girl is of marriageable age. Thus, the primitive base their procedure upon definite biological evidence which is somewhat in contrast to the civilized method of legalizing an arbitrary age in terms of the calendar. When a girl in a primitive community begins to menstruate, the event is publicly solemnized by a ceremony and thus it becomes known that she is sexually mature. After this, marriage may follow at any time. Reliable statistics as to the age of marriage among primitive people are not available, chiefly because they have no means of accurately recording age, but it is safe to say that few girls reach the age of fifteen and remain unmarried, many of them becoming mothers at an earlier age. Yet, it is not only primitive peoples who indulge in early marriages, for we find them everywhere, in China, India, and to a slightly less degree in Europe. The laws of the United States also permit marriage at early ages under restricted conditions. Public opinion, on the other hand, now discourages such marriages, especially among those above the average economic level. Our educational practice may accentuate this attitude, since the national ideal is to furnish a public high school education to every girl, to attain which she must remain in school until about seventeen years old. If we add to this the ideal

of college training, to which a large minority in our population aspire, we see how the approved marriageable age for girls is advanced another four years. We all know how the ideals of the upper levels filter down to the lower, and so may expect in the country at large a rising average of marriageable age for women.

However, early marriage is frequently opposed on biological grounds. Medical opinion seems to condemn both early and late marriages as injurious to the mother, as well as to the child; but, as in many cases of this kind, satisfactory statistics are wanting. To furnish some objective data on this question Miss Stoner collected maternity records from hospitals in the United States. In these data the ages of mothers range from thirteen to forty-three, but, so far, the records fail to show any important differences in the health of the infants or of the mothers, except a slightly unfavorable average for those below seventeen years. However, the number of cases below that age is small, rendering even this result somewhat uncertain. Primitive girls are believed to mature earlier than European girls, but in such biological matters as this, it is the physiological age of the individual that counts. At least until it is shown that menstruation appears at different stages of bodily growth among different races, there is no reason for assuming that early marriage will be less favorable in one race than in another. Anyway man has survived, suggesting that the danger in early motherhood cannot be great, though it does follow that the mortality rate might be lowered by raising the marriageable age to seventeen.

So far we have not considered the marriageable age of the male. It is generally assumed that boys mature later than girls, but there is no certain proof of this. Baldwin reports spermatozoa appearing in the urine of some boys at eleven years, suggesting an earlier maturity than usually supposed. However this may be, it seems that among civilized countries the average age of grooms exceeds that of brides by two or three years. Some observations among primitive peoples suggest a somewhat greater disparity, estimated by Pitt-Rivers at seven to fourteen years. Where polygyny prevails and the tendency is for the older men to

claim the young girls, the disparity of age will be greater still. On the other hand, the scarcity of available brides may be so great that a number of young men will marry women much older than themselves. In general, however, the tendency is for the age of the groom to exceed that of the bride, whatever the state of society.

The term, child marriage, recently given wide publicity in "Mother India," suggests the marriage of immature girls to adult men. Such a marriage custom is found in India, where infant marriages are frequent and in cases where the male reaches maturity many years in advance, grave abuses may occur. Child betrothal, however, is widespread; usually it is found to some degree in all polygynous countries where competition for the marriageable women is keen. On the whole, however, society frowns upon the consummation of marriage before puberty, even the crudest of peoples regarding such practices as abnormal and injurious.

POSSIBLE BIOLOGICAL CONTROL OF MARRIAGE

In any consideration of social behavior and sex functions, it is well not to forget that whatever form institutions take, they rest upon a biological foundation. As we have stated, a discussion of marriage involves both biological and social factors, between which we cannot always clearly distinguish. It may be that the two are always in process of integration, the result being community life as we find it. Some of the biological factors involved are obvious, as the external sex characters, the physiology of reproduction, the urges that express themselves as interest in the opposite sex, love of sex companionship, jealousy, etc. Participation in sex life, as the functioning of the biological organism, may be said to involve psychological as well as physiological activities, more or less integrated. It is usual, however, to consider anything beyond the most temporary association of the human pair as not a biological matter, but a social or conventional one, to which the term marriage is applied. Here is the parting of the ways in the interpretation of human sex life. If one takes a birdseye view of the literature of the subject, from Morgan, McLennan, Westermarck,

to the most ultramodern advocate of promiscuity, certain assumptions are stated or implied. One of these is that, if biological factors alone ruled, all sex unions would be transitory, or promiscuous; the converse being that, when human sex life is observed to be otherwise, the conventions of the group bar the way. In other words, every individual would be promiscuous, if he were permitted. The alternative assumption, and one stoutly defended, is that biologically man is monogamous; that the association of one man and one woman tends to be of long duration, that occasional promiscuity and plural unions are social developments. It is observable that, in either case, the appeal is made to biological factors as determiners. It may be profitable, therefore, to consider some of the possible ways in which biological factors may control marriage, rather than the reverse. Our usual way of approaching problems of control is to consider biology the offender and society the disciplinarian. The danger here is in taking too much for granted.

Thus, polygyny has been explained as due to an excess of women, or to a variation in the sex ratio.

THE SEX RATIO

At the outset we assumed that in a normal community the sexes would be approximately equal, but careful investigations of the sex ratio in man indicates a slight tendency for males to predominate at birth. Here, however, we are concerned with the sex ratio at marriageable age, or the survival sex ratio. Even the birth-rate ratio for males and females is a survival ratio, for many die in embryo, concerning which reliable statistics are wanting. Again, the infant mortality tables for some national populations show sex differences in the survival rate, and vital statistics, in general, a difference in the death rate, the summation of which gives a higher survival ratio for women. This is evident in the census tables for Great Britain, United States, France, Germany, Sweden, and some other countries. In all of these countries monogamous marriages are enforced, from which it would appear that an excess of marriageable women is accumulating. This is undoubtedly true, but to see the relation of this excess to marriage calls for a careful

analysis of census data according to age. However, our present interest is as to whether plural marriages result from an excess of women. Or, to state the case in general terms, can it be shown that an excess of one sex over the other determines the form of marriage?

On logical grounds, assuming that every sexually mature individual will seek a mate, a system of monogamy could be followed only when the number of mature females approximates that for males. Otherwise, the enforcement of monogamy would meet with resistance on the part of the minority. Should there be a marked excess of females, then polygyny would be the most probable social adjustment. If, however, the males outnumbered the females, polyandry might be the solution. While, at first reading, such a causal relation may seem obvious, the weak point in it is that the regulation of marriage is a social matter, and there are still other solutions. For example, a monogamous community may be reasonably successful in preventing plural and random matings; another may be polygynous, without excess of females, the minority of unmarried males living celibate or in irregular polyandry. Merely casting up the possibilities will not help us here; to find to what extent, if any, the sex ratio influences marriage, we must approach the question empirically. One obvious procedure is to compare sex ratios among monogamous, polygynous, and polyandrous peoples.

Such a comparison is rendered difficult for want of data, since good statistics are available for monogamous countries only. Nevertheless, we have some information worth considering. Buxton reported for the New Hebrides island population a marked excess of males, amounting in one island to more than 10 per cent. Similar reports come from New Guinea and other islands in the Melanesian area, suggesting that whatever may be the sex ratio at birth, Melanesia as a whole tends to a marked excess of male survivals. The marriage systems for these islands vary somewhat, but on the whole tend to be polygynous, the older men claiming the young women. On the other hand, the Navajo Indians of the United States are also largely polygynous, but the females are in excess. The best known

polyandrous peoples are the Todas of India, among whom the males are markedly in excess of the females. These are fair samples of the data available and what we observe is that polygyny may flourish in an excess male population as well as in the reverse condition. But even should the correlation be regular, we should hesitate to regard the sex ratio as the determiner of the marriage system, since by infanticide and other means the community may so regulate the survival sex ratio as to conform to the marriage ideal.

The studies of Pitt-Rivers indicate no direct relation between the sex ratio and the form of marriage, but show that a declining population, regardless of the form of marriage, is accompanied by an excess of male survivals, and an increasing population by parity, or an excess in females. In the cases cited, the populations in the New Hebrides and that of the Toda country are declining, and that of the Navajo increasing, which is consistent with the conclusions of Pitt-Rivers. While it may be wise to reserve decision as to the general validity of this theory, it is clear that the sex ratio can no longer be considered an important initial factor in determining the form of marriage.

PROMISCUITY AND THE BIRTH RATE

Having shown that the sex ratio has in itself no claim as a determiner of the marriage form, we may consider the relation between birth rate and marriage. It is conceivable that if a form of marriage is highly unfavorable to a parity of the sexes, the groups practicing it will either die out, or be socially demoralized, and that in this way it should come about that one or two of the possible forms of marriage would dominate. Thus, it has been said that polyandry leads to extinction because the birth rate is low; but many groups of primitive people having other forms of marriage are dying out equally fast. Further, data upon the birth rate of primitive peoples are scarcely obtainable because mothers do not accurately recall the number of children they have borne. The attempts recently made to check up on the birth rates for Eskimo and American Indians are not conclusive, but as far as they go, indicate a birth rate as high as that of White Americans in colonial days. This

should encourage caution in dealing with the statements found in ethnographic literature. One of the arguments against polygyny is that it tends to reduce the birth rate, but studies in native Africa and elsewhere suggest that when economic and social conditions are similar, the birth rate for monogamous marriages is the same as for polygynous. In this respect, then, monogamy and polygyny are upon the same level. The case for polyandry is not so good, but there is still reason for doubting that the birth rate is seriously impaired by this form of marriage; for one thing, it seems to have existed in certain parts of the world for a long time.

On the other hand, promiscuity is under suspicion. It is generally believed that the few females in modern society who are promiscuous are rarely mothers. In many primitive populations a period of promiscuity precedes marriage and it is the belief of observers that pregnancies are rare during this interval. This implies that in a state of promiscuity, the birth rate will be near the vanishing point. Yet, too great weight should not be given this evidence, because such approximate sterility seems to result from intense sexual activity, stimulated by special conditions, whereas advancing age and preoccupation with the affairs of life might be expected to eliminate excessive unions and so approximate the normal conditions favoring reproduction. Prostitution is not peculiar to modern monogamous society, but occurs regardless of the form of marriage. Even in primitive communities prostitutes are to be found. The number of women so engaged is always small and though this number may rise and fall with the changing social complex of the group, it rarely rises above a negligible minority, and so cannot materially affect the birth rate as a whole. If then, a condition of absolute promiscuity should prevail, there is some reason to expect a lowered birth rate, which in turn might militate against promiscuity in favor of marriage. Also, there is some reason to believe that promiscuity would be incompatible with stable group life and would materially interfere with the proper care of children. So, on the whole, it seems a justifiable conclusion that there are biological obstacles to general promiscuity in favor of unions of reasonable stability

and duration. In other words, the community that does not maintain a well-ordered system of marriage is in danger of extinction.

THE PERIOD OF INFANCY

So far we have looked upon marriage as primarily a matter of mating, whereas the biological necessity in human life is the rearing of children. It is a reasonable expectation, then, that both the biological and the social aspect of marriage will be adapted to the child; hence, it would appear that marriage is primarily a social adjustment to the bearing and rearing of children, rather than to sex life. That primitive peoples have given thought to the child, there is abundant evidence. A child born out of wedlock is looked upon as abnormal, but not necessarily for the same reason that we assign to such happenings. In defence of these practices, they insist that the child and the mother need the care of a man, and where there is a child there should be both a wife and a husband. So taking account of the way even primitive peoples react toward the child bearing and rearing cycle, it appears that any serious consideration of marriage must recognize children as an important, if not the important element in the social complex.

The child, also, is a probable factor in the duration of marriage. In contrast to the young of other mammals, the child grows slowly, causing an overlapping of childhood in the family. If the child matured in a season, unions of short duration might suffice; but since a woman may bear children at short intervals for approximately thirty years, their childhoods will so overlap that, during this whole period one or more will be dependent. So the long growing period of the child, as a biological factor, puts a condition upon tribal marriage practice.

We have called attention to the reports of observers that some primitive tribes permit unmarried unions to continue until a child is born and it is usual to assume the truth of what is implied, viz., that the custom is for no marriage to take place until a child is born. If, however, it were the custom to postpone marriage, then an earlier

marriage would be irregular and so frowned upon, if not dealt with in harsh fashion. But a look back over the literature scarcely warrants such a statement. We may, therefore, entertain serious skepticism concerning the prevalence of marriage only when a child is born, until a more searching investigation makes it clear that such a custom does prevail in a large number of tribes. This is offered as a caution, for there is sufficient evidence that the ever present and necessary children are an important consideration in marriage, without falling back upon such assumed universal practices as the initiation of marriage only after children are born. It may well be, that all such cases are social demands, or that what the group feels should be, is marriage as anticipatory to the rearing of children. Even so interpreted, however, they are evidences of the universality of the belief that children and marriage are complementary.

Some alarm has been felt over such proposals as trial marriage, contract marriage, companionate marriage, etc., all of which have been proposed as checks upon the rising frequency of divorce. The ideas underlying these proposals are not new, but seem to have been tried one time and another. In Scotland, we are told that prior to the Reformation, there was a custom known as "hand-fasting," which was a trial marriage not to exceed a year, at the end of which period the couple married or separated as they desired. The reader of ethnographic literature is well aware that among many primitive peoples the prospective bride and groom, preliminary to marriage, live together as man and wife, often in the hut of the parents of one of the contracting parties. Such a trial marriage tests two important qualifications of the pair, fecundity and ability to support themselves economically.

In conclusion, then, it appears that a much stronger claim can be made for the long period of infancy as a determining factor in marriage, than for any other biological factor so far considered. Slow growth is also characteristic of the higher primates and one may expect more exact observations on the gorilla and the chimpanzee to give us further light upon this hypothesis.

SPONTANEOUS ATTRACTIONS AND AVERSIONS

Among the more intangible factors in human sex life are the spontaneous attractions and aversions between the sexes. Romantic love is supposed to be peculiar to cultured nations, but something like it turns up among the most primitive. Elopements are frequent among the Australian natives and in Africa the warrior is said to go into battle singing of his lady love. Aversions on the one hand and spontaneous attachments on the other seem everywhere to result in the breaking of law and custom and these unions are, for a time, monogamous. Here may be a reassertion of the basic behavior that forms the biological background to marriage. With these factors go jealousy and the effort to maintain the exclusive relationship set up, which also seem to be natural responses. In this way it seems possible to arrive at a behavioristic view of marriage, or at least to justify it as a social necessity in the harmonious functions of community life.

So far we have not referred to the aversion known as "incest." Though a great deal of thought has been given the subject there is still no unanimity of opinion as to whether incest is instinctive or conventional. All peoples make a distinction between an incestuous group and those among whom sex relations may be established, but these distinctions, while eminently practicable, are variable and arbitrary. If incest is an instinct, it is difficult to see what biological use it serves. The old idea that inbreeding was destructive has met with little support from experimental biology, though some doubt is expressed as to how incest would work in a small savage tribe which is, for the most part, inbreeding. In such cases incest would serve as the only check to free mating. But the inbreeding argument is so weak that most supporters of the instinct theory of incest fall back upon aversion toward those with whom one is closely associated, as parents and children, brothers and sisters. Psychologists, on the other hand, are disposed to regard the incest aversion as a result of repression. A survey of primitive practice reveals a universal taboo on unions of mother and son; the case for father and daughter is not so strong, because

there are existing forms of relationship which strongly hint of a time when fathers regularly married their daughters. Recalling that under primitive conditions the biological relation of the husband to the daughter of his wife is uncertain, such union may or may not be incest as we use that term. It is also true that brother and sister marriages, though unusual, are found among a few peoples. Cousin marriage, on the other hand, occurs in many parts of the world. However, most primitive groups set up arbitrary divisions between which the incest taboo holds. These rules are equally binding upon the married and the unmarried, the young and the old. In many cases death is the penalty for transgression. So, as a controller of sex activity, incestuous prohibitions are often more effective than marriage, even when so clumsily formulated as to be inconsistent with biological relationship. It is this inconsistency in primitive incest regulations that makes it difficult to explain incest as an instinct.

ECONOMIC CONTROL OF THE FORM OF MARRIAGE

Suppose at this point we turn aside to consider marriage as the economic integration of the sexes; perhaps that is too high-sounding a term, but society does seem to have an economic cornerstone. There is a school of thought which teaches that humanity sweetens the course of life by pretending that the stern unpleasant realities do not exist; perhaps that is why so many people reject the idea that society has an economic side. Their excuse is that such a statement is rank materialism and they further profess horror at the suggestion that marriage, the acme of sentiment, could have grown up as an economic adjustment. But when we face the realities of life, the truth of the old Chinese proverb comes to mind with special force, "After food and clothing are sufficient, honor and disgrace can be distinguished. After a regular stipend is guaranteed, good manners can be appreciated." One might with equal truth say that after the family is housed, clothed, and fed, the future looks bright. Anyway, the most serious business that confronts a social group, or a tribe, is to feed itself, and close upon the heels of this need are shelter and clothing.

Even the most thorough-going idealist admits as much and there is little need to do more than remind the reader of these homely facts. It is well, also, to remember that a primitive community is self-contained, but that it can only be so through differentiation of labor and orderly cooperation.

We have considered the force of certain biological factors in the shaping of marriage, but it is conceivable that economic factors also play a part. The researches of Hobhouse and others indicate that polygyny is far more frequent among pastoral and agricultural peoples than among hunters. This is attributed in part to differences in individual wealth and in part to the need for labor. Instead of a retinue of female servants the head of the family acquires wives whose children are also a labor asset. Monogamy, on the other hand, is almost non-existent among pastoral peoples. The economic relation is even clearer when we turn to such practices as "wife purchase," the custom being rare among hunters, but very frequent in pastoral and agricultural states. In general, then, we can say that economic factors in the life of the community do bear upon the form of marriage. Wife purchase, of course, results in regarding women as property, something particularly abhorent to our culture. Yet the male tendency to possess is fundamental, and the last thing a man is disposed to release is his woman. Modern communistic reformers seem to sense marriage as the bulwark of private property, and so usually try to set up communism in sex, so far without success.

When we take into account the sharp distinctions primitive people make between the work of men and women, it appears that one outstanding feature of modern life is the degree to which the sexes are integrated. Step by step, industrially, politically, socially and intellectually, the women of the civilized world are advancing to equal rights of participation in national life. This is a matter of current history and a subject with which the reader is familiar. Nor can it be said that the change has been wholly irrational or unconscious, because there have been and exist today, organizations of women, laboring to bring about further specific adjustments in their favor. Even the slogan "all sex distinctions must go" is familiar. Presumably, what is meant by "sex distinctions"

are conventions, social attentions, legal discriminations, political privileges, and obliteration, for the most part, of the objective "sex tags" society places upon the individual. Women sometimes charge industrial and political systems with being man made, demanding that society be revamped so that a woman can automatically take the place of a man and the reverse. The major premise of this syllogism has the appearance of soundness, and once granted, it would follow that the complete social integration of the sexes calls for a new system in which biological sex distinctions are to be ignored.

We may, however, appraise this ideal of modern woman by looking back upon our ancestors and upon living savages who resemble them. The popular idea of savage life is a social order in which the women do all the work and are barred from all pleasures of life; but upon closer inspection, this is not a fair characterization of the part woman plays in savage society. However, our concern at this moment is not so much with the amount and kind of work savage women did, as with the degree of specialization of labor with respect to sex. It does appear that in savage society the distinctions are sharp; few tasks are looked upon as appropriate for both sexes. If the women make baskets, the men leave them alone; if the women hoe the fields, the men stay away, and vice versa. We are often told that modern industrialism deprives woman of her aboriginal occupations. Thus, the baking of bread gradually passed into the hands of men; weaving and spinning, the ancient and honored work of woman, was gradually driven from the home to the factory dominated by man, and so on. But too much should not be made of this analogy, for there is evidence that even in savage society shifts occurred from one sex to the other; the question of importance is, as to how successful society has been in keeping vocations open to the sexes on equal terms. In modern savage society, as we have hinted, there are few, if any, specialized vocations without sex discrimination. On the contrary, these distinctions are so emphasized that they frequently rise to the level of taboos, and anything that is closely associated with one sex is approached by the other with caution. Every reader of primitive lore knows how rigidly

woman is excluded from the preparation for the hunt and for war; the explanation usually given is that men fear she will magically contaminate their weapons and offend their guardian spirits. But this is probably putting the explanation before the thing to be explained; the chances are that the segregation of the sexes is deep set in savage society and that these superstitions are afterthoughts in defence of the practice.

The adult who attempts to justify a social convention to a questioning child uses such secondary explanations, and those who recall such experiences can the better understand the savage mind. Yet this is of little moment at present, since we find savage society marked by what seems to us extreme segregation of the sexes, and the failure of any savage to conform to the tribal patterns of segregation would be frowned upon as a matter of course. What our women complain of is this same savage exclusiveness on the part of modern man. It is this old attitude, they say, which attempts to bar women from industry and from political life. If, however, this segregation, this resistance to integration, is as old as the race, we are justified in suspecting a biological basis. Recent studies of primates present in clear outline a distinction in behavior patterns between the males and the females. Female primates adjust themselves to a new situation by attitudes and movements of one kind, the males of the same species by another. These respective attitudes are seen in the adults of the species in purposeful association, not only in sex activity, but in other lines of action. This suggests that submerged in the organism of the human species are sex patterns which tend to segregate the sexes. In simpler terms, men have a group of response patterns peculiar to themselves, by virtue of which they draw apart from women. Women, on their part, are thrown together for similar reasons. The process is automatic, or at least subconscious. One or two women may readily adjust themselves to a group of men, or be harmoniously tolerated, and vice versa; but when, as in a normal human community, the number of each sex is about the same, each tends to respond *en bloc*, and thus they pull apart. This is much like what happens when dark and white races attempt to live

together, a small minority will not be disturbing, but a bloc will take form if this minority becomes formidable. The question then is, in how far can modern society overcome this tendency?

In industrial life, from time to time, new lines of work are opened to women, but we may ask, to what extent do men and women work at the same thing in the same place and time? More than once, it has been remarked that when women constitute a respectable minority in any trade or profession, men tend to shift to other lines. The usual explanation for this is economic, viz., wage competition, but the subject has not been studied searchingly enough to make it certain that this is the only factor or even the primary one, since it is possible that the segregation tendency is reasserting itself. As we have noted, even the most primitive of communities gets on by coordinating the segregated labors of the sexes, rather than by attempting wholesale integration; and there are signs that something like this is going on in modern industry.

Noting then, how segregation of the sexes with respect to work has been the rule in the past, we may consider how far biological factors control the kinds of work performed by women and by men. From the first, we see men handling the more violent tasks of life, women the routine work. Even primitive woman seems to have had leisure to indulge in basketry, pottery, and other like occupations, as a visit to a museum will show. Altogether, she had a varied life, but in modern industry, she specializes in what was formerly considered man's work. Yet, on the whole, we seem to find modern woman in industry engaged in occupations which require less muscular exertion and which otherwise remind us of her primitive labors. Nevertheless, again, we advise caution, because this subject has not received the attention it deserves, but the suggestion is that biological factors are operating now as in the past, to differentiate the work of men and women.

Some alarm is felt, however, because the organized woman's movement decries all distinctions, and seeks to put women into all kinds of work. The fear is that injury to health and offspring will result. Space does not permit a

review of what has been written on the biological fitness of women to do man's work, but from the very first, she has shown a capacity for hard work, and while on the average not so strong as man, she can, if need be, come sufficiently near that average to satisfy most requirements. Anyhow, modern society gives so much concern to the health and well-being of employes, that the danger here, if any, will be transitory; the expectation being that segregation will reassert itself along favorable lines. Again, the increasing economic independence of women is believed to impede marriage, to encourage divorce, and to stimulate birth control. If this be true, economic factors are not only controlling marriage as a social institution, but also exercising a control over the biological factors of reproduction as well.

DIVORCE

Current discussion of divorce often leaves one the impression that the practice is something new. On the contrary it is as old as marriage itself, for while a few primitive peoples are said to consider marriage insoluble, as do orthodox Hindus, these are exceptions. Hobhouse examined the data for 271 independent tribes, finding that in about 72 per cent of these the parties could separate at will, 24 per cent could do so under stated conditions, while in only 4 per cent was divorce barred. From this it appears that divorce is recognized almost as widely as marriage. As to the frequency with which these people exercise the option of divorce, one cannot be definite for want of statistics, but the casual observations of travelers indicate that divorce among them frequently exceeds the civilized rate. However, not being able to determine these frequencies, we cannot say in how far they are due to economic conditions. Yet, we can correlate the degree of divorce toleration with the economic type of culture; thus, the 271 tribes just referred to were about equally distributed between pastoral peoples, hunters and agriculturists, and these types, in turn, manifested the same degree of tolerance toward divorce. It would follow, then, that neither denial nor freedom of divorce depends upon the economic status of a people. This is consistent with certain recent stud-

ies which show no economic control over the divorce rate in the United States.

We have expressed doubt that the integration of sexes in industry was destined to be realized. On the other hand, our people have achieved a measure of success in educational and social integration. Such integration seems to work well in the secondary school and the college, and we should add, in church functions, social gatherings, and so on. In short, recreations, theaters, lectures, radio programs, newspapers, etc., are all enjoyed by the sexes in companionship. This is in sharp contrast to primitive and most oriental peoples among whom men and women rarely go about companionably or participate equally in social activities. We also regard this joint companionable participation as an ideal to be striven for, and so endeavor to bring about more complete integration. One peculiarity, however, is that all these activities are something apart from one's daily work, and are not in that sense governed by economic factors.

Further, it is ideal companionship of this kind that is usually cited as the objective in marriage, and there is reason to suspect that the high standards of companionship thus set up are responsible for part of the increase in the divorce rate. Again, as we noted above, the postponement of marriage and the realization of a high standard of education, may increase the difficulty in deciding upon a mate and even develop an aversion to sex life. Also, the statistics on divorce indicate that separations are relatively frequent among marriages in which brides are under twenty-two and grooms under twenty-five, and that the younger the one or the other, the more frequent the divorce. Also, marriages after twenty-nine and thirty-four, respectively, show a higher divorce rate, increasing with age. This means that the most stable unions are those for women of twenty-two to twenty-nine and for men of twenty-five to thirty-four. No doubt these data need rechecking, but they are fairly consistent with the logic of the situation. Women advocates declaring for the abolition of marriage and the economic independence of women say that in such an ideal society, women will become mothers whenever they are ready; but if motherhood is postponed until woman is economically in a position to support children, she

may find the necessary responses fully inhibited. Such radical proposals, however, are always upon the assumption that men will be non-resistant and that all women will be ruled by the head rather than otherwise, something biologically improbable. To return to our subject, it appears, then, that divorce occurs in all states of society, regardless of economic status and that a number of factors must be considered in assigning causes to the modern trend in divorce, the chances being that economic factors are the least of them. Many students of the subject now regard maladjustments in sex life and failure to realize the new ideal of companionable integration as the factors disturbing the stability of the marriage relation.

THE MARRIAGE OF THE FUTURE

However, so complex a matter as the integration of the sexes cannot be treated adequately in a brief sketch, for there are many other aspects of the subject to be considered before one can form a properly balanced view. Since, however it appears that a change in the degree and direction of sex integration is now under way, one is justified in trying to form some notion of the direction in which modern society is moving. The increasing economic independence of women, or economic integration, has no doubt contributed something to reduce the economic aspect of marriage, and anything that so tends throws the emphasis more and more upon child rearing and other biological relations. At the same time our social drift, as shown in education and companionship ideals, has emphasized the intellectual and emotional integration of the sexes generally, encouraging free association in recreation and uplift pursuits. The suggestion is, therefore, that the future marriage in our society will be a readjustment to biological rather than to economic factors.

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PART IV. EFFECTS OF ENVIRONMENT

Chapter XIII

THE EFFECT OF CLIMATE AND WEATHER

Ellsworth Huntington

THE CLIMATIC FACTORS

WEATHER, as everyone knows, is the natural atmospheric changes from day to day; climate is the sum total of the weather year after year. In studying their combined physiological effects it is advisable to begin with the individual factors of which they are composed. Temperature is the most important of these. Ordinary experience gives some idea of how temperature may influence human health and activity. It is not so easy, however, to appreciate the effect of *changes* of temperature, for changes often produce effects totally different from what the actual temperature as measured by the thermometer would lead one to expect. Humidity probably comes next in importance, but it is difficult to differentiate between the direct effect of atmospheric moisture itself upon the skin, nerves, mucous membrane and the like, and its indirect effect upon the *sensible* or "feelable" temperature. When the thermometer reads 70°F., unmoving air that is saturated with water feels warm, for its sensible temperature is high, but perfectly dry air feels cool because evaporation causes the sensible temperature to be too low for comfort.

The effects of wind are even harder to isolate than those of humidity. That the movement of the air has a direct physiological effect in addition to its cooling power is evident to anyone whose eyes have watered in a high wind. The wind also does much harm by carrying dust and other impurities. Yet its most important physiological effect is to lower the sensible temperature. Sunlight, the fourth great climatic factor, resembles both humidity and wind in being highly important because of its effect on our feelings of warmth or the reverse, and yet in producing its own individual effects of quite a different kind. The moment the sun's rays are intercepted we feel cooler, but the complete

effect of sunlight depends on how much radiation we receive from the red end of the spectrum with its long heat waves and how much from the blue end with its short-waved, highly active ultraviolet light whose chemical effects upon rickets and the like have recently been much discussed.

No study of climatic factors is complete unless it includes atmospheric pressure and electricity, but we shall mention them only to dismiss them. Time and again inexperienced investigators think that they detect a close relationship between barometric pressure and physiological activities. Such a relationship is, indeed, very evident when the low pressure on high mountains is compared with the normal pressure at sea level, but thus far the most painstaking investigators have had little success in isolating any clear-cut effects of the barometric variations at any one place. Supposed effects of this kind appear to be due almost wholly to the accompanying changes in temperature, relative humidity, winds and sunlight. As to atmospheric electricity, many little scraps of evidence suggest that it may exert an important influence upon human well-being. People appear to feel stimulated after thunder showers, or in factories where electric sparks are active, but no one yet knows whether the supposed effects are really electrical or are due to special combinations of temperature, humidity, and wind.

THE LAW OF CLIMATIC LIMITS

The physiological effects of temperature, humidity, atmospheric movement, and sunlight can best be understood in the light of two fundamental laws, those of climatic limits and climatic optima. Although both laws are almost self-evident, they are rarely understood or consciously used as the basis of adjusting mankind to his environment.

The law of limits may be stated thus: Almost every environmental factor may be so extreme that it is fatal to the individual, or prevents reproduction and is thus fatal to the species. Sometimes there are both upper and lower limits, and sometimes only one. Every form of life is subject to two limits of temperature. A rise of 100° in the temperature at

the earth's surface would destroy most forms of life excep near the poles. Some bacteria do indeed live in hot springs, while dormant seeds and spores can endure still higher temperatures provided the air be dry, but even in the lowest organisms reproduction appears never to take place unless the temperature is well below the boiling point of water. As for man, the obvious limit is a temperature such that the cooling mechanism of the sweat glands, skin, lungs and circulation is no longer able to prevent the body temperature from rising permanently above normal. Experiments indicate that even when healthy persons are at rest and practically unclothed, a temperature of 93°F. in saturated air is likely to cause the body temperature to rise as much as 5° in two hours—a genuine fever which would presumably increase and soon prove fatal if the atmospheric conditions were prolonged. In dry air a higher temperature can of course be endured; a century and a half ago bold experimenters remained uninjured in temperatures as high as 262°F. but even seven minutes of such air raised the pulse from the normal of about 70 to 144 beats per minute.

In Death Valley in southern California, a summer temperature ranging up to 120° or 130° each day for several months is practically unendurable, even though the air is very dry. A single season of such weather has been known to drive people crazy, and almost no one can endure two summers. A very strong woman might possibly bear healthy children in such a place and the children might grow up, but it is extremely doubtful whether any kind of human beings could stand the summer heat if it continued all the year.

As for the lower limit, many forms of life die promptly if the temperature reaches freezing. Some fairly high forms however, such as cold-blooded vertebrates like frogs, can be frozen stiff and yet recover completely when melted. No one knows exactly how low a temperature they can endure, but so long as they are frozen and dormant, there can be no reproduction and they are as good as dead. Hence for plants and cold-blooded animals a freezing temperature is practically the lower limit for the reproduction of the species. Warmblooded animals can reproduce at lower temperatures, and man seems able to withstand the lowest temperature of

all. But if the human race were not protected by clothing, shelter and fire, it would almost certainly fail to reproduce itself wherever the temperature falls far below the freezing point for any great length of time.

The limits imposed by humidity are clear enough at high temperatures, but fade away at the most favorable temperatures. If warm air is completely saturated, the absence of evaporation and the consequent difficulty which the body experiences in cooling itself make it doubtful whether the human species could keep on reproducing itself even though other conditions were propitious and the temperature no higher than 90°F. In Japan at the end of the hot damp summer the conceptions which result in living births are less numerous than the deaths. How much of this is due to high temperature and how much to excessive humidity it is impossible to say, but humidity is of decisive importance, for similiar temperatures with moderate humidity do not produce any such results. If humidities and temperatures like those of the summers in Japan and along the coast of South China persisted indefinitely the inhabitants would presumably diminish in numbers until natural selection had eliminated all who were unable to endure extreme humidity at the ordinary summer temperatures. Slightly higher temperature and humidity might easily prevent all reproduction.

We are not yet sure whether man is excluded from any part of the earth by the direct effect of a lower limit of humidity, although he is obviously excluded by the indirect effects upon water supplies and vegetation in places like the uninhabited southern part of the Arabian interior. In Death Valley, even when one does not feel uncomfortably hot, the dryness of the air makes one uncomfortably thirsty practically all the time. One drinks till his stomach is seriously distended, and yet is never satisfied, for the moisture content of the tissues cannot be kept normal. Whether such conditions would permanently prevent the reproduction of the human race we do not know. At lower temperatures the bad effects of extreme aridity diminish and there is no evidence that even complete dryness would in itself prevent human existence, provided food and water were available.

If the earth should be deprived of sunlight all life would soon perish, and the same thing would happen if the sunlight were sufficiently intense. Thus there must be both lower and upper limits of sunlight, but neither appears to be reached naturally on any part of the earth's surface. The dwellers in dense forests and in the Arctic region with its long night seem at first thought to get as little light as anyone, but as a matter of fact such people at certain times or seasons get a great deal of light either directly from the sky or by reflection from the snow. The people who really approach the lower limit appear to be the poorest workers in the factories of our smokiest cities. In some places such people may be slowly dying for lack of sunlight, even if other conditions are not intolerable. As to the upper limit, Woodruff, in an interesting book on "Tropical Light," maintained that the light within the tropics approaches the upper limit for the white man, but experiments on both men and monkeys indicate that much of the ill effect which he ascribed to light is really due to heat. Yet the intensity of the light may reduce human efficiency in the great tropical deserts. Long experience has convinced the Arabs that they need heavy, opaque clothing and headgear to keep out the sunlight. How far this is for protection against heat and how far against sunlight is not clear, but the trouble which such people experience from the desert glare is enough to show that the light is too strong.

The limits of atmospheric movement include almost complete quiescence at one extreme and intolerable gales at the other. If the air should become absolutely quiet, the exhalations from plants and animals, and from man and his works, would soon contaminate it to a degree that can scarcely be appreciated. Evaporation would saturate the the lower atmosphere with vapor, thus intensifying the ill effects of the gases and odors. Life would become intolerable. An approach to such conditions is found in a few sheltered and undrained valleys where volcanic gases temporarily accumulate, and in the streets and tunnels of great cities where the fumes from factories, automobiles and other sources poison the air. On the other hand, if the wind were to blow constantly with hurricane force, the larger forms of life

would doubtless disappear by reason of starvation, exhaustion or failure to reproduce. The nearest approach to a limit imposed by the wind is probably found in western Tierra del Fuego. There the winds of the "Roaring Forties" make life one long, cold, miserable struggle. A handful of lowly Alikaluf do indeed manage to survive in the more protected spots, but even they cannot live everywhere. In eastern Persia the almost equally violent "Wind of a Hundred and Twenty Days" prevents the growth of trees and makes life scarcely worth living throughout the summer, though it does not prevent the existence of a fairly abundant and moderately civilized population. But such a wind throughout the year, in the cold winter as well as the hot summer, might render the region uninhabitable.

Although the various kinds of climatic limits are not always sharply drawn, I have dwelt on them because the physiological relationships of all types of inhabited climates can best be grasped by thinking of them as lying *between* the limits and the optimum; we do not know of any climate which enjoys the optimum in all respects. Thus every climate is more or less unfit, a fact which entails most serious consequences as to health and progress. Another important generalization concerning man's climatic limits is that in practically all cases they fall not far from the most extreme conditions that now exist upon the earth. Perhaps this merely means that man's mentality has enabled him to overcome most of the climatic handicaps which he has yet encountered. Presumably the limits can be pushed back still farther, but for thousands of years to come they are likely to be a vital factor in human existence. This becomes more obvious when we remember that there are at least three great sets of limits—individual, racial and cultural. Even in the earth's uninhabited climatic borderlands such as the ice sheets of Greenland and Antarctica and the hot desert of southern Arabia, individual members of the human race can undoubtedly survive indefinitely; therefore such regions are not beyond the outer climatic limits, but whether they are beyond the limits where healthy children of our own race can grow up is by no means so certain. And even if they lie within the racial limits, does the physiological handicap of

the extreme climate leave the people enough energy for the advancement of civilization? Both history and geography seem to answer in the negative, for the intrusions of civilized people in such regions are sporadic and temporary and the permanent inhabitants invariably stand very low in civilization.

The Onas of Tierra del Fuego, the Indians of the moistest Amazon forests, the primitive pre-Arabic people of central Arabia, the most northerly Ostiaks and Samoyedes of Siberia, and the shepherds of the highest, coldest parts of Tibet illustrate the two-fold effect of life near the climatic limits. Such people are kept in a low stage of civilization partly by their inability to wrest from their poor environment a sufficient surplus of food and other commodities to give them the leisure to make new inventions and devise new modes of life, and partly by their tremendous physiological handicap. They must indeed be constitutionally vigorous in order to survive, but a large part of their vigor is consumed in resisting extremes of climate. Bitter cold, intense heat, over-powering sunshine, or hot, enervating humidity may not kill a man or even make him sick, but they diminish his surplus energy. He uses up so much of his strength in keeping his blood at the right temperature and so often fails to do this that in his leisure moments he is tired and sleepy, and rarely possesses the extra energy which enables men in better climates to advance civilization. Thus the climatic limits of civilization or progress seem to be much narrower than those of the human race as a whole, and those of the race are narrower than those of the individual.

CLIMATIC OPTIMA

1. *Temperature.* Interesting and important as are climatic limits, they do not concern us so closely as do climatic optima. The optimum or most favorable condition for each climatic factor varies in accordance with the other factors, but if those other factors remain constant, the optimum for any one factor can be fairly accurately determined. The optimum temperature for various living organisms is shown in Figure 1. Low temperature is represented on the left and high on the right; the vertical height of each curve

indicates the efficiency of the life process at any given temperature. At the bottom the generalized curve for the growth of plants indicates that at 50°F. the ordinary plant

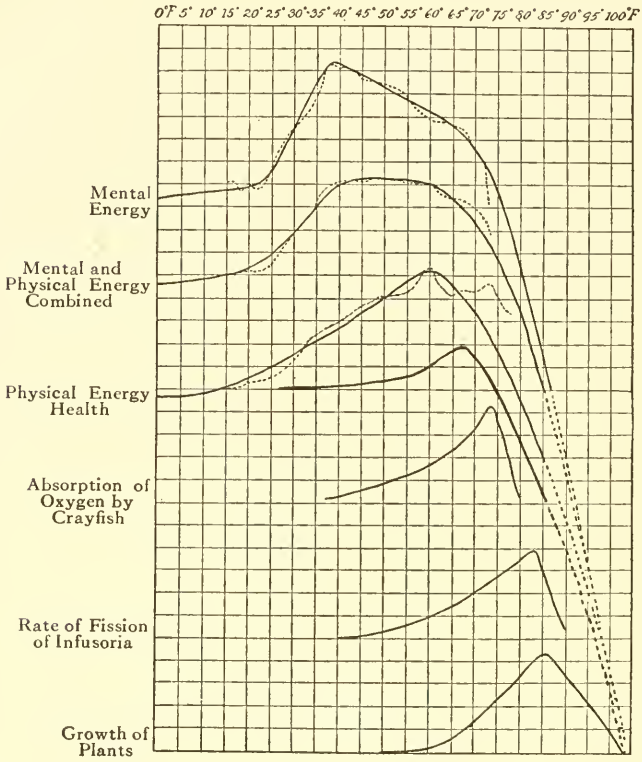

FIG. 1. Mean Temperature and Vital Processes.
(From Huntington's Civilization and Climate, ed. 3, Yale Univ. Press.)

makes no growth; at 55° growth is very slight, and at 60° slow; but at higher temperatures it rapidly increases and reaches a maximum at 85°. Above that level the rate of growth rapidly diminishes and the plants die if the temperature for night and day together averages above 100°F. In this curve, as in the others of Figure 1, all conditions of humidity, air movement and sunlight have been averaged together, so that they neutralize one another, and the resultant curve represents only the effect of temperature.

The second curve from the bottom in Figure 1 shows Prof. L. L. Woodruff's measurements of the rate of fision among the lowly one-celled infusorians known as paramoecium. At 40° no fision and hence no reproduction take place; higher temperatures are accompanied by increasingly rapid fision until the optimum is reached between 80° and 85°. In a still warmer environment reproduction diminishes rapidly and finally ceases at about 95°. The total activity of animals like the crayfish may be measured by their absorption of oxygen as shown in the next curve. Here the phenomena are almost the same as in the other cases, with an optimum at about 74°.

The other four lines in Figure 1 represent human activity. The lower, marked "Health" is based on the work of the National Research Council's Committee on "Atmosphere and Man." In shows the daily deaths of persons five years of age and over in New York City on and immediately after days having the temperatures indicated at the top. It has been inverted so that the high portions mean good health and low portions poor health. The resemblance of this curve to those for plants and animals in unmistakable. The only important difference is that the left-hand portion tends to become horizontal at a level much higher than that to which the other end descends. This merely indicates that in cold weather mankind protects himself against low temperature in a way that is impossible for other creatures. At high temperatures however, he does not protect himself and therefore his health diminishes just as does that of animals and plants. The highest point or optimum comes when the temperature for day and night together averages 66° to 70°. Numerous other investigations give a similar result except that the optimum appears on an average to be slightly lower, namely an average of 64° or 65° for the entire twenty-four hours.

The next curve, "Physical Energy," shows the amount of piece-work accomplished by five hundred men and women in Connecticut factories on days with various mean temperatures. Its resemblance to the line for "Health" need hardly be pointed out. There is the same tendency toward levelness on the left, and the same rapid falling off at high tempera-

tures. The chief difference is that the most rapid work is done when the outside temperature averages 60° for day and night together instead of 66° to 70°. One reason for this lower optimum is doubtless that when people are at work they warm themselves at least a little and therefore prefer a temperature somewhat lower than that which is most favorable for people who are inactive, and for those who are ill. Perhaps, too, the lower optimum means that in the work of factory operatives not only physical energy but mental activity is required so that this curve tends somewhat to approach the mental curve which lies just above. The optimum for football is obviously much lower than for factory work.

The curve for "Mental Energy" represents the scholarship records of about sixteen hundred students at West Point and Annapolis. It resembles the curves for health and physical energy except that the optimum lies at about 38° and there is a plateau from that point to the physical optimum at 65°. Although the reliability of this curve is not so great as that of the others, several investigations confirm the general thesis that the optimum temperature for mental activity under our conditions of clothing, housing, and diet is lower than that for physical activity.

Taken as a whole, Figure 1 illustrates the laws of both climatic limits and climatic optima so far as temperature is concerned. It suggests that for every living creature there is a distinct degree of activity for every condition of temperature. The activity is highest at the optimum; with lower temperatures it falls off rapidly at first and then more slowly until the lower limit is reached. Above the optimum the activity tends to decline rapidly and under all circumstances appears to cease at least by the time a mean temperature of about 100° is reached. The exact position of the optimum appears to vary from one individual or race to another, but the general law is of universal application.

The four upper curves of Figure 1 illustrate the further law that the optimum temperature varies according to the type of activity. When taken together they suggest that so far as temperature is concerned the best climate for people of European ancestry who live under our conditions

of clothing, housing and diet is one where the summer months are close to the physical optimum and average about 65° with daily maxima of 70° to 75° and night temperatures of 55° to 60°, while the winters approach the mental optimum with midday temperatures of 45° to 50° and mild frosts at night. London and the southern end of Puget Sound approach this as closely as almost any places; Oakland in California, Santiago in Chile, Wellington in New Zealand, and the Australian seacoast south of Melbourne also come near to it, although a little too warm in winter. But not even London or Puget Sound has an ideal climate, for other factors as well as temperature must be considered.

2. *Humidity*. In attempting to determine the optimum humidity it is essential to employ a method such that the overwhelming effect of temperature does not hide the effect of humidity. One excellent way is by means of climographs. A climograph is one form of what I have called an *isograph*, which is a general name for a kind of diagram in which two variables are represented by the horizontal and vertical ordinates and a third by isopleths or lines representing equal degrees of intensity. A contour map is a familiar kind of isograph. On such a map one variable is latitude which we measure up and down, or along the vertical ordinates as the mathematician puts it; another is longitude which we measure east and west, or along the horizontal ordinate; the third is altitude which were represent by sinuous contour lines. All points along the coastline are at sea level, or on the zero contour; all points a thousand feet above sea level lie along the thousand-foot contour, and so on until a small area of the highest land may be enclosed by the twenty-thousand-foot contour line. By coloring the space between sea level and the thousand-foot contour dark green, the space between the thousand- and two thousand-foot lines pale green, and so on with different shades up to dark brown for high altitude, we get a map which gives a general picture of the height of the land.

A climograph is simply another form of isograph. In the one given in Figure 2 latitude is replaced by temperature, longitude by relative humidity, and height above sea by the

death rate. In other words climatic *conditions*, regardless of their geographic location, take the place of distances east and west or north and south, and excess or deficiency of deaths is substituted for height of the land above or below sea level. Figure 2 illustrates how the matter works out for 3,700,000 deaths in the cities of France and Italy. In the upper left hand corner the number 31.6 is located at the high monthly temperature of 82° to 83° and the low relative humidity of 45 to 50 per cent. It is based on all months with that kind of weather no matter what city or year they occurred in. For each month the death rate for the city in question is first expressed as a percentage of the normal death rate, that is, of the rate to be expected in that city in that particular year when due allowance is made for the steady improvement in medical methods. In the case before us the percentages for several months in several cities averaged 31.6 *higher* than the normals for the places and years of their occurrence.

Run down the figures below 31.6. The relative humidity remains constant, but the temperature becomes lower. The percentages likewise diminish steadily, then they begin to have minus signs; and finally at a temperature of 67° to 68° the deaths average 7.8 *less* than the normal. Skip now to the next column and begin with −9.4 at a temperature of about 64° and a relative humidity of 50 to 55 per cent. Passing from this number to the right, we maintain the same temperature but reach higher degrees of atmospheric humidity. The death rate steadily diminishes until at a relative humidity of 85 to 90 per cent it averages 14 per cent less than the normal.

Now that we understand what the figures on our isograph mean, we can draw isopleths which will be like contour lines. Each will pass through all points having a given departure of the death rate from the normal. The central solid line in Figure 2 is the isopleth indicating 10 per cent less than the normal number of deaths; the lines above and below represent 5 per cent less than normal, then come two solid lines, the normal. Beyond that the dotted lines indicate a greater and greater excess of deaths above the normal. In spite of some irregularities on the edges where the number

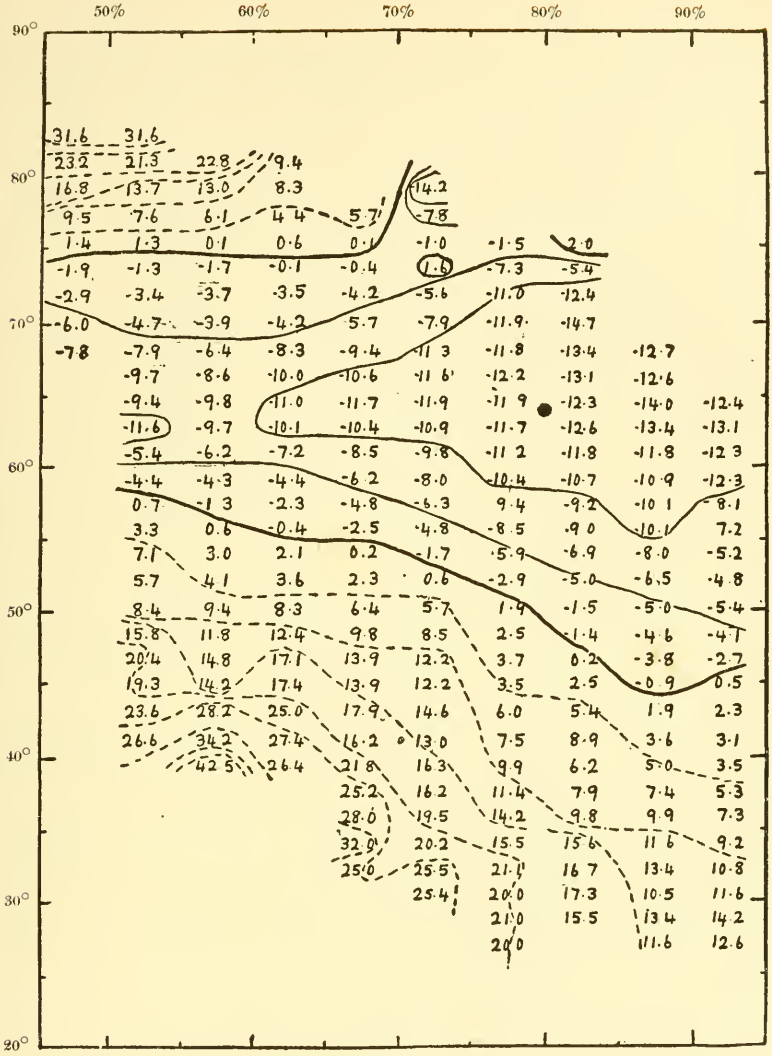

FIG. 2. Climograph of 3,700,000 Deaths in France and Italy, 1899–1913.
(From Huntington's World Power and Evolution, Yale Univ. Press.)

of months is small because the weather conditions are extreme, the general degree of regularity in Figure 2 is high. The optimum temperature is evidently 64 to 65° which is close to that which we found in New York City. At that temperature the best condition of humidity appears to be 80 to 85 per cent. Thus the main climatic optimum for the cities of France and Italy is an average monthly temperature of 64° to 65° and an average relative humidity of 85 to 90 per cent.

As one departs from the optimum in any direction, the death rate increases, slowly along the line indicating the optimum temperature, most rapidly where the temperature and humidity both become unfavorable. Low temperature is bad even if the air is moist, but very bad if the air is dry. The worst figure on the climograph is an excess of 42.5 per cent with a humidity of 55 to 60 per cent and a temperature of 40°. Under the very hot, dry conditions shown in the upper left hand corner of Figure 2, the death rate likewise rises very high, being 31.6 per cent above normal. Under hot moist conditions the rate might be still higher, but France and Italy, with their dry summers except in the cool north, are free from such conditions.

Turn now to Figure 3, representing 921,000 deaths from non-contagious diseases among white people in the cities of the eastern United States from 1912 to 1915. It is like Figure 2 except that the numbers have been omitted, the isopleths have been smoothed to remove irregularities, and shading has been added so that good conditions are dark and bad conditions light. The general aspect of the climograph is almost identical with that of Figure 2. The best health and fewest deaths occur with a temperature of approximately 65° and a relative humidity of 80 to 85 per cent. Poor health and many deaths prevail when the weather is hot and dry and especially when it is cold and dry.

Many other investigations give similar results. Under most conditions fairly moist air is better than dry, and this is true even when the optimum temperature prevails. In both very hot and very cold weather, however, extreme humidity is less favorable than more moderate conditions. In cold weather this must be partly due to the exposure

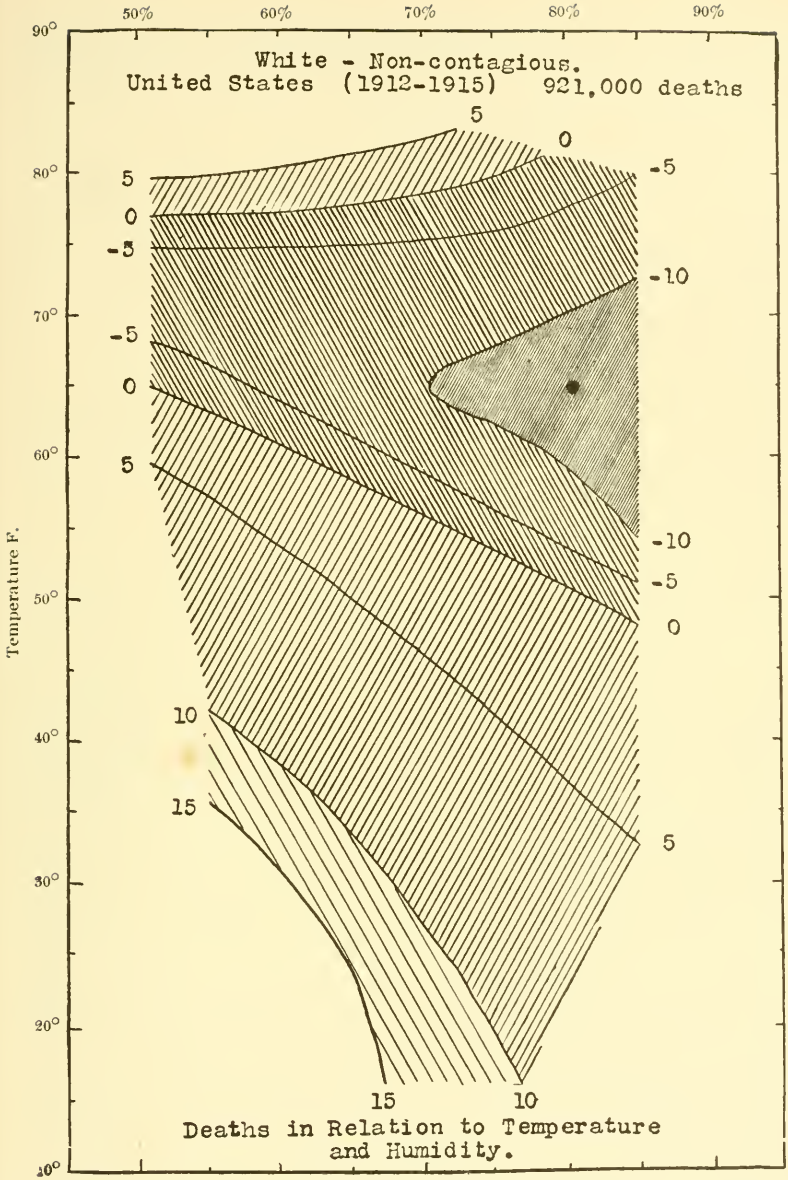

FIG. 3. Climograph of 921,000 Deaths of White People in the Cities of the United States, 1912–1915.

(From Huntington's World Power and Evolution, Yale Univ. Press.)

which occurs in storms, but it may be connected with the fact that at very low temperatures moist air feels colder than dry air, although at more moderate temperatures the

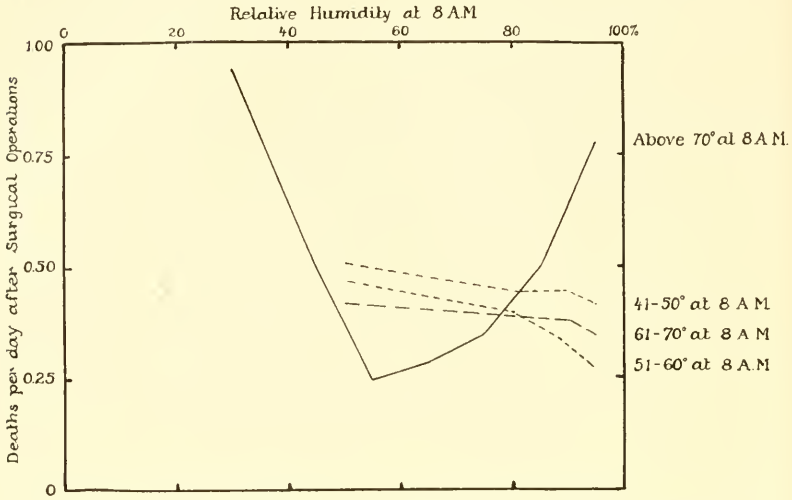

FIG. 4. Post-operative Death Rate at Boston in Relation to Humidity and Temperature.

(From Huntington's Civilization and Climate, ed. 3, Yale Univ. Press.)

reverse is true. In hot weather the excess of deaths at high humidities represents the discomfort, weakness and ultimate illness which are often the direct result of heat combined with moisture, as in cases of sunstroke. It should be noted however, that even in tropical countries damp heat does less harm than dry heat. Thus in India and similar countries the death rate reaches a maximum during the excessively hot dry weather of the spring months and systematically falls as soon as the rains begin. Part of this is unquestionably due to somewhat lower temperature, but the more favorable conditions of humidity also appear to be important. Nevertheless, if the summer air in India should approach saturation all the time, which is by no means the case, the conditions would be almost unendurable. The exact state of affairs is illustrated in Figure 4 showing the relative number of deaths following surgical operations performed in Boston hospitals on days with various temperatures and humidities. When the temperature at 8 A.M. is below 70°F., the number

of deaths declines steadily as the humidity increases, as appears in the dotted lines, but when the 8 A.M. temperature is above 70° it is very dangerous to submit to a surgical operation if the relative humidity is either very low or very high, whereas with a humidity of 55 to 60 per cent the chances of survival are excellent. In this particular case other factors such as the change of temperature from day to day are doubtless concerned, but abundant other evidence shows that at high temperatures there is a decided optimum of humidity which is far more favorable than either extreme.

Optima Determined by Laboratory Experiments. The conclusion that there are very definite climatic optima is supported by numerous experiments as well as by the statistical methods already described. At the Pittsburgh Laboratory of the U. S. Bureau of Mines hundreds of persons have been tested in experimental chambers where the temperature, humidity and movement of the air can be controlled with great accuracy. The following table summarizes the results thus obtained at various temperatures in saturated air with subjects who are very lightly clad. The pulse rate, body temperature and metabolism are all influenced. With ordinary clothing and for persons absolutely at rest, the most comfortable temperature in saturated air appears to be not far from 70°, but when work is done the most comfortable temperature is lower.

Another way of representing the same experiments appears in Figure 5. There temperature is measured horizontally from low on the left to high on the right; the amount of moisture in the air is measured vertically, the bottom of the diagram representing absolutely dry air and the top 300 grains of moisture per 100 pounds of air; the curved lines show percentages of relative humidity. The heavy "comfort line" indicates that when people are normally dressed and absolutely at rest, the most comfortable temperature in motionless saturated air is 64°. A departure of a single degree from this condition is at once perceptible. In unsaturated air an equal degree of comfort is felt at all other points along the comfort line. Thus the feeling of comfort at 68°F. and 60 per cent humidity is the same as at 64°F. and 100 per cent, or at 76°F. and 10 per cent or any other

EFFECTS OF ABNORMAL ATMOSPHERIC CONDITIONS*

Temperature of air; relative humidity 100 per cent	Effects when at rest				Effects when at moderate work		
	Pulse Rate	Body Temperature	Metabolism	Remarks	Pulse rate	Body temperature	Remarks
°F. 98	Greatly increased	Marked increase	Marked increase	Very hot, even with little clothing	Very rapid	Marked increase	Very hot
95	Marked increase	Increased	Increased	Hot, even with little clothing	Very rapid	Marked increase	Very hot
90	Increased	Increased	Increased	Very warm	Rapid	Increased	Hot
85	No change	No change	Slight increase	Warm	Increased	Slight increase	Very warm
75–80	Slight increase	Slight decrease	Minimum metabolism	Comfortable	Slight increase	Slight increase	Comfortable or warm
65–70	Decrease	Slight increase	Slight increase	Slightly cool to comfortable	Slight increase	Slight increase	Comfortable
55–60	Decrease	Slight increase	Slight increase	Cool, clothing needed for comfort	Slight increase	Slight increase	Comfortable to cool
45–50	Decrease	Slight increase	Increased	Cool, clothing needed for comfort	Slight increase	Slight increase	Cool

* SAYERS, R. R., and DAVENPORT, S. J. Review of Literature on the Physiological Effects of Abnormal Temperatures and Humidities. *U. S. Public Health Rep.*, April 8, 1927, pp. 933–996.

point along the heavy line. But even though the feeling of comfort may be the same, the effect upon health, as we have already seen, is apparently not so good when the air is dry

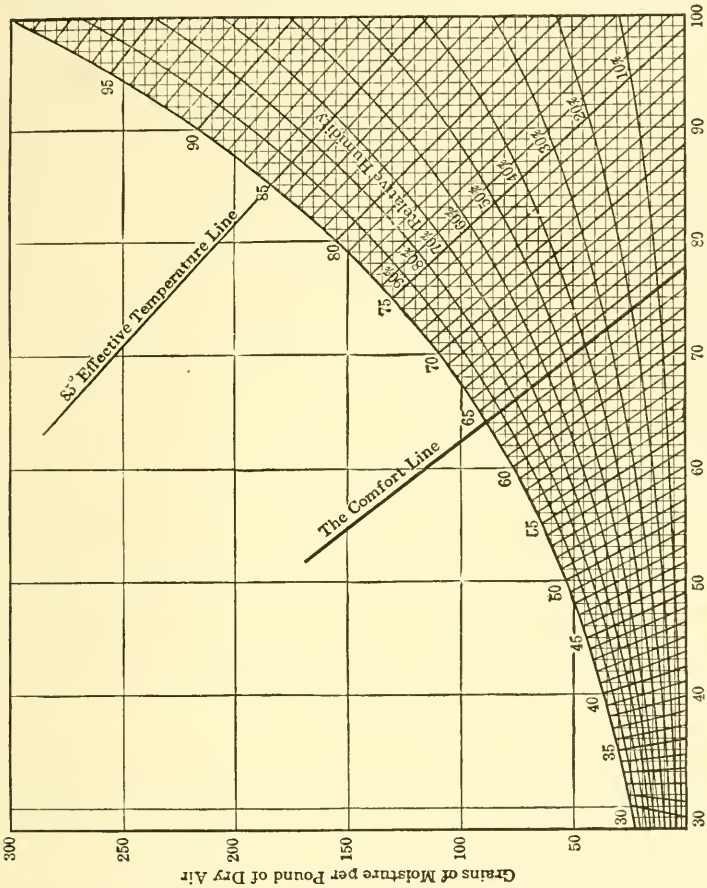

FIG. 5. The Comfort Zone According to the Pittsburgh Laboratory.
(From Huntington's Business Geography, ed. 2, John Wiley & Sons, Inc.)

as when it is moist. In similar fashion along each of the other lines parallel to the comfort line the atmospheric conditions are at all points equally comfortable, although the degree of comfort diminishes as one recedes from the comfort line. Nevertheless the effect on health varies along each line in accordance with the humidity.

The most significant fact about the experiments just described is their close agreement with the statistical results

already given. The absolute optimum appears to be a temperature of 65° or 66° and a relative humidity of about 80 per cent. Such conditions are like those which prevail in cool greenhouses, the kind which have a springlike freshness and in which one feels neither hot nor cold and can either work or rest without discomfort.

3. *Air Movement.* Thus far we have considered only still air. That is by far the most important condition because most civilized people spend much of their time where the air moves only slightly. Nevertheless the movement of the air is so important that Dr. Leonard Hill and others have made vigorous efforts to devise an instrument which will measure the combined effect of temperature, relative humidity, and movement of the air. The resultant instrument is known as the katathermometer. A large wet-bulb thermometer is heated to 100°F., or approximately the temperature of the body, and exposed to the air. Its rate of cooling depends on all three atmospheric conditions. Thus the time required for the katathermometer to drop from 100° to 95° gives an approximate measure of the cooling power exerted by the air upon the human skin. That is one of the best measures of the extent to which the air is comfortable and healthful. It is by no means a perfect measure however, for hot, dry air may have as great a cooling power as moist air of moderate temperature, but it is by no means so healthful.

The relation between movement of the air and temperature is illustrated in Figure 6. Here the reading of the dry bulb thermometer is indicated on the left, and of the wet bulb thermometer on the right. The lower curved line above the words "Effective Temperature" indicates the degree of heat or cold experienced at any given temperature when the air is at rest and is saturated with moisture. The greatest degree of comfort is found of course at 66° where the effective temperature line joints comfort line. At both higher and lower temperatures discomfort increases until the limits are reached and death ensues.

The other long curved lines indicate the conditions when the air moves with velocities such as 100, 200, or more feet per minute. The faster the movement of the air the higher

the temperature at which any given condition produces a specified cooling effect. Thus when the air moves 700 feet a minute, saturated air with a temperature of 70° feels as cool as still air with a temperature a trifle below 60°. If the air is not saturated, the dry and wet bulbs of course stand at different levels, and the effect of atmospheric movement is increased, as is indicated by the example which accompanies the chart.

At temperatures above that of the body, as appears from the crossing of the wind velocity lines, any movement of the air increases the feeling of discomfort. The reason for this is that after still, hot air has touched the body and thereby been cooled, it acts as a sort of blanket to keep away still hotter air. But when the air is in motion new air keeps touching the body, thus tending to heat the body more and more.

In both Figures 5 and 6 we may well think of a comfort *zone* lying on either side of the comfort line. This zone is practically identical with the areas of heaviest shading in our climographs. It likewise represents the atmospheric conditions under which factory accidents are least numerous, and various other human conditions are most favorable. Thus from whatever side we approach the matter we find the optimum at a temperature of 65 or 66° and a relative humidity of approximately 80 per cent in still air, or else under other atmospheric conditions which give the air essentially the same cooling power. Nevertheless high wind, like great dryness, is not so desirable a means of securing the right cooling power as is the correct temperature. The best combination of all is probably air at about 67°F. and 80 per cent relative humidity, with a barely perceptible movement. A departure from these conditions in any direction diminishes people's comfort, reduces their capacity to work, presumably increases their susceptibility to disease, and unquestionably raises their death rate.

4. *Variability*. Even yet we have not reached a final definition of the optimum climate. Variability must also be considered. Experiments show that plants kept uniformly at their optimum temperature grow faster than if kept uniformly at any other temperature, but not so well

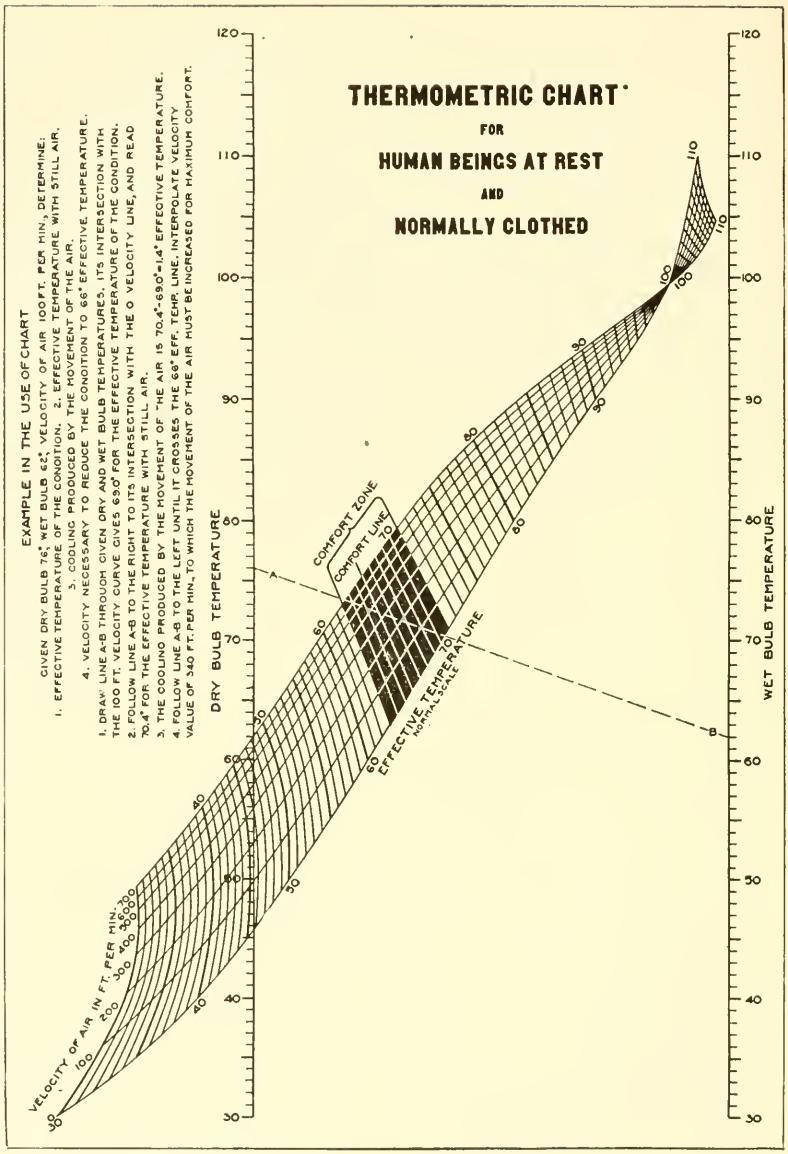

FIG. 6. The Effect of Temperature, Air Motion and Humidity on Human Comfort.

(From Sayers and Davenport, U. S. Public Health Rep., 1927.)

as when the temperature varies above and below the optimum. In other words the most favorable condition is a variable temperature whose average is the optimum. Similar experiments have not yet been performed upon human beings to any appreciable degree, but studies of factory work and death rates indicate that man is benefitted by variability quite as much as are plants.

The daily deaths in New York City illustrate the matter. At all seasons, summer and winter alike, a drop of temperature is systematically accompanied by a drop in the death rate. It is reasonable enough that in summer a drop from a high temperature toward the optimum should reduce the death rate, but how can a drop downward away from the optimum in winter produce the same result? Although the exact physiological processes are not yet known, the answer appears to be that the conditions are analogous to those of a cold bath. A healthy adult can take a dip in cold water and emerge with a decided glow of warmth and with a stimulus to activity and health which lasts for hours. But let that same person stay in water with a temperature of 50° for an hour or two, and he may be so chilled that he will not recover for days.

The analogy of the hot bath perhaps applies to the seemingly unreasonable proposition that even in winter a rise of temperature is accompanied by an immediate rise in the death rate, but the case is not clear. If bath water of almost any temperature is gradually warmed, a feeling of relaxation generally ensues, which perhaps means less power to resist disease. A less speculative cause of a rising death rate associated with a rise of temperature even when the temperature thereby approaches the optimum is found in the almost universal tendency for houses to be greatly heated on days when the outside temperature is rising or has just finished rising. We cannot seem to make our furnaces and our windows keep pace with the weather. If we were able to do this, much of the rise in the death rate because of a rise in the winter temperature might possibly be eliminated. Each month in the year the same conditions are manifest: many deaths when the temperature rises, few when it falls.

In this connection the question at once arises whether the good effect of falling temperature is completely counteracted by the bad effect of rising temperature. Among plants, as we have seen, this is not the case; the net effect of the two types of change is stimulating. Among men the most extensive of the few investigations along this line is that of the Committee on the Atmosphere and Man in New York City. There during a six-year period, a very systematic relationship was found between the average change of temperature from one day to the next during ten-day periods and the deaths at the end of such periods. If the variability is small, no matter whether the temperature be high or low, the death rate is high. When the average variability amounts to 3° during most of the year, or to 4° or 5° during the winter, the death rate is at a minimum. If the variability rises higher, the death rate likewise rises, but even with the most extreme variability it is not so high as with extreme uniformity. In New York variability appears to have more effect on health than does humidity and about half as much as mean temperature. If such a relationship is universal, as appears to be indicated by many scattered bits of evidence, variability must be of the utmost importance in determining man's health and energy all over the world.

Other things being equal, extreme uniformity of temperature from day to day is decidedly undesirable; extreme variability is also undesirable, but to a less degree; and between the two extremes lies the optimum. From this point of view the climate of Newport in Rhode Island appears to approach the ideal quite closely, while climates with great uniformity as in southern California or very violent changes as in central Siberia are far from the optimum. Apparently the moderately variable type of climate is good by reason of its changes not only in temperature, but in humidity, sunshine, and wind.

This is as far as we can carry our study of climatic optima. We may hazard the guess that the optimum atmospheric pressure is found within one or two thousand feet of sea level, and that the optimum conditions of sunlight are found in different latitudes according to the pigmentation of the skin.

CLIMATIC DIFFERENCES OF RACE

Up to this point our data have applied only to the European branch of the white race. But do other races react like the white man? What little exact evidence is yet available suggests distinct differences in the climatic optima of different races or of the same race when living in different climates, but it also suggests that these differences are slight. In Japan the optimum appears to be almost the same as in the United States. At Osaka for example, the 126,000 deaths from 1913 to 1917 indicate an optimum of approximately 66°F. and 70 to 80 per cent relative humidity. Among Cuban cigar-makers in Florida the best work is done when the temperature averages from 65° to 70° which is somewhat higher than among the factory workers of New England. The conditions among Negroes in the United States are illustrated in Figure 7 which is like Figure 3 except that it is based on 167,000 colored people instead of 921,000 white people. Although the cities were the same in both cases, the colored people are mainly found in the more southerly of them so that Figure 7 represents a somewhat more southerly region as well as a more tropical race than Figure 3. Nevertheless the two figures are almost identical. The only important difference is that the optimum temperature for the Negroes is about 4° higher than for the whites, and the optimum relative humidity also a trifle higher.

Fortunately we are not limited to the American Negro for our knowledge as to the climatic optimum of tropical people. In Java the Dutch have gathered exact statistics for a race that has lived close to the equator for many centuries. Of course there are no low temperatures even in the towns at greatest altitudes, but so far as they go the Javanese data agree closely with those for whites and Negroes. Although the dark-skinned Javanese have lived close to the equator for so long, their optimum temperature appears to be near 70°F. or only about 5° above that of the white race; and their optimum humidity does not seem to differ materially from that of the Europeans. Morever, what little evidence we have suggests that mild changes of temperature are just as stimulating to tropical people as to the

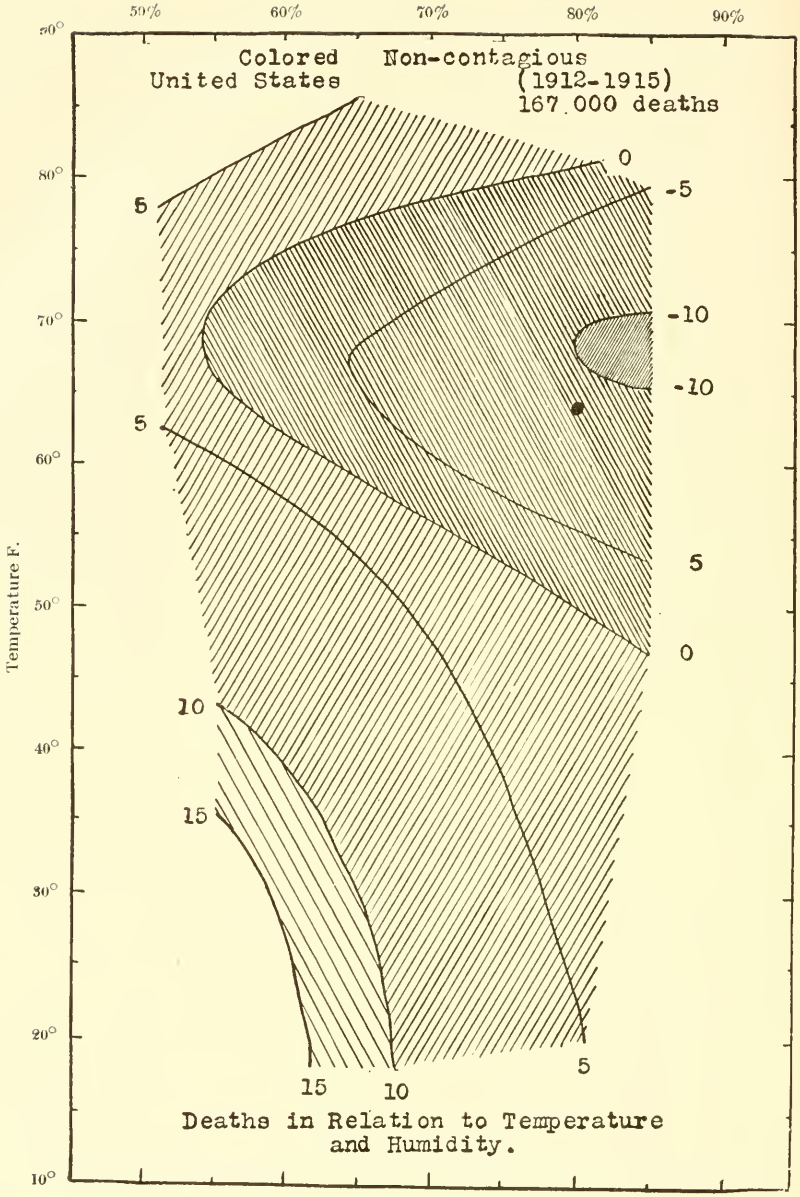

FIG. 7. Climograph of 167,000 Deaths of Negroes in the Cities of the United States, 1912–1915.

(From Huntington's World Power and Evolution. Yale Univ. Press.)

rest of us. If all this is true it puts a wholly new aspect on the problems of acclimatization and the geographic location of the origin of man.

THE GEOGRAPHIC DISTRIBUTION OF HEALTH AND ENERGY

The data now before us enable us to gain an approximate idea of the effect of climate upon health throughout the world. Hundreds of experiments, the work of thousands of factory hands, and the deaths of millions of persons, as we have seen, enable us to determine the approximate degree of health and energy under any given combinations of temperature, humidity and variability. On the basis of weather records it is therefore possible to construct a map showing the approximate degree of health that would be enjoyed by the white race in any part of the world if climate were the sole determinant of health. Such a map, Figure 8, shows two main areas where the climate approaches the optimum, namely the northeastern quarter of the United States from the Atlantic to beyond the Mississippi River, and the parts of Europe centering around the North Sea. Other minor centers are the Pacific Coast of the United States, New Zealand, Japan, and probably Chili, although the South American portion of the map is not very reliable. The whole map is, indeed, tentative and should be revised as soon as possible. Nevertheless there is no reason to expect any important charge in the main outlines.

In a similar map for tropical people the optimum areas would be located a little nearer the equator than in Figure 8, but the general aspect of the map would be changed only a little. The tropical regions and continental interiors would still be low and the warmer parts of the stormy temperate zone would be high. Another and highly significant feature would also still be evident, namely the decline of health and energy toward the centers of the continents even in the most favorable latitudes. The reason for this is partly the dryness of the interiors and their extreme changes of temperature at certain times coupled with other periods of very little change from day to day. These latter conditions apply especially to central Asia because of its relative lack of cyclonic storms

such as give to the northeastern United States, northwestern Europe and Japan a constant but moderate variability from day to day at all seasons.

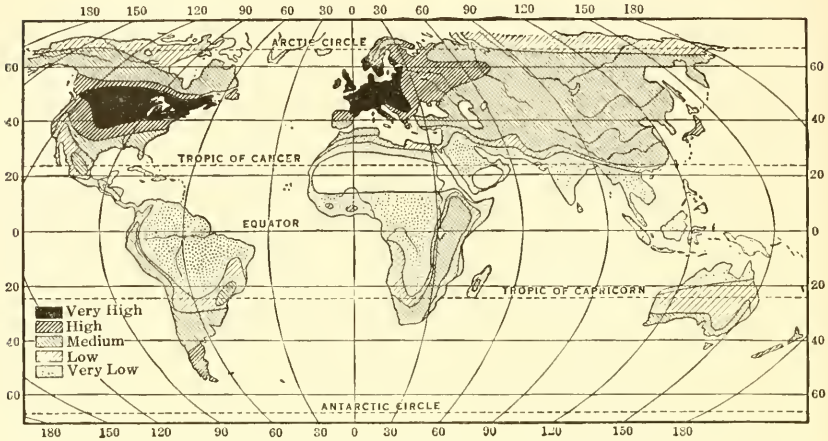

FIG. 8. World Map of Climatic Energy.
(From Huntington's Business Geography, ed. 2, John Wiley & Sons, Inc.)

It cannot be too strongly emphasized that Figure 8 is a purely climatic map showing the degree to which the climate probably departs from the optimum for health and activity. Nevertheless this map of climatic energy is almost identical with maps of both health and civilization. The interpretation of this threefold agreement is clear in the light of our previous discussion of limits and optima. The climatic map must be the foundation, for neither health nor civilization can possibly produce any appreciable effect upon the distribution of climate. Hence it appears that in the world today the primary control of the distribution of health and civilization is climate. The way the matter works appears to be as follows:

The more nearly the climate approaches the optimum the greater the degree of health and energy. The greater the degree of energy, the more likely people are to make advances in civilization. But an advance in civilization means improvement in health by reason of new knowledge, and improved health in turn helps toward still further advance in civiliza-

tion. The gap between the regions that lie near the climatic optima and those lying near the climatic limits becomes steadily greater.

The only serious objection to such a connection between the distribution of climate and civilization is found in a comparison of the past with the present. Everyone knows that ancient civilizations reached their height in regions where the climate is of only medium quality according to Figure 8. Does not this prove that whatever may be the fact today the climate of the past cannot have been a main factor in the distribution of civilization? This question has been carefully studied but is still in dispute.

Two points however seem clear. The first is that the climatic optimum, as has been implied in previous pages, varies according to people's stage of progress. For unclothed people a higher temperature and a lower degree of variability are required than for people who wear clothes. The same is true when people without fire are compared with those who have that marvelous means of keeping warm. Houses, stoves, furnaces and various other methods of keeping warm have also tended little by little to lower the optimum temperature and increase the optimum variability. This tendency in itself is enough to account for a considerable part of the shift in the centers of civilization.

In addition to this a second point needs emphasis before we can understand the relation of climate to civilization. Geologists universally agree that 25,000 or 30,000 years ago great ice sheets covered large sections of North America and Europe where civilization today stands very high. The climatic change which caused the ice sheets to disappear has taken place irregularly, sometimes proceeding rapidly, then slowly, and even reversing itself. Even during the historic period similar climatic pulsations appear to have taken place on a smaller scale. For centuries the climate has swung in one direction and then for centuries in the other, just as during shorter periods it swings first one way for a few years and then the other. Yet on the whole dry lands like western Asia and the southwestern United States appear to have been somewhat drier during the last one or two thousand years than during the previous period.

One feature of these climatic pulsations has undoubtedly been a certain change in mean temperature, but changes of this sort have evidently been slight. Even at the height of the Glacial Period the average temperature of the earth was probably not more than 15° or 20°F. lower than now and since the dawn of civilization the temperature has presumably not fluctuated more than perhaps a tenth or at most a fifth as much as this, far too little to be readily evident either from the ordinary historic records or from the known facts as to plants and animals. On the other hand the amount of storminess has apparently varied considerably from century to century. Part of the evidence is found in ruins, irrigation ditches, and traces of old fields in areas where the water supply is now utterly inadequate; another part appears in the level of salt lakes, the location of ancient roads, the rate of growth of ancient trees, and many other features which indicate a greater water supply during some centuries than during others. Such evidence, be it noted, applies mainly to the drier parts of the world, where even a slight change in rainfall may produce serious results.

This is not the place to discuss the matter in detail, but greater rainfall appears to indicate greater humidity and greater storminess; and greater storminess means more frequent changes of temperature. Thus although the average temperature of any given part of the earth has probably changed very little during historic times, the degree of humidity and still more the degree of variability from one day to the next appear to have varied considerably. All this means that during the Glacial Period the optimum climate was located much nearer to the equator and to the great deserts than at present. Since then it has moved poleward and at the same time toward the margins of the continents, but the movement has been irregular. During the historic period for centuries at a time, especially in the era ending with the time of Christ, the optimum *for the stage of human culture then existing* appears to have been located in the dry lands around the Mediterranean and in western Asia where ancient civilization made its greatest progress. The centuries of greatest storminess when the climate most nearly approached the optimum appear to have been periods of

progress; the centuries of diminishing storminess when the optimum swung northwestward appear to have been times of distress and decline.

This conclusion is by no means universally accepted. In fact many able people assail it vigorously and even ridicule it. They say that such an hypothesis is unnecessary because other historic and cultural conditions afford a full explanation of the rise and fall of civilization. They also say that the facts on which the hypothesis is based are scanty and are subject to various interpretations. Therefore it is wise to suspend judgment, but it is highly significant to see the way in which independent lines of investigation dovetail. One line, the earliest, suggests that the great centers of ancient civilization rose to their highest levels when their climates were more moist and variable, and hence nearer to the physiological optimum than at present. Another shows that the optimum varies according to the degree of civilization, and man's consequent ability to protect himself from low temperature and excessive dryness. A third indicates that at present the distribution of civilization and progress is almost identical with that of climatic energy. All three together suggest, although they do not prove that in the past as at present, the distribution of civilization has been closely determined by the physiological effect of climate.

CLIMATE AND RACIAL CHARACTERISTICS

This brings us to the vexed question of the relation of climate to racial characteristics. So far as external characteristics are concerned, the case is fairly clear. In general the pigmentation of the races of the world varies according to the intensity of the sunlight, for pigment appears to be primarily a protection against ultraviolet light. The center of the fair Nordics today, and we know not how long in the past, is Scandinavia where the sunlight, especially in its shorter ultraviolet wave lengths, is never very strong. The blackest races are all found in low latitudes. Here and there to be sure, we find relatively fair people in low latitudes and moderately dark tribes in high latitudes, but in most cases this is the obvious result of migration. When once a race has acquired a given pigment, it presumably requires a long time for a new

environment to induce any important change, unless the pigmentation is so unfavorable that the race tends to die out. If mutations occur on a large scale, a rapid change is of course possible, but barring that a moderately fair race, if it lives out of doors and becomes well tanned, can presumably subsist in a tropical region for thousands of years, provided it is adapted to the environment in other ways and is not in competition with a darker race.

Other forms of adaptation can be scarcely more than mentioned. One is the condition of the sweat glands of the skin. Among Negroes and other dark races the sweat glands are more numerous, smaller, and less active than among white people. They flood the skin with fine droplets of moisture, but do not pour out such streams of perspiration as do the glands of the white man. Another apparent adaptation is found in the form of the nose. Among northern races the nostrils tend to be small and relatively round, not admitting a large amount of air at one time, and forcing the air to pass through a relatively long passage where it is warmed before reaching the throat. Among Negroes on the other hand, the nostrils are short, and wide open so that large amounts of air can be taken in at once. Such a condition is favorable in a warm climate where the heat often compels rapid breathing even when people are at rest. But is decidely disadvantageous where the temperature ranges far below zero, and may be an important reason why colored people do no thrive in regions like the most northerly parts of the United States.

The relation of mental characteristics to climate is not so obvious as that of physical characteristics. Most biologists believe that there are mental as well as physical differences among races; many say that the brain, being the most recently evolved organ, is likewise the most variable. Yet an important group of anthropologists and psychologists deny this; all mental differences which others call racial, so they say, are due to training and social inheritance. Although the brain varies in size and intricacy from race to race and in that respect is like the skin, sweat glands, nose and other organs, it is assumed to be uniform in its functions. A more reasonable view seems to be that the powers, aptitudes and functioning of the brain vary like those of any other organ and are

similarly subject to climatic influences. According to this interpretation a biological process of selection weeds out certain types in certain regions. Occupations are often the basis of selection, but occupations in turn depend largely on climate, especially in primitive communities. Thus where rice-culture prevails the family which cannot force itself to undergo the degree of steady work required to plant the rice, guard it, and keep up the little canals and dikes needed for irrigation is almost sure to be either poorly nourished, so that it does not raise many children, or else to be forced into another group which gets a living in some other way.

The most far-reaching of all climatic factors in producing deep-seated mental differences appears to be the seasons. In warm moist lands some sort of food can be procured at almost any season. Where a long dry season occurs this is not so easy, and where there is a cold winter practically no food can be procured for many months except by hunting. Under these latter circumstances an agricultural population can scarcely survive unless it possesses sufficient foresight to see that in summer supplies of food, skins and the like are laid by for winter. It must also possess sufficient intelligence to plan for such supplies, sufficient energy to gather far more than is needed for immediate use, and sufficient self-control to husband the supplies through the whole of the period of scarcity. In a tropical climate many people can survive without these qualities; in a region with well-defined winters, such mental weaklings tend to be weeded out, leaving only the more intelligent, energetic and self-controlled. That such selection is the primary cause of the apparent biological difference in the mental powers of tropical and non-tropical races has never been positively proved, and perhaps never will be. Yet as a working hypothesis it seems to fit the facts extremely well.

ACCLIMATIZATION

Our last topic in connection with climate is acclimatization, especially as it concerns the white man in the tropics. The materials for an intelligent opinion as to this much-debated problem have already been presented. Mankind presumably originated in one or more climatic provinces which were

moderately warm, although probably not tropical. One of the chief arguments for this viewpoint is that the optimum climate for tropical races, as we have seen, is almost the same as for others. Thus it seems probable that all races, if obliged to live with little or no clothing and with unwarmed shelters, would find their optimum where the average temperature for the summer does not run much above 75°, and that of winter not much below 55°, or let us say an extreme range from 80° in the hottest summer month to 50° in the coldest winter month. If such a climate were blessed with frequent but not too extreme variations of temperature, it would be well-nigh ideal for almost any race which did not have our modern means of protecting itself against the cold. The seacoasts of southern Palestine and northern Florida come close to having such temperatures. But if conditions of this kind really come so near to being the optimum for all races in the primitive state, we are perhaps justified in assuming that they may not be very different from those of the climate in which man originated and in which he became stamped with a climatic relationship which he has never been able to eliminate.

From some such region then we may suppose that man has spread into regions as hot as the southern end of the Red Sea, as warm and moist as the Amazon Basin, as windy as Tierra del Fuego, as cold and snowy as Greenland, and as mild and even as Hawaii. In each of these places he has become sufficiently acclimated to survive even if he cannot prosper, and yet in each of them he is still far from being perfectly acclimated, for nowhere does he find the perfect optimum.

This gives us a clue to white acclimatization in the tropics. If mankind is derived from one original stock and yet can live comfortably in so great a variety of climates, there is every reason to believe that the white man might become acclimated in the tropics, provided he subject himself to a sufficiently rigid process of selection.

The secret of the matter seems to lie in selection. Today the white people who live permanently in tropical countries and especially those who bring up children there are an extremely highly selected group. They themselves may not

realize it when they tell how well the tropical climate agrees with them. Yet for every individual who goes to the tropics as a sojourner, a large number have thought of doing so but have refrained because of limitations of health. Again, among those who actually go to tropical countries a large proportion leave after a few years because they do not like the climate or because some member of their family suffers from it. The few who remain permanently and bring up families are in most cases persons of a peculiar type of constitution which adapts them to the tropical climate. By means of such selection for generation after generation a strain of white people could probably be produced which would be able to stand the tropical climate quite as well as do any of the present tropical races.

If the specific tropical diseases like malaria and hookworm could be eliminated, the chances are that such people could live in comparative health and comfort. They might also maintain their present stage of civilization and go on to a higher stage provided they could overcome the tremendous handicap of contact with tropical races of lower standards. There is not, however, the slightest reason to believe that such tropical white people would change their climatic optimum any more than the Javanese have changed theirs. They would of course, be better adapted to tropical conditions than are the ordinary white people of Europe and the United States, but they would presumably still be living in a climate which departs far from their optimum and in which it is much harder to overcome the departures than is the case in cooler climates.

Perhaps some day some race will learn to guard itself against high temperature, high humidity, and undue monotony, but that is likely to prove far harder than to guard against low temperature and undue dryness. Low temperature is the easiest of all climatic handicaps to conquer, for fire, houses, clothing and exercise are all methods of overcoming its effects. Undue dryness too can be overcome to a considerable extent by clothing which keeps the skin moist. But high temperature, excessive humidity and excessive monotony present a problem of far greater complexity especially because those conditions predispose the individual

toward inertia whereas cold and dryness predispose toward activity.

Thus our final conclusion is that although it is probably possible for selected portions of the white race to become as well adapted to the tropics as are the Javanese for example, it is far from probable that they will maintain a degree of energy and progress equal to that of similarly selected people of the same race in a better climate. Always, it would seem, the people who live near the climatic limits will be at a disadvantage, while those who live near the climatic optima will be the most healthy, energetic and progressive.

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Chapter XIV

THE REACTION TO FOOD

Elmer V. McCollum

PHILOSOPHERS in all ages have given thought to the nature of foods and of nutritional processes. Spallanzani (1729–1799) who occupied himself with many experiments on the digestion of foods, was of the opinion that there was but one kind of food or aliment. This view had seemed satisfactory to some early Greek philosophers, but by the beginning of the nineteenth century the eminent French physiologist Magendie reached the conclusion that there are several kinds of nutrient principles in a chemical sense. Even as late as 1835, when Dr. William Beaumont, a surgeon in the U. S. Army, was writing about his famous experiments on digestion conducted with Alexis St. Martin as a subject, he expressed the view that there was but one kind of nutrient principle or aliment. He believed that this aliment was contained in all the many varieties of foodstuffs consumed by man and animals and that the process of nutrition involved dissolving out this principle by the digestive juices and converting it into a salt-like derivative of a substance which he called gastrite, forming gastrite of aliment. This he believed with slight modifications entered the blood and served with little change for the upbuilding or repair of tissues.

During the nineteenth century much knowledge accumulated concerning the nature of proteins, carbohydrates, fats and the inorganic or mineral constituents of foodstuffs. About 1865 a method was formulated and adopted by the Association of Agricultural Chemists as official for the analysis of foods. In this method proteins, digestible carbohydrates, cellulose, fats and mineral constituents were separately estimated with a fair degree of accuracy. The belief became almost universal among students of nutrition that these four classes of nutrients were all that were necessary for the support of animal nutrition.

After 1865 there was an era of enthusiasm for the study, with both human and animal subjects, of the protein requirements and energy requirements of the individual as influenced by age and condition of life. Such studies were carried on by Prof. Carl Voit of Munich, and his students extended his studies in many countries. W. A. Atwater was the great exponent of nutrition work of this kind in the United States prior to 1900. He thought that nutrition would be placed upon a strictly scientific basis when all the ordinary foodstuffs had been analyzed chemically, their energy values and digestibility determined, and the cost of production of each of our important farm crops had been studied. Atwater spent the active period of his life in the collection of data along these lines.

The results of the chemical analysis of foods showed striking differences in their composition. Meats, eggs, and the flesh of poultry and fish consist in great measure of water, protein, fat and inorganic salts. Milk in a dry state contains in addition to a large amount of protein much carbohydrate (milk sugar) and a relative abundunce of fat as well as the various inorganic elements found on the ashing of an animal body. Among the vegetable foods, peas and beans contain extraordinary amounts of proteins, very little fat, but a moderate amount of carbohydrate, and an ash of characteristic composition. Cereal grains contain much less protein and relatively much more carbohydrate and starch, and but a little fat. The nuts, with the exception of the chestnut which contains starch, contain almost no carbohydrate, large amounts of protein, and are exceedingly rich in fats. Fruits and some of the tuber and root vegetables are exceedingly rich in water, so that in the form in which they are ordinarily purchased their energy and protein values appear quite low in contrast with many other foods. It is not surprising that in the era of enthusiasm over the analysis of foods, the striking differences in composition should have raised great expectations in the minds of investigators concerning their ultimate value in the planning of diets. Atwater cherished the hope that when his elaborate plan of study was complete it would be possible to advise the housewife concerning the most

economical choice of food, and that the farmer could readily calculate the most economical combinations of feeding stuffs which would supply the necessary protein and energy for animal production, milk and egg production, etc. Soon after 1900 it became possible to begin the application of this line of reasoning in the feeding of farm animals, and the fact came to light that two diets might have the same chemical composition so far as analysis can show, yet one might be highly satisfactory and the other a complete failure from the physiological standpoint. It became evident, therefore, that the chemical procedure in analyzing foods has distinct limitations and that there are qualities in foods which even the most searching analysis cannot reveal.

As early as 1843 Pereira in a book, "A Treatise on Food and Diet,"called attention to the fact that there must be other principles than aqueous, saccharine, albuminous, and oleaginous principles in lemon juice, which was known to be a valuable food in the treatment of scurvy, for he pointed out that it did not owe this property to any of the principles recognized by chemists.

As early as 1881 Lunin in Germany had attempted to feed laboratory animals on mixtures containing exactly those principles which the chemist determines in his analysis, proteins, carbohydrates, fats, and a mixture of those mineral salts known to be normal constituents of the animal body. He made the interesting and unexpected discovery that such diets were inadequate, although from a standpoint of chemical analysis they appeared to be complete. It was many years before this subject was again studied in an effective way. Wide publicity was given to Lunin's results in a much used textbook by Bunge, and these doubtless led to many speculations by physiologists.

In 1905 Pekelharing in Holland published experiments comparable to those of Lunin. He fed white mice on a bread of casein, albumin, rice flour, lard and a mixture of all the salts which ought to be found in their food, and gave them water to drink. He observed that they all starved to death, even though they ate greedily of the food in the beginning. He further showed that if instead of water they were given milk to drink they continued to thrive. He established the

fact that something, which was lacking in his basal diet, was contained in the whey from which the casein and fat had been eliminated. He states: "My intention is only to point out that there is a still unknown substance in milk which even in very small quantities is of paramount importance to nourishment. If this substance is absent the organism loses the power properly to assimilate the well-known principal parts of food, the appetite is lost, and with apparent abundance the animals die of want. Undoubtedly this substance not only occurs in milk but in a series of foodstuffs both of vegetable and animal origin."

The following year Hopkins in England described experiments almost identical with those of Pekelharing and drew the same deductions.

After 1900 rapid progress was made in the study of the chemical properties of individual proteins isolated from many foods, and it soon became apparent that proteins are of many kinds, and that they yield varying proportions of their several digestion products.

Interest was greatly stimulated in the study of nutrition by a series of experiments conducted between the years 1906 and 1911 at the University of Wisconsin. In these experiments animals were fed diets restricted as to source, certain ones being fed solely upon corn products, others upon oat products, and still others on wheat products, etc. In the case of cattle, the leaf, stem and seed were all included in the ration, but in the case of mammalian animals, such as farm pigs and rats, diets of a yet simpler character were tested. The curious discovery was made that none of the cereal grains, such as whole wheat, rolled oats, corn meal, either singly or collectively were adequate for the support of growth and the promotion of well-being in animals when they formed the sole source of nutrient. It was later found that even diets of great complexity, the components of which were derived solely from cereal grains, peas, beans, tubers, starchy roots and fruits, proved insufficient for the promotion of satisfactory growth or for the maintenance of prolonged physiological well-being. At one time a diet containing 23 articles, all known by experience to be wholesome components of the diet, was tested on young rats and found inadequate.

On the other hand, so simple a mixture as 70 or 75 per cent of rolled oats, and 30 or 35 per cent of a flour prepared from a broad leaf such as clover, alfalfa, turnip, celery, etc., induced very good growth, some reproduction, rearing of young, and the repetition of the life cycle in the family restricted to this diet.

Little rats have grown from soon after weaning to maturity with capability to reproduce when fed nothing but hard boiled egg yolk. It is evident that neither monotony nor restriction as to source is the determining factor, but rather the unique constitution of the diet in a chemical sense which determines its quality.

The most significant investigation in nutrition leading to the modern era of research was that of Eijkman, who in 1897 at Batavia, Java, discovered that fowls fed solely upon polished rice develop a disease characterized by multiple neuritis which was recognized as the analogue in the bird of a disease long common among the rice eaters of the Orient under the name beri-beri. Eijkman showed that various extracts of plant products including rice polishings, produced a spectacular cure in birds which were within a few hours of death. He demonstrated that the dose of active material necessary to produce such a cure was extraordinarily small. His experiments attracted little attention for a decade, but were discovered and repeated about 1910 by Funk, who confirmed Eijkman's results and coined the term "vitamine" to designate the active principle, a lack of which causes the development of polyneuritis in both man and animals. In 1912 the first of the fat-soluble vitamins, now known as vitamin A, was discovered in butter fat. Up to this time it had been accepted that all foods have essentially the same fuel or calorific value and approximately the same digestibility, hence the same nutritional value. It was clearly demonstrated by McCollum and Davis, and by Osborne and Mendel, that butter fat, egg yolk fat, and cod liver oil had growth and health-promoting properties not possessed by such foods as lard, olive oil, almond oil, etc. In 1912 Holst and Froelich of Norway conducted experiments with guinea pigs in which they produced experimentally the lesions

characteristic of scurvy in man. They showed that scurvy would develop in guinea pigs confined to dried or cooked foods and that scurvy was prevented by the inclusion of small additions of fresh green foods such as dandelions. Their experimental work placed upon a scientific footing the knowledge of the etiology of scurvy which had been vaguely recognized since the appearance of a book on this disease written by James Lind in 1754. Lind recognized the importance of fresh uncooked vegetable foods in the diet for the prevention or cure of scurvy, and his advice was acted upon for many years in the rationing of soldiers, sailors and prisoners before any clear concept was gained as to the nature of the substance in certain foods which prevented this disease.

In 1922 it was demonstrated that there is a special vitamin, now designated as D, in cod liver oil which plays a special rôle in bone growth and is a protective agency in the prevention or cure of rickets in infants and animals. In 1922 Evans and Bishop discovered the existence of a vitamin which plays a special part in fertility. It may be explained that a system of nomenclature was adopted in 1916 whereby the class of nutrient principles typified by that discovered by Eijkman in 1897, of which very small amounts in the diet suffice for the promotion of health, are designated by the first letters of the alphabet. They are now known as vitamins A, B, C, D, E and F. Vitamin F, the most recently discovered of these principles, was demonstrated by Smith and Hendrick, and later shown by Goldberger to be concerned in the etiology of pellagra, which is now generally believed to be a vitamin-deficiency disease.

As our knowledge now stands it is accepted that vitamin A when lacking in the diet causes damage especially to cells of the epithelial type. Glandular structures such as the lacrymal glands, salivary glands, and digestive glands, suffer injury and partial or total loss of function. As a result of such injury to the lacrymal glands eye secretion is interfered with, and the consequent drying of the eyes together with the bacterial growth which freely takes place in the conjunctival sac results in profound injury and eventually in destruction of the eye. This is so characteristic that observations on the appearance of ophthalmia under a

controlled dietary regimen are accepted as a qualitative test for vitamin A.

The term "vitamin B" now designates the principle discovered by Eijkman which is the etiological agent in beri-beri. When this substance is lacking from the diet the motor nerve cells in the cord are damaged and peripheral neuritis followed by atrophy of those groups of muscles whose motor nerves are injured develops.

In vitamin C deficiency the walls of the capillary vessels of the vascular system are especially injured, but it is not known with certainty whether the endothelial cells suffer the principal damage or whether the cement substance holding them together is destroyed. Certain it is that hemorrhage due to rupture of the capillaries is the most striking feature of scurvy but resolution of bone substance is also quite marked.

Vitamin D is concerned with the deposition of calcium and phosphorus in the bones. It regulates in some way the concentration of phosphorus and to a lesser degree the calcium of the blood. In the absence of vitamin D the amount of phosphorus falls to a surprisingly low level so that the solubility product of calcium $\times$ phosphorus is not great enough to permit of the precipitation of tricalcium phosphate for deposition in the osseous system.

Vitamin E functions in some manner not yet understood. Sterility is produced alike in males and females by a deficiency of this principle but the manifestation of a deficiency of vitamin E in the two sexes differs considerably. In males atrophy of the germinal epithelium and consequent loss of the power of spermatogenesis is seen. In females ovulation tends to remain normal but death of the young in prenatal life and their resorption constitutes the mode of termination of an incomplete gestation.

Vitamin F, originally called by Goldberger p-p to designate its pellagra-preventive properties, is now believed to be the etiological agent in pellagra. According to such data as exist, a deficiency of this principle promotes the development of changes in the skin which result in a characteristic erythemia, bronzing, injury to the mucosa of the mouth and digestive tract, chronic diarrhea and the nervous symptoms characteristic of that disease.

Vitamin A is found abundantly in fish liver oils, fats from mammalian livers, butter fat, egg yolk, yellow pigmented vegetables and leaves of plants generally. It is absent or nearly so from vegetable foods of all kinds, white varieties of fruits and vegetables and in fact all fruits and vegetables not containing yellow pigments. Thus, red beets, red and

blue varieties of corn, etc. do not contain it. It is nearly absent from cereals and absent from such refined cereal products as white flour, corn meal, polished rice, etc.

Vitamin B is most abundant in yeast, wheat germ, rice polishings, and various leaves of plants. It is relatively abundant, however, in whole grains, peas, beans, tubers, roots, and fruits of all kinds. It is less abundant in milk and scarcely present in muscle types of meats, although abundant in glandular organs, such as liver, kidney, etc. It is essentially lacking in the refined cereal products.

Vitamin C is contained in fresh raw fruits and vegetables of all kinds, but is especially abundant in the juice of lemons and other citrus fruits, and fresh green leaves such as cabbage, lettuce, etc. It is found in small amount in winter milks, is more abundant in summer milks, is nearly lacking in lean meats but the raw glandular organs contain it in fair abundance. No dry grains or other plant seeds contain the principle but it is rapidly generated in liberal amounts when seeds are germinated or caused to sprout. During cooking, vitamin C is destroyed, principally because of its ready oxidizability. It can be heated to fairly high temperatures provided oxygen is excluded. In the process of canning the smothering of the fruit or vegetable in syrup or juice during the interval while the cans are in the exhaust box causes them to undergo a gradual heating process which accelerates for a time the rate of internal respiration, which tends rapidly to use up the oxygen dissolved in the tissues. After this is effected subsequent heating does not tend to destroy vitamin C. Canned goods, therefore, are superior generally in this respect to foods of all kinds which are cooked under ordinary kitchen conditions; the latter tend to destroy practically completely all of the antiscorbutic vitamin C.

Vitamin D is found in large quantities only in the liver oil of fishes. It is most abundant in puffer liver and slightly less so in the liver of the cod and the haddock. These two fish oils furnish the principal source of this vitamin.

There is growing evidence that vitamin D is a modification of some sterol, a relative of cholesterol. Ergosterol, from ergot, yeast and other fungi, is, when irradiated, the most active substance known in the prevention or cure of rickets.

Doses of 0.001 mg. daily suffice to cause the healing of a rachitic lesion in little rats. It appears, however, that other substances among the sterols are capable of possessing the vitamin D property. The sterols which can acquire vitamin potency are activated by exposure to ultraviolet irradiations. It appears that in the tropics where there is much ultraviolet energy from the sun, the rays with certain frequencies activate the pro-vitamin D contained in the skin. This is then transported throughout the body and becomes a regulating agency in bone calcification. In those parts of the world where radiant energy from the sun is low, or for long periods non-existent as in the polar regions, this deficiency must be made good by the consumption of oils from marine sources. In the north temperate zone where the great centers of population subsist in a climate where little of the skin surface can be exposed to light during the colder parts of the year, and where only small quantities of marine food are eaten, rickets among children and animals is most prevalent. An important factor appears to be the smokiness of the atmosphere of cities which tends to filter out much of the radiant energy of a frequency capable of activating the pro-vitamin D. It is for this reason that the practice has now become established throughout the United States and much of Europe of giving cod liver oil to infants as a routine measure of protection against the development of rickets.

A substitute for cod liver oil is now much promoted in the form of radiant energy derived from the quartz mercury vapor lamp which is rich in wave lengths of frequencies necessary for the activation of pro-vitamin D. While there can be no doubt of the effectiveness of this physical substitute for the chemical principle, vitamin D, there is little justification for the extraordinary enthusiasm shown by many physicians and lay persons for treating all manner of ailments with the ultraviolet lamp. No evidence has yet been brought forward which indicates that the ultraviolet lamp is effective in any other condition than in safeguarding skeletal development.

Vitamin F has much the same distribution as vitamin B, but is apparently considerably more abundant in lean meat

than is the antineuritic vitamin B. Vitamin F is much more stable to heat than vitamin B, a fact which was instrumental in bringing about its discovery. Yeast, lean meats, leafy vegetables and milk are among the common foods available in abundance which are potent in vitamin F, the most important being the first named. Other common foodstuffs cannot yet be classified as to their values in preventing pellagra.

During the last fifteen years Dr. Simmonds and the writer have given much attention to the study of human dietaries in different parts of the world. The results can be furnished briefly as follows: Successful human dietaries are found in three types of geographic environment. In the coldest parts of the earth mankind subsists essentially upon a carnivorous diet. The Eskimos of Northwest Greenland live mainly upon birds, eggs and seals. They eat no land animals and fish only for a few weeks in mid-summer. Although small, they are very hearty people and have held their own under the most unfavorable conditions of climate through many generations. It is interesting that they have excellent bones and that their teeth rarely decay. It should be emphasized that they eat glandular organs as well as other parts of the creatures which serve as food.

In the warmest regions of the world, which are also characterized in general by excess of wetness, live the rice-eating peoples. Their diet is in the main vegetarian and consists of rice as the principal cereal, with additions of soy beans, various tubers and root vegetables, and large amounts of leafy vegetables of many kinds. These include Chinese cabbage, leaves of sweet potato, bamboo sprouts, water cress, spinach and other similar vegetables. The leaf of the plant is superior to the seed, tuber, root or fruit in its dietary properties. In fact, the edible leaf is in itself complete from the standpoint of its dietary principles.

In 1915 the writer and Miss Davis described a procedure consisting of a properly planned series of feeding experiments in which a single natural food is supplemented singly or in a multiple fashion with known nutrient principles, such supplementing increasing in complexity as the series is extended until it is discovered what constitutes the fewest additions

of known nutrient principles which just suffice to complete the food in question and form an adequate diet. This system is known as the "biological method" for the analysis of a foodstuff. We now have a great body of knowledge based upon the application of this procedure to all our more important natural foods.

Many kinds of grazing animals subsist well solely upon leaves of grass or other forage crops. The importance of the leafy type of vegetable in the diet of the rice-eating peoples cannot be overestimated. Because of the density of population, milk-producing animals are not kept in the rice-eating regions so these people have never had a supply of dairy products. Their only food of animal origin is eggs, poultry and pork, which are eaten somewhat sparingly, but in some places considerable amounts of fish are available. People on such a dietary regimen are very successful in their physical development and compare in the most favored districts with the best specimens of the human race anywhere to be found.

A third type of diet which is satisfactory is found in use in the dryest regions of the world. On the margins of the Sahara and Arabian deserts, and in the great dry belt extending across Asia from Arabia to Mongolia, the inhabitants subsist only through the conversion of pasturage into human food through the agency of flocks and herds. Here the only article fit for human consumption which is likely to be available in abundance is milk, which ordinarily sours quickly because of the contamination of the containers with remnants of sour milk and the absence of means of refrigeration. In Arabia the typical diet of the native consists mainly of sour milk, but this is supplemented with a small amount of barley bread, dates, and with meat approximately once a month. Even under the trying conditions of desert life people live and maintain surprising vitality on such a simple regimen. There are certain characteristics about the diet of people in the great centers of culture in the north temperate zones, which include the United States, Canada, and Central Europe, that tend to induce malnutrition. The significance of this could not be appreciated until research on quality in foods and the

nutritive requirements of the body had progressed to a suitable stage. For example, although refined bolted flour has been manufactured to some extent from time immemorial its use never became general until after 1879, in which year the roller mill process for making white flour was invented. Considerations of commerce, the great distance to the centers of population in the eastern United States from the great grain growing regions in the west, and the inevitable transport of flour for long distances by ship or rail, necessitate keeping qualities in flour which were entirely unnecessary two generations ago when the milling industry was a neighborhood one and the stock of flour relatively unrefined was replenished at intervals of two to three weeks. We are now, therefore, eating highly refined white flour, degerminated corn meal, and polished rice, in different parts of the country in amounts never before approached.

At present the annual consumption of sugar per person per year in the United States is 115 lbs. The consumption has increased about ten times in a century and now constitutes as much as 8 or 10 per cent of the total energy supply of many people, who are likewise consuming a high intake of refined cereal products. For some years I have described the typical American diet as a white bread, muscle meat, sugar and potato combination. Such a mixture is a failure in animal experiments and would be a failure in human experience if it were not for the regular addition of small amounts of certain foods which have the property of enhancing the quantity of the principal articles of the diet. These are especially of two classes, namely, the leafy type of vegetable, and milk and other dairy products.

From what has already been said it will be appreciated that on certain kinds of diets the so-called deficiency diseases due to lack of one or another vitamin will develop. Beri-beri is the most widespread of these but at times in the past scurvy was also of common occurrence. Epidemics of vitamin A deficiency have in general affected smaller groups of people. Pellagra has in certain regions reached the proportions of a scourge. As many as 200,000 people were reported suffering from this disease in the United States alone in 1917. From then until the flood of 1927 in the

Mississippi Valley the incidence of the disease has been considerably less, but it rose again on that occasion.

A common defect in the diet of Americans and Europeans is that of a deficiency of calcium together with an excess of phosphorus in the food supply. It has been clearly demonstrated that an unfavorable ratio between these two elements in the food tends to disturb the metabolic processes in the bones. The disease known as rickets can readily be produced in animals in either of two ways: by feeding a diet low in calcium and disproportionately rich in phosphorus, or deficient in phorphorus and disproportionately rich in calcium. In either case in order to have the disease develop there must be a paucity of sunlight containing radiations of ultraviolet wave length, and also of vitamin D. Marked deficiency of protein in the diet over a considerable period, as when the population is at war or approaching famine conditions and is forced to subsist upon a diet of cabbage, lettuce and other green foods has been observed to cause epidemic dropsy.

The idea prevails in many minds that so long as people escape developing the characteristic syndromes of the deficiency diseases, the diet may be said to be adequate. This rests upon a failure to appreciate nice distinctions in physiological well-being. In experimental work with animals it has been found readily possible to distinguish a number of grades of malnutrition. Diets which are very badly constituted may result in total failure of young creatures to grow, or the diet may be sufficiently good so that growth may take place but at two-thirds of the normal rate, the animals eventually presenting the appearance of runts. Again the diet may be good enough to induce growth at the normal rate until adult size is attained and yet be inadequate for the support of physiological well-being throughout the normal span of life.

We have often recorded the chronological age at which distinct signs of senility appear in comparatively young animals as evidence of the quality of the diet. Again, creatures have been observed to develop in a manner apparently normal and in adult life appear to be well-nourished, yet fail in one or another way in fertility: (a) having no young,

(b) producing young but failing to secrete a milk supply for their nutrition, (c) producing a milk supply inadequate in quality such that the young do not thrive, (d) developing cannibalistic tendencies leading the mother to destroy the young.

Recent studies of Koessler lend strong support to the view that chronic underfeeding with respect to vitamin A can produce pernicious anemia. The trend of events in the history of such patients includes digestive disturbances followed by decreased acid secretion in the stomach, resulting eventually in achlorhydria. Under such conditions bacteria frequently develop in the stomach, while peptic digestion fails. The periodic inundation of the duodenum with badly infected food, or half-digested bacterially contaminated food, results in seeding the entire small intestine with putrefactive organisms. The mucosa of both the stomach and intestine is believed to be impaired in respect to secretion and absorption, so that the body tends to be injured by failure of its food supply because of faulty digestion, and also through intoxication caused by absorbing the products of putrefaction which are produced under such circumstances in extraordinary amounts. These substances are in the main destroyed in the process of absorption in normal individuals but the impaired intestinal mucosa appears to promote their passage directly into the blood stream where they tend to destroy the corpuscles and also to injure the blood-forming tissues. One of the most notable discoveries of recent years is the extraordinarily beneficial effect of feeding liver to patients suffering from pernicious anemia.

Since in recent years the tendency in the United States has been in the direction of subsisting upon a diet derived from refined cereals, such as white flour, degerminated corn meal, polished rice and other similar products, meats of a muscle type, potatoes, and sugar, the author has for a decade offered what appears to be the simplest advice as to how the diet may be greatly improved in quality without interfering with our established dietary practices. Milk and the leafy type of vegetables are the only calcium-rich foods, and both of these are so constituted as to have proteins peculiarly effective in supplementing the rather inferior

proteins of many vegetable foods, and are otherwise appropriately constituted with respect to the vitamins and mineral salts. For this reason the writer has designated these as "protective foods" and has urged the planning of the daily diet so as to include more liberal amounts of both than are ordinarily eaten. The recognition of the likelihood of taking a diet which consists too largely of cooked or dried foods, with consequent deprivation of vitamin C, justifies our emphasizing the importance of including in each day's ration some article known to contain vitamin C, the anti-scorbutic principle. This is especially important in the feeding of infants whose milk supply is pasteurized, because pasteurization destroys practically all of the vitamin C. The regular administration of fruit juices, especially orange and tomato juice, has practically caused infantile scurvy to disappear in the United States. In out of the way places, especially during the winter, potato juice, cabbage juice, or turnip juice are often to be had and form an excellent substitute for orange or tomato juice. As has already been said, certain foods canned by modern processes are also a fairly good source of vitamin C. Reduced to the simplest possible terms, the best advice as to how to insure an adequate daily diet is as follows: The daily diet should be built up around the consumption of approximately one quart of milk a day. This will afford about 800 calories of energy and will constitute from ¼ to ⅙ of the total energy intake of most individuals. There should be one serving of leafy vegetables such as cabbage, spinach, Brussel's sprouts, cauliflower or other greens, and two servings of salad each day. It would be logical to always eat these at the end of the meal because of the detergent properties of raw lettuce, celery, apples, cabbage, and other raw fruits or vegetables which may constitute part of the salad. This custom would, however, be difficult to establish. The salads are of special importance in furnishing vitamin C. After these simple regulations are complied with the rest of the diet may be selected to satisfy the appetite and may include any of the refined cereal products, sugar-rich foods, etc.

In general the greatest amount of injury through malnutrition results from a diet which is poorly constituted

with respect to several nutrient principles, so that the individual is brought into a condition of chronic injury from lack of one or another of the vitamins, or from an inappropriate supply of mineral elements. The most advertised inorganic deficiency in recent years is that of iodine deprivation in its relation to the development of simple goiter. It is now known that a lack of sufficient iodine will result in a certain type of thyroid enlargement which is very common in so-called goiter areas of which there are several in the United States and Canada. To offset this deficiency enterprising salt manufacturers have put upon the market iodized salt which is said to contain approximately 4 ounces of potassium iodide to a ton of salt. At the present time there is some difference of opinion regarding the soundness of the practice of offering iodine to a population in this manner. The truth appears to be that almost all people in goitrous districts would be benefitted by taking iodized salt. On the other hand, a small number who suffer from adenomatous thyroid are likely to be injured by taking more than the very minimum of iodine upon which health can be maintained. It is always wise, therefore, for one with thyroid disease to secure the advice of a specialist concerning the procedure to be adopted.

A few words concerning the danger from spoiled food should be added. There is considerable carelessness in the household in the matter of odd remnants of food which are often kept for many hours or several days in ineffective refrigerators. Foods which become contaminated with certain kinds of organisms are very dangerous indeed. What is still frequently called "ptomaine" poisoning—a word which has tended to fall into disuse in recent years, the term "food poisoning" having taken its place—is in general poisoning from paratyphoid infected food. It appears also that other kinds of spoilage, especially that in which the proteins tend to undergo decomposition, may cause severe and often fatal illness. It is therefore never safe to serve poorly preserved remnants of food. If any taint is suspected food should be discarded, and should never be eaten except after re-heating for some minutes at boiling temperature. Another type of food poisoning is due to the growth of the

botulinus organism. The *Bacillus botulinus* does not grow at body temperature, therefore it does not develop in the alimentary tract. It becomes dangerous when food contaminated with its spores is canned without the application of sufficient heat to kill the spores. Under such conditions the organism develops at room temperature and in the course of time produces an extremely toxic product. Even taking a small taste of such spoiled canned food has resulted in death. Owing to the gravity of botulinus poisoning the commercial canners have for years made a thorough study of the conditions which they must meet in order to render their products safe and wholesome. For this reason commercially canned foods are now safe in respect to botulism, but home canned foods, especially those canned by the so-called cold pack method, which was so greatly in vogue for some years, are a source of danger. Those who preserve foods at home by canning should secure advice from the U. S. Department of Agriculture or from the National Canners Association, as to methods which are safe.

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Chapter XV

THE INFLUENCE OF URBAN AND RURAL ENVIRONMENT

Haven Emerson and Earle B. Phelps

IS the city or the country proving the better place for man to live in? Are there advantages in the *urbs*, a place of strength with walls, beyond those of the *rus*, a region of broad lands? Has human adjustment to the congregate existence, implying compromise and sacrifice, resulted also in biological adaptation, or success in a new relationship between the individual and his material and social environment?

LIFE IN CITIES

Cities are an experiment for man. He blundered and wasted, lost and suffered in them for centuries before sanitation made cities safe for living, as they had long before become relatively safer than the country for material possessions.

Only within the last hundred years have the changes come which made the city dominate national and even continental populations, at least in the number of inhabitants.

The London of the Saxons held hardly 20,000 people. From the time of Richard I to that of Henry VII, about three hundred and eleven years, the population fluctuated between 40,000 and 50,000. Between 1700 and 1800 there was a growth of 65 per cent and in the next hundred years an increase of over 600 per cent. The extraordinary growth of London did not begin until after 1850. Similarly New York with under 80,000 in 1800 and about 600,000 in 1850, has increased tenfold in the past seventy-eight years.

And this is not exceptional either in the national or continental sense, for the same influences and resource, economic, social and scientific have prevailed widely, at least in Europe and the Americas.

In 1890 only 33 per cent of the people of the United States lived in cities, but the shift from farm to factory, from village to town has been at an increasing rate until today not less than 55 per cent of our total population of 120,000,000 are city dwellers. Among the eleven and a half million people of the State of New York, 85 per cent are classed as urban. In Dakota 86.4 per cent of the people are rural.

What is the effect on human life of moving from farm, forest and shore, where a square mile of continental United States shelters and supports 17.3 persons (40 per square mile for total urban and rural) to the metropolitan area of New York where there are 14,438 persons in the same unit of area, and where there are in many regions of the city 300 to 400 persons living on the acre, or 224,000 on the square mile area?

It is the very best, not merely the average, quality of life which we strive for, as well as for a greater length or quantity. It is the satisfactions of human life, the function of enjoyment, not merely the status of material existence or survival we try to attain. Any index of success in man's gradual or forced adaptation from his so-called natural, his primeval or ancient manner of life to the prevailing trial or test of existence in great community aggregations will prove incomplete and inadequate unless it includes a spiritual as well as a physical element. However successful the historians and philosophers of tomorrow may be in evaluating the relative merits of our present preference for mass existence as distinguished from the family or unitary life of our but recent ancestors, we can at least relate today those differences and similarities of record which characterize the lives and deaths of city and country residents.

MODERN MUNICIPAL SANITATION

It was not until such alert and analytical citizens as Chadwick in England and Shattuck and Stephen Smith in Massachusetts and New York began to study the balance sheet of their fellow citizens that the desperate plight of the town dweller was made known. Cities could not grow or

even survive when the death rate exceeded the birth rate. Immigration from the land and from other countries could not long make good the losses from disease when half of all the babies born died within the year. Even with birth rates almost twice as high as those prevailing in our cities today, the annual death rates of London and New York in the middle of the nineteenth century not infrequently exceeded them.

The alarm raised, together with the constant evidence on all sides that the wealth and influence, the commerce and industry of the cities were at stake, created a public opinion which was finally responsible for the era of modern municipal sanitation.

Seventy-five years ago the large cities of Europe and America were unsafe for human habitation. Death rates of 30 per thousand of the population were not uncommon and the loss of child life was appalling. Extinction was prevented by the organization of services and facilities for disposal of human waste, the provision of safe food and water, some control of housing and work places, and specific measures for limiting the spread of the communicable diseases.

There are cities in the United States today where the Negro fraction of the population, constituting from 10 to 20 per cent of the total, shows an excess of deaths over births. The urbanized Negro, the most primitive of the races engulfed in city industrial life, suffers as the white races of England and America did in our cities of 1850, from factors which are not solely those of educational and economic disadvantages.

Everywhere the Jew exhibits a superiority to other races in his ability to survive the city handicaps, possibly as a result of the long centuries of enforced ghetto existence in many lands, and his thriftiness, his intelligent use of professional and communal services for his health protection.

Municipal sanitation saved the life of the city. The city would now be king. In fact the balance of power not only of wealth, but of actual numbers of our population has shifted to these artificial environments we have created. The city seems now to supply to the majority of our people those

satisfactions that constitute the object of life in larger measure than does the country.

How nearly has man overcome the handicaps he has created by crowding together? What has he acquired which can be considered a biological asset?

COMPARATIVE DEATH RATES

In its simplest terms the truth appears to be that the death rate is higher and the expectation of life is less in city than among rural populations. Differences of age, sex and race composition of the populations cannot wholly explain the disadvantage of the city people. Either the greater prevalence and severity of diseases or the lower resistance of the people in the city seems to be responsible.

Perhaps the best single index of the relative hygienic value of living conditions in city and country is to be found in the death rate from tuberculosis, a disease which expresses, certainly in comparable racial aggregates, the sum of environmental, social and economic conditions which we speak of as the standard of living. When due regard is given to the place of origin of the disease as distinguished from the place of death of the patient we see emphasized in a striking way the advantages of rural over urban conditions.

The residential death rates from tuberculosis in New York State as analyzed for the year 1926 by J. V. DePorte show them to be consistently higher among city dwellers than among rural residents. Thus the tuberculosis death rate, computed on the basis of resident deaths for New York City irrespective of the place of death in the State was 102.5 per 100,000 of population and for the rest of the State it was 74.3.

Similarly the resident tuberculosis death rate for the urban part of New York State outside New York City was 83.2 per 100,000 population, while that of the rural portion of the State was 59.4.

This same difference is maintained throughout all classes of cities when compared with the rural areas of their respective counties, whether we deal with cities of large sizes or with those of 100,000 to 250,000, 50,000 to 100,000, 25,000 to 50,000, or places of 10,000 to 25,000. These differ-

ences cannot be explained satisfactorily on any basis of selective race, age, sex, occupational or economic differences among the 11,318,734 people dealt with in this study. As Dr. DePorte well says: "Among the several important causes of death, the element of residence is perhaps of greatest weight in mortality from tuberculosis."

Turning now to the death rates of the registration area of the United States in 1910 and 1920 we find not only in the rate for all causes combined, but for a goodly number of the more common causes of death, higher rates among the city people than among the rural. The following table gives not only the differences between urban and rural rates, but the trend and the consistency of the differences over that decade during which the shift of population to the cities took on the highest speed, to be exceeded in all probability, however, by the period since 1920. No similar period of time has been characterized in this country by a greater improvement in general health conditions in both city and rural regions. At no previous period have the services of science and of the medical profession and public health workers been more nearly similar in value for the great majority of rural communities as well as for the cities.

Various parts of the country, notably in the states of New England and in northern New York where extreme changes have occurred in the age grouping and rural proportion of the populations concerned, there has been observed during the past fifty years an increasing inadequacy in the number and distribution of physicians to meet the desires or necessities of small and widely scattered village and farm groups. Physicians distribute themselves very much as other people do, on the basis of more advantageous economic and social conditions for themselves and their families. They too, therefore, have gravitated to city centers where hospitals, laboratories, libraries and schools are available. While one physician to seven hundred people was a reasonable ratio in the era of the horse and buggy and dirt roads, today with no more effort or time, a physician can readily serve a thousand people as well or better, even if they are as scattered and distant, as were their ancestors. There would seem to be no evidence that health protection or

care of the sick in rural areas has yet been sacrificed to any degree by the cityward trend of country folk and physicians, although within the next twenty years, failure of medical services, if determined exclusively on an individual preference or competitive basis by physicians, is likely to develop, especially where the clearing of the roads in winter cannot be relied upon. The local county or crossroads hospital available for all patients and for all physicians is likely to prove a sufficient advantage to attract the young physician again to enter rural practice. In the sparsely settled mountain regions of the Carolinas, Kentucky and Tennessee there never has been any self-supporting basis upon which adequate medical services could be provided, and a retrograde condition both physical and mental has prevailed.

The active public health movement, encouraged by funds from private philanthropy, which has already resulted in the provision of full-time health officers for more than

TABLE I

URBAN AND RURAL DEATH RATES BY PRINCIPAL CAUSES PER 100,000 OF POPULATION IN THE UNITED STATES REGISTRATION AREA (U. S. CENSUS BUREAU, MORTALITY RATES, 1918–1920)

	1910		1920	
	Urban	Rural	Urban	Rural
All causes	1590.0	1340.0	1411.0	1194.0
Diseases of the Heart	157.6	142.1	168.1	133.1
Appendicitis	14.0	7.2	19.2	7.5
Pneumonia (all forms)	171.2	109.5	168.5	107.0
Tuberculosis (all forms)	179.5	127.4	118.5	108.2
Nephritis and Brights' Disease	111.3	76.5	100.2	78.0
Cancer, Malignant Tumors	81.5	70.1	99.8	68.0
Puerperal Septicemia	8.1	5.8	7.8	5.4
Cerebral Hemorrhage	72.3	80.0	80.5	81.4
Diabetes	16.8	13.5	19.4	13.1
Diarrhea and Enteritis (under 2 years)	118.0	77.3	52.2	35.1
Diphtheria and Croup	25.8	15.9	18.9	12.1
Measles	13.4	11.5	10.3	7.4
Typhoid fever	22.4	23.3	5.5	9.6
Scarlet Fever	14.2	8.2	5.4	3.9

12 per cent of all the counties of our states, promises to be of increasing value in carrying the benefits of the applied medical sciences of today to remote homes and small villages. Rapid increases in means of communication and transportation and wider spread of reliable information about personal health will continue to bring benefits to the rural family which have up to this time been available only in large centers of population.

It will be noted that the crude general death rates from all causes, without adjustments for age, sex and racial differences in the populations (first line of table) are higher for city populations for each of the years by almost exactly the same degree, i.e. about 18 per cent. The improvement in health and security of life has been at the same rate during the decade 1910–1920 in both city and country populations, and still we find that the city rate in 1920 is not yet as low as the rural rate in 1910.

Apparently the disadvantage of city existence as compared with rural, for the population groups as they are constituted today, in the United States, is represented by approximately 2.2 deaths per thousand per annum, which for the estimated 65,000,000 people classified as urban dwellers amounts to a total of 143,000 deaths per year.

The chief racial differences of population are in favor of the city group since the negroes are to be found in larger proportion in rural than in urban populations and it is their presence which always raises a general death rate. Any correction made on the basis of proportion of white and colored races would result in a greater disadvantage in urban death rates.

Similarly in the matter of age differences the result of adjustment would be to raise and not lower the city rates. It will be seen from Table 11, summary of age groups of the urban and rural populations in the State of New York, that the city population has a greater proportion of younger persons.

Again in the matter of differences in the proportions of the sexes in the two groups of population, the city contains a generally higher ratio of women than does the country, as for example in the metropolitan area of Boston there are

TABLE II

AGE GROUPS IN NEW YORK STATE POPULATION

Age (years)	Urban (per cent)	Rural (per cent)
Under 15	27.9	27.8
15–24	17.2	14.5
25–34	18.8	13.8
35–44	15.1	13.4
45 and over	21.0	30.5
Total	100.0	100.0

just over 80 males for every 100 females, while in Massachusetts as a whole there are found to be 96 males for each 100 females. The death rates of females are in general lower than those of males, and their life expectancy on the whole two or three years longer than that of males for the various decades of life.

The upshot is that when we adjust and correct city and rural death rates by taking into account the differences of race and age and sex, the resulting city rate is higher and the rural rate lower. When this process is carried out for New York City as compared with the rest of the State, the city death rate is raised at least one point per thousand and that of the state, preponderantly rural, correspondingly lowered. The disadvantage of city existence as compared with rural for similarly constituted population groups, therefore, would be materially greater than has been indicated above, and the comparative death rates of Table 1 uncorrected for age, sex and race differences, represent a distinctly conservative statement of that disadvantage.

How much of this excess is chargeable to the environment, physical and social, of the city, and how much to the trades and occupations, which are now conducted in the city and which might if carried on in rural communities cause at least as much loss of life, we have no way of knowing.

Much evidence, however, for the essential hazards of city life *per se* as compared with rural can be had from a study of individual causes of death among young and old, and from factors not primarily or necessarily related to

occupations. Particular death rates for the principal causes are with few exceptions higher for urban than for rural populations (Table 1).

THE EXPECTATION OF LIFE

More satisfying than death rates in picturing the relative healthfulness of groups of people is the life expectancy table in which we see reflected the experience of the past in terms of probability of survival of those now living. It may be explained that the "expectation of life" is the average length of life remaining to all persons alive at the beginning of a specified year of age. For our present purpose we can quote as applicable, with a high degree of probability, the experience of the white race in the original registration states (New England, New York, New Jersey, Indiana, Michigan and District of Columbia). The rural population described is that part of the people living in communities of 10,000 or less.

TABLE III

EXPECTATION OF LIFE FOR THE WHITE POPULATION OF THE ORIGINAL REGISTRATION STATES (1909, 1910, 1911)
(Bureau of the Census, U. S. Life Tables, 1910)

Years remaining:	Male		Female	
	Urban	Rural	Urban	Rural
At birth	47.32	55.06	51.39	57.35
At age 10	49.13	54.53	52.22	55.54
20	40.51	45.92	43.51	46.86
30	32.61	38.1	35.52	39.05
40	25.32	30.20	27.88	31.15
50	18.59	22.43	20.53	23.27

There is then no exception to the advantage at every age group of the rural as compared with the city dweller in the average length or expectancy of life.

This does not, however, tell the whole story any more than one can get all the truth from the death rates of an individual year. These figures mean that under a uniform condition as to death rates at each age group, equal to that of the period 1909–1911, a male child born and continuing

to live in the country will, on the average, live nearly eight years longer than a male child similarly born and living in the city. The difference for a female child is about six years. These advantages of the country decrease numerically with advancing years, until at the age of fifty they are about one-half the initial value.

The life tables deal with death rates at each specific year of life and hence the results are automatically corrected for any disparity in age grouping as between city and country. It cannot be assumed, however, that the generally greater expectation of life enjoyed by the country dweller is due wholly to his physical environment.

TABLE IV

LIFE EXPECTANCY IN THE ORIGINAL U. S. REGISTRATION STATES
(Bureau of the Census, U. S. Life Tables, 1910)
White Males

	Age	0	10	20	30	40	50
1901	Urban	44.0	47.5	39.1	31.9	25.1	18.6
	Rural	54.0	54.4	46.0	38.4	30.5	22.8
	Difference in favor of rural	10.0	6.9	6.9	6.5	5.4	4.2
1910	Urban	47.3	49.1	40.5	32.6	25.3	18.6
	Rural	55.1	54.5	45.9	38.1	30.2	22.4
	Difference	7.8	5.4	5.4	5.5	4.9	3.8
Change 1901–1910	Urban	3.3	1.6	1.4	0.7	0.2	0
	Rural	1.1	0.1	−0.1‡	−0.3	−0.3	−0.4
	Difference	−2.2*	−1.5	−1.5	−1.0	−0.5	−0.4
	White Females						
1901	Urban	47.9	50.3	41.9	34.5	27.3	20.3
	Rural	55.4	54.4	46.1	38.8	31.2	23.5
	Difference	7.5	4.1	4.2	4.3	3.9	3.2
1910	Urban	51.4	52.2	43.5	35.5	27.9	20.5
	Rural	57.4	55.5	46.9	39.1	31.2	23.3
	Difference	6.0	3.3	3.4	3.6	3.3	2.8
Change	Urban	3.5	1.9	1.6	1.0	0.6	0.2
	Rural	2.0	1.1	0.8	0.3	0.0	−0.2
	Difference	−1.5	−0.8	−0.8	−0.7	−0.6	−0.4

* Difference in favor of rural is decreasing.
‡ Rural expectancy decreased.

By comparison of the life expectancy tables of 1901 with those of 1910 it appears that by this criterion there has been a gradual reduction of the disadvantage of the city dweller. While the rural population still (1910) enjoyed a substantially longer life expectancy at every decade of from four to eight years, than did his city friend, the gains of the city man and woman have been a little greater; thus the difference has been reduced. There is good reason to believe that there has been a continued reduction in the handicap of the urban population since 1910, but the life expectancy tables have not yet been officially issued since then.

A white male born and continuing to live in the country had an expectation of life at birth, in 1901, 10 years greater than that of a similar male child in the city. At the age of fifty this advantage had decreased to 4.2 years. Similar values for white females are 7.5 years and 3.2 years.

In 1910 the actual expectancy of a male child had increased in the city by 3.3 years and in the country by 1.1 years so the advantage in favor of the country had been reduced 2.2 years, that is from ten years to 7.8 years. At the age of fifty the expectation was unchanged in the city and 0.4 years less in the country, reducing the country advantage from 4.2 to 3.8 years.

Turning now from the quite convincing evidence that, taken as a population group, city people die earlier and at a higher rate from the principal causes than do country people, we have many elements, entirely apart from those of heredity, race, age, sex and a possible social selection, any one of which may have a share in causing the disadvantages, and which are worthy and possible of analysis.

In the environment of the city dweller, compared with that of the rural family, we appreciate differences of atmosphere, water, food, clothing, lighting, insects and personal contacts, each a possible factor in modifying the safety of life.

While there seems to be almost no limit to the adaptations of life to differences of environment in permitting these to occur without sacrifice of the individual, there is some reason to believe that we have not caught up with the rapid changes which have accompanied the artificial environment we

have created in our cities. We are largely in control of environment but we do not yet know with certainty the lengths to which we can safely go in modifying it for our convenience, comfort or pleasure.

THE ATMOSPHERE

The atmosphere is man's most intimate physical environment. Physiologically it has two primary functions: It provides for the necessary respiratory exchange, oxygen being taken into the system, and carbon dioxide being given out. It also provides for the removal of heat from the body surfaces, lungs and skin, by processes of convection and evaporation. Except under conditions of asphyxiation, smothering or drowning, the respiratory exchange function seldom fails. The modern problems of ventilation concern themselves to a large extent with the second or heat-removing properties of the air.

As has been previously suggested, the air provides a climate, and under our present-day habits of life, especially in the cities, we deal largely with an artificial climate. In addition to the temperature, humidity and movement of the air, its three significant physical properties affecting comfort and health, the atmosphere has qualities that determine the character and extent of solar radiation reaching the earth's surface. It is in fact a selective screen through which the sun's rays pass with more or less modification. Of the light of the visible spectrum, "light" in the common use of the word, about 20 per cent is absorbed by a clear atmosphere at sea level. The rate of absorption increases with decreasing wave length so that only a small part of the total ultraviolet radiation of the sun ever reaches the earth's surface, while a large proportion of the infra-red spectrum and the heat rays do come through. This selective screening effect is of course modified by the thickness of the air layer (altitude of the place) and by the clouds, fog, smoke and dust.

Another property of the atmosphere, concerning the effect of which we know but little, is its electrical property. We live in a strong potential gradient by reason of which an electric current is always passing between the earth

and the air. The amount of this current is dependent upon the ionization of the atmosphere, which in turn is affected by the presence of radio-active substances, by ultraviolet radiation and probably by the penetrating radiation recently studied by Millikan. The relation of these electrical properties of the air to health and comfort offers an interesting field of study. At present our knowledge concerning this is imperfect.

As regards urban and rural atmospheres, great differences are at once apparent. The physical properties, temperature, humidity and movement, are determined, of course, by latitude, altitude and relation to seashore and mountains, but under otherwise equivalent conditions, the "open air" of the country has advantages, especially in the summer time.

A characteristic of large cities is the mass of heated brick, stone and concrete that reflects much of the sun's heat back upon the dwellers and retains what heat is absorbed, giving it out in the night hours, preventing the natural cooling that comes in the country with the setting of the sun. Air movement is lessened by tall buildings, and the human output of humidity and heat becomes a distressing factor in crowded places.

Whereas in the city the radiant heat of the summer sun, striking the masonry of buildings and paved streets, is either reflected, adding to the immediate discomfort, or absorbed and stored, to be returned during the night-time, in the country it is to a large extent absorbed and neutralized by green foliage. The full significance of this phenomenon can best be shown by a brief mathematical computation.

It has been estimated (Bailey) that an acre of beech trees, 400 to 600 trees, will evaporate about 2,000,000 pounds of water during the season, or let us say 10,000 pounds per day. The heat absorbed by this amount of evaporation amounts to 65 small calories per square centimeter per day.

The solar constant, as defined by the Smithsonian Institution, represents the quantity of heat that would be received from the sun if there were no atmosphere. On a clear day, at sea level, the actual heat received is of the order of 90

calories per square centimeter per hour, on a surface facing the sun. On surfaces inclined to the sun's rays the heat received is less according to the cosine of the angle of inclination. The earth's surface is more or less inclined first according to latitude and season, and again according to the hour of the day.

At latitude 42° the sum of the hourly values of the cosine of the angle of inclination is 7.61 for the 15 hours of sunlight at the summer solstice, and 5.67 during the 12 hours at the equinoxes. These values then represent the equivalent hours of normal exposure during each day, and their mean value, 6.6, may be taken as a fair representation of the average daily number of hours of normal exposure during the summer. The average daily amount of heat received, therefore, on a square centimeter of surface does not exceed the value for normal exposure, 90 calories per hour times 6.6 hours or 594 calories per day. It is always less than this by the proportion of cloudiness, and by the amount of heat intercepted by fog, smoke and dust. In the vicinity of New York City, the cloudiness alone diminishes the sunshine to 60 per cent of its possible value during the summer months.

The computed absorption by trees, 65 calories, is 11 per cent of the total heat received over the forest area through clear and dry air, and a much greater proportion of the actual radiation through the average atmosphere. The significance of this value will be appreciated if it be noted that, taking in the hours of normal exposure as computed, the difference between the summer solstice and the equinoxes amounts to only 25 per cent of the former.

It will be noted in Table 1 that the death rate from diarrhea and enteritis under two years of age was 48 per cent higher in the urban than in the rural populations (52.2 urban, 35.1 rural) in 1920, and in 1910, 53 per cent higher. While diarrheal disease of infants has generally in the past been thought to be due chiefly to the spoilage of food, to bacterial contamination of milk and water and to lack of care in washing and clothing infants, strong evidence has recently been presented by Arnold suggesting that such high effective temperatures as commonly prevail in our cities in summer are a definite predisposing cause to this

disease. The city child suffers more from diarrhea and enteritis probably because the environment of brick, stone, concrete and asphalt prevents his adjusting to temperature, humidity and air motion, as favorably as he does where foliage is present. Carelessness in the city household in many of the minor details of cleanliness and care of children may result from the general demoralization which commonly accompanies spells of hot weather. Even among cities there are differences in the unfavorableness of environment. For instance, in Washington, where the expectancy of life is the highest of all the cities of 500,000 and over in the registration area, and in Pittsburgh, where it is lowest, we have the extremes of abundant foliage, parks and spacious streets in one place and an almost treeless, parkless city of bare streets in the other. Pittsburgh's death rate from diarrhea and enteritis under two years of age has for many years ranged from two and a half to four times as high as that of Washington, for the white population, although much of this difference is doubtless due to differences in age, sex and social elements. In view of all these facts, it seems not improbable that the atmospheric environment of Washington is responsible in considerable measure for the advantages which its children enjoy in a low death rate from this chief cause of infant mortality.

TABLE V

DIARRHEA AND ENTERITIS UNDER 2 YEARS OF AGE: DEATH RATE PER 100,000 WHITE POPULATION

Year	Washington	Pittsburgh
1911	55.4	132.0
1912	31.2	116.0
1913	34.9	138.0
1914	18.9	106.7
1915	26.3	100.6
1916	27.5	123.6
1917	35.3	130.8
1918	35.5	121.2
1919	28.6	89.2
1920	22.6	75.5

Most of the large cities have ordinances designed to prevent the smoke nuisance, but strict enforcement has generally been tempered by a knowledge of the difficulties involved, especially in the combustion of soft coal. The railroads are among the worst offenders and a recent survey in New York has indicated that the harbor boats are frequent and serious offenders.

In certain of the larger mid-western cities, determined efforts have been made to abate what was rapidly becoming a most serious nuisance. In Pittsburgh, in particular, it was decided to clean up the atmosphere, for the nickname of the "smoky city" was not one to be proud of, nor did it confer commercial advantage. Quantitative measures of the actual pollution of the atmosphere have indicated a very great improvement since the active campaign of abatement was begun, and the improvement is obvious to the regular visitor. Many other of the great industrial cities of the Middle West have had similar experiences, although present conditions in most of them are still bad according to the standards of the eastern cities, where soft coal is not used to so great an extent.

In New York, on the other hand, the tendency has been in the opposite direction during recent years. Labor troubles in the anthracite coal regions have led to a relaxing of the rules against bituminous coal and the taxpayers are becoming accustomed to a gradually increasing load of atmospheric pollution. The efforts of the health department to prevent the growing evil have so far had little or no result apparent to the dwellers in certain sections, although it cannot be denied that the strong presence of attempted law enforcement has partially stemmed the tide of growing disregard of the sanitary code. A most suggestive aspect of the situation has recently been recorded in a report of the Committee of the Merchants' Association of New York. They show a definite and very large economic injury to merchants, manufacturers and others, due to the increasingly smoky atmosphere. As soon as we begin a scientific evaluation of the economic losses resulting from the unrestricted use of soft coal, probably conservatively expressed at $20.00 per capita per annum, it will no longer be necessary to

meet the strong economic argument *for* soft coal by the less definite and oft-questioned statements of possible health hazards *against*. When economic gain meets economic loss on even terms, health and comfort and civic pride may ultimately determine the issue.

Atmospheric pollution with smoke and dust, and the fog, which is increased by the presence of both of these in the air, is greater over cities than in the country, with a resulting reduction of the permeability of the air by those valuable short rays of light which are known to be preventive and curative for rickets. While rickets may occur in any latitude if there is interference with the metabolic processes which determine normal development, particularly of the soft growing ends of the long bones of the body, it is found most abundantly, and indeed almost universally, among babies in their first year of life in the large northern cities of Europe and America. Here, in addition to the limitations of the sun's rays by low inclination and cloud, children are housed unsuitably as to light and fed unsuitably as to antirachitic elements of diet.

Rickets is but rarely found as a direct cause of death, but its harmfulness if reflected in increased susceptibility of children to bronchitis and pneumonia, and in the difficulty of childbearing in women whose pelves have been deformed by rickets in childhood. Even with the widespread use of cod liver oil and artificial sunlight to correct and prevent the rickets of infants in the cities of the United States there was even as late as 1920 a ratio of 1.75 cases per child population in cities to every one among country children.

While many elements go to make up the causes of death from bronchitis and pneumonia, it is worth noting that in the registration area of the United States the city rates were far above those of the country as shown in Table VI.

In those areas of our cities where rickets prevails among children, for example where Negroes and Italians live in crowded tenements, the death rates of children from pneumonia and bronchitis are found to be from two to three times as high as in the rural areas of the same latitude. The same races that exhibit rickets most abundantly in

TABLE VI

BRONCHITIS AND PNEUMONIA: DEATH RATES PER 100,000 POPULATION, 1910 AND 1920

(U. S. Registration Area)

	1910		1920	
	Urban	Rural	Urban	Rura
Acute Bronchitis	16.8	10.7	9.7	5.9
Broncho-pneumonia	61.0	28.9	69.9	40.2
Pneumonia	110.2	80.6	98.6	66.8
Total	187.0	110.2	178.2	112.9

northern congested city quarters, where sunlight and even sky-shine is difficult to get for many months in the year, are entirely free from rickets in southern climates and in rural regions.

Children of school age show consistent differences in the prevalence of acute respiratory tract disease, "colds and coughs," which betrays one of the apparent and perhaps temporary superiorities of city environment. From the studies of the New York Ventilation Commission in regard to heating and ventilating schools, with every factor controlled as far as was humanly possible, it was found that the acute respiratory disease rate among children of rural Cattaraugus County resulted in an absence rate of 23 per cent of possible days of school attendance, while among the urban children of Syracuse this absence rate was 9.9 to 11.7 per cent for the same school year (1926–1927), with the experience in New York City in other years almost identical with that of Syracuse. In cities the inclemencies of weather are much less of a hazard, because of nearness of the child to school, the freedom of the pavements from snow, slush and water, and the quicker drying of hard, drained street pavements. Wet feet, wet clothing, long distance in wind and rain and snow seem to have been among the important factors to the disadvantage of country children, all of which, however, are nowadays being offset to a great degree by the concrete or hard surfaced country

highway, and automobile transportation between home and school.

While the aesthetic and economic dangers of a city atmosphere polluted by smoke, dusts, industrial gases, fumes and odors is easily determined and measured, it is a matter of great difficulty to prove that the fouling of the air in cities is the direct or contributing cause of important groups of sicknesses and deaths.

Where evergreen trees, vines, shrubs and the sturdy grasses and flowering plants cannot survive the deposit of tar, ash, sulphur and the limitation of sunlight even in the open yards and park spaces of cities, we may assume that the area is not fit for the human child. City environment as sketched here is common in many American cities. In all such city quarters we find the poorest paid, least intelligent or certainly the most underprivileged of our unskilled laboring population and the high sickness and death rates. It is impossible to be sure what part of the poor hygiene is properly chargeable to the bad city-made physical environment and what is the share of ignorance, poverty, foreign birth and unstable economic status.

WATER SUPPLIES

From the point of view of our present study, water represents one of the essential contacts between man and his environment. It extends the range of the environment and makes it possible for an adverse condition, such as a typhoid case or carrier, at some rural point, to affect the individual or a large part of the population in a distant city community. The prime essential in a domestic water supply is freedom from pathogenic bacteria, and this in general means freedom from human pollution. Typhoid fever is the disease, in this country at least, most frequently associated with polluted water and the typhoid fever statistics of cities before and after they have undertaken the purification of an impure water supply furnish clear evidence of this association. In the city of Pittsburgh, for example, filtration was begun in 1908, although portions of the city continued to drink unfiltered river water for the next two years. The typhoid fever death rate for the period

1900–1908 averaged 133 per 100,000 population. In the period 1911–1915 the average rage was 15.9. For comparison, Boston showed rates of 16.0 and 8.0 for the five year periods before and after 1910 without change in its fairly satisfactory water supply.

At Columbus, Ohio, the typhoid fever death rate had averaged over 75 and had frequently been in excess of 100. The filtration plant was completed in the fall of 1908. The two years following showed rates of 20 and 18, and during the next five years, the rates averaged 15.8. Similar instances could be multiplied to almost any extent, for in the whole field of sanitary science there is no clearer proof of the adequacy of any measure taken for the protection of the public health than is to be found in the reduction of typhoid fever through water purification.

As a general thing the water supplies of cities are of satisfactory quality. This is one advantage enjoyed by a large, congested population over a smaller one. New York City, for example, has been compelled by the gradually increasing density of population in its environs to extend its water supply catchment further and further afield, until today it reaches into the Catskills and appropriates water at a distance of 135 miles from the city. The sources of this water are carefully protected and controlled; it is submitted to the purifying action of storage in great reservoirs, and is protected against any small remaining chance of pollution by chlorination at several points in the system. The result is a water supply that in point of view of safety and general desirability is all that can be asked for and is excelled by few if any large city supplies.

The reason this amount of effort can be expanded to procure a satisfactory water supply is the astonishingly low per capita cost to the city dwellers. The cost of collecting, storing, protecting, purifying and conveying from the mountains and delivering to the people of the city their individual daily allowance of a hundred and thirty gallons of a safe, attractive, palatable water is about three-quarters of a cent a day in New York City.

The smaller town supplies are proportionately more expensive, and cannot afford the same degree of protection.

The difficulty of supervising a water supply and of supplying water which is safeguarded and not merely passively "safe" increases with diminishing size of community, and reaches its limit at the farm well.

A modern water plant for the farm, including adequate protection of the well and a pumping outfit with storage tank, will cost more per capita than the New York City supply, both as to installation and for operation and maintenance. In general the rural supply is inadequately protected. On the other hand it has the advantage of isolation. Many dangerously pollutable wells are harmless because of the absence of disease among the immediate members of the family.

Both the typhoid fever and dysentery rates confirm the opinion as to relative safety of urban and rural water supplies in the United States, based upon sanitary and engineering information.

TABLE VII

TYPHOID FEVER AND DYSENTERY: DEATH RATES, U. S. REGISTRATION AREA, 1910–1920

	1910		1920	
	Urban	Rural	Urban	Rural
Typhoid fever	22.4	23.3	5.5	9.6
Dysentery	4.4	8.3	2.0	5.9

The typhoid fever death rate has fallen 75 per cent in cities during the ten year period and that of rural populations, 59 per cent. The city populations have an advantage in security against communicable diseases transmitted through discharges from the bowel, because they have used their combined resources to buy engineering skill to dispose of human wastes in a sanitary manner and for the protection of their communal water supplies. It has been stated that nine-tenths of the problem of rural sanitation consists in protecting the water supply of the household from pollution by its own human wastes.

FOODS

Foods are properly considered from the sanitary point of view a factor of environment only less immediately or momentarily essential to life processes than water and air. Through foods our contact with physical environment is most widely extended. Entirely apart from the quality and relative proportions of the essentials of human nutriment expressed in protein, fat, carbohydrate, salts and vitamines (discussed in Chap. XIV) there are in the processes of production, transport, storage, preparation and serving of foods, factors in the cause of preventable diseases of the communicable and nutritional groups affecting in different ways and to different degrees urban and rural residents.

Variety, range, freshness and cost of foods used to be all to the advantage of the country family, but today the control of food supplies, through the power of demand by cities, has so far altered the situation that in fact even the family of small means in the city may supply its nutritional needs more reliably throughout the seasons and often at less expense than can the dweller on farm or in rural village.

The greater buying power of the city permits a degree of supervision over the sanitary safety of foods quite impossible for scattered rural households. Today the city dweller commands a range of foods, of higher standard, and better guarded against the hazards of contamination by disease than does the rural householder. Federal inspection of meats is one of the great central sanitary services which protects city food consumers to a degree quite lacking for those who use almost entirely locally butchered and distributed meats.

Foods from all parts of the world are found in our city markets, those from even distant lands being delivered fresh on our tables by virtue of the superior character of ventilation, chilling and speed in transportation, while the canning, desiccation and cold storage of foods makes it possible to have all the year round diets adapted to every reasonable need or taste, and appropriate to age and occupation.

If there is advantage in food supplies today, it probably lies with the city dweller, particularly during the winter

season, but certainly unfavorable distinctions are fast breaking down.

However, in regard to fluid milk and fresh milk products, the greater hazard of the distant city consumer has demanded a degree of protection which has so far not been equally available in the regions of milk production.

The milk supply of cities in particular required and has received more attention from the health authorities than any other food. Milk has long been recognized as a possible cause of disease, coming directly from the cow (e.g. bovine tuberculosis and streptococcus sore throat where this is due to an inflamed udder discharging pus in the milk) or indirectly from the handler (e.g. typhoid fever, diphtheria, septic sore throat, when this is due to sore throat in the milker, etc.), and has in fact been a prolific source of epidemics.

Of the 776 epidemic outbreaks of disease traced to milk in the United States in recent years, as reported by Armstrong and Parran of the United States Public Health Service, 613 were of typhoid fever, 7 of paratyphoid, 6 of dysentery and diarrhea, 42 of septic sore throat, 65 of scarlet fever and 43 of diphtheria. Probably only a low percentage of tuberculosis in humans (less than 5 per cent) is due to the bovine tuberculosis conveyed by milk or its products.

By pasteurization and central bacteriological control of the milk supply, cities have learned to protect themselves against the hazards of disease germs introduced into the milk during its production or distribution. All forms of pathogens likely to be found in milk are destroyed at a temperature of 140° in twenty minutes. Commercial pasteurization applies this treatment. Because of numerous possibilities of milk escaping the full treatment intended, the equipment must be carefully designed and operated. Legal definitions of pasteurization differ. New York City requires 143° for thirty minutes. At about 145° in thirty minutes definite physical change begins, the fat globules become dispersed and cream does not rise as completely. At higher temperatures a more definite chemical change occurs.

Pasteurization is little practiced in the country and small town. Here again isolation is a safeguard. Suppose

one farmer supplies ten families, two persons only handling the milk. Each member of those ten families is exposed to the possibility of infection from two persons. But if fifty farmers bring milk to a central plant where it is mixed, stored and sent out to 500 families, a total of 150 persons handling the milk at various stages, the exposure of each individual user to a possible source of infection is now increased seventy-five fold, and a large outbreak of disease now becomes a definite possibility. Nevertheless, the general use of unpasteurized milk in the rural districts is doubtless one of the factors contributing to the higher rural typhoid fever and dysentery rates.

A secondary result of the higher and more uniform standards of safety of the milk in cities is the increase of the per capita consumption of it by city residents. The more reliable the city milk supply the more does it enter into the dietaries of the people, and the city dweller is approaching an optimum use of milk, with resultant benefits to his health and economy for his pocketbook.

It is evident from study of the prevailing diseases of the Porto Ricans and of our native American Indians that in spite of favorable rural environmental factors in other respects, they are suffering severely from the lack of milk, particularly for their children.

LIGHT

Light as a factor of environment, quite apart from the accompanying effects of warmth, or radiation, or specific nutritional effects, bears directly upon the differences of urban and rural life, the dweller in towns submitting to physiological disadvantages from the use of articificial lights to which the human eye is not fully adapted, which the rural resident does not have to suffer. We have no information which can carry us at present beyond the stage of general impression, but it would seem that the artificial conditions of lighting that prevail indoors, in transit, in factory and office, in kitchen, nursery and school, in church, theater and club, in cities constitute a physiological handicap to the function of vision even if no other harmful effect can be determined.

Progress in illumination engineering has probably reduced the injury to the clerk, the factory operative, the student by more nearly approaching an optimum quality and quantity of light upon the near object or throughout the hall and shop, so that a tendency towards equalization of this factor as a selective city disadvantage is undoubtedly occurring.

INSECTS

One further environmental factor not included under the term social or human relations is that of insects which serve as a means of transmitting disease. Cities are certainly at present favored beyond their country neighbors in relative freedom from the fly and mosquito. This is due to the reduction in the number of horses in cities following the advent of motor transportation, to the great pains taken to prevent fly breeding in and about stables and garbage dumps, and to the inevitable destruction of mosquito breeding places, when low land is filled and drained in the process of reclamation for housing, parks and industry.

The urban malaria death rate in 1920 in the United States was 0.9 per 100,000 population and the rural was 5.9.

The body louse and the rat flea are potentially greater hazards in cities than in rural regions but both are so readily controlled by cleanliness and suitable building construction and maintenance for the exclusion of vermin that we may properly ignore them as environmental factors, at least in the United States. It is true, of course, that in many rural counties of California and adjacent states the distribution of the flea (*X. cheopsis*) by the ground squirrel and possibly other rodents constitutes a rural danger, and it is recalled that typhus fever is widely reported from small town and rural regions of Georgia and Alabama, pointing to some still undetermined insect conveyor of disease which apparently operates as well in small as in large communities.

PERSONAL CONTACT

Certainly with the communicable diseases, particularly those transmitted by discharges through the nose and

throat, a chief determining factor is the frequence and intimacy of personal contact, especially if this is uncontrollable, as in the stores, conveyances, public streets, eating places, and industries of many cities. From the experience of the United States it would appear that the acute communicable diseases of childhood are acquired earlier in life in cities, that they cause a higher death rate for this very reason among children and that adult city populations are more generally immune to measles, mumps diphtheria and scarlet fever than are country people of the same ages.

It has been noted in army experience in many countries, in the course of enlistment for obligatory routine military training, and in the emergency of mobilization for war, that young men from the cities are less likely to develop the acute communicable diseases than are those coming from rural regions. Only recently has the science of immunology advanced to the point where proof of immunity can be given, in two of the diseases in question, i.e., diphtheria and scarlet fever, and it is found that the prevalence of immunity to these diseases is greater among city children than in rural children even when there has been no history of attacks of the diseases in question. There is good circumstantial evidence to suggest that by the very process of widespread exposure to those contacts through which communicable diseases are spread, many children in cities acquire, possibly through unrecognized mild attacks of infection and carrier stages, an active and fairly permanent, if not absolute, immunity, which serves as an important protection to them earlier in life and more commonly than to children relatively isolated in rural households who meet a smaller play and school and work group. In other words, there are some compensations in the form of immunity for the higher death rates for these diseases now generally recorded in urban communities.

In spite of our inadequate reporting of the venereal diseases and the uncertainty as to certificate of deaths from these causes, all the experience with both white and colored populations in the United States tends to show their much wider prevalence and higher mortality in cities

TABLE VIII

MEASLES, SCARLET FEVER, DIPHTHERIA AND CROUP: DEATH RATES PER 100,000 POPULATION, U. S. REGISTRATION AREA

	1910		1920	
	Urban	Rural	Urban	Rural
Measles	13.4	11.5	10.3	7.4
Scarlet fever	14.2	8.2	5.4	3.9
Diphtheria & croup	25.8	15.9	18.9	12.1
Combined	53.4	35.6	34.6	22.4

than in rural regions. The mortality rates serve as a probable reliable index of the degree of difference. In 1910 the urban rate from syphilis was 7.3, the rural 3.0, while in 1920 these were 11.9 and 6.0 respectively. Similarly for gonococcus infection the urban rate was 0.5, the rural 0.1 in 1910, and 1.2 and 0.4 respectively in 1920. Some of the difference may be due to the greater proportion of persons of the earlier decades of life in the cities.

All differences in the mortality and morbidity of city and rural populations cannot be explained on the bases of risks of infection, nor yet by the alternations from optimum in the factors of physical environment. The marked and consistently higher death rates from diabetes and appendicitis in cities are in all probability related to the manner of life, with superalimentation and the decreasing necessity for bodily exertion in the ordinary conduct of life as the major causes.

While there is an obvious tendency towards a similarity in the physical equipment of life and labor of the country and city households, there remains the fundamental difference between the closed places of work and the nature of work under unfavorable atmospheric conditions in cities, and the outdoor occupations of the rural family which more nearly approach a favorable biological opportunity for both survival and development.

There is no controlled mass of information upon the relative frequency of mental and nervous diseases among city and rural populations except in the matter of such advanced, serious or terminal conditions as are of necessity

provided for in state hospitals for mental disorders. While to persons of sensitive and intellectual type, living in the great city, the hurly-burly, racket, turmoil and press of persons, the constant pressure of contacts neither sought nor desired, the bombardment upon one's sensations through all the senses of strong stimuli, even the mere physical presence of streams of fellow-beings, the necessary rapidity of reactions, all combine to cause a sort of spiritual fatigue or social nausea, probably the great mass of people are happier when going along in a crowd than when self-reliance and independence are required and where loneliness is the one great horror of their lives. If noise and crowding were causes of disease, boiler makers, pneumatic drill operators, traffic police and motor truck drivers should provide us with abundance of clinical material, and the rate of mental and nervous disease would mount rapidly as we enter the homes on metropolitan thoroughfares where underground, surface and elevated traffic vie with each other in one great competitive inferno of noise and smell, speed and crowding.

With the exception of those mental diseases which follow alcoholism and syphilitic infection, diseases r,ecognized as more frequent in the city than in the country there is no evidence in the admissions to state mental disease hospitals that the city offers a worse environment than the country. In fact, quite the reverse conclusion can be drawn from the reports of several of our states. Loneliness, lack of recreation, the drudgery of farm and housework, the monotony of life unrelieved by visitors or visits, all combine to create disorders of personality and eccentricities of character which lead to such extremes of conduct as to call for medical protection and guidance among rural families.

Like other elements of his most complicated and elaborate being, man's mind and senses are apparently more apt to remain healthy if they are in use than if atrophy or stagnation are permitted. The confirmed city dweller may suffer nervously from the eternal quiet of the open spaces, as the country wife may find her head confused where the city noises never cease. There may be effects of noisy hurried city life upon heart, digestion, or other tissues and functions, so obscure that we cannot detect them or isolate the factors

of human crowd or noisy street as in any way causative of the premature degenerations or decay of tissues that we rather thoughtlessly attribute to the tension of city life rather than admit that they follow perhaps more intimate and personal factors of individual hygiene.

Our study of man in relation to the environment of city and country is directed towards the structure and function of his organs and their reactions to external stimuli. We see him adapting himself with remarkable success to a wide variety of physical and emotional environments. We express the lag in his adjustment to the artificiality of the city by increased death rates from many causes, some of which we know to be preventable and to be related to man-made conditions.

The conditions of life, particularly in cities, have been changing with increasing rapidity during the recent decades in which the shift of population has also been strongly to cities. Our problem as socially organized units, our communal difficulty, is so to modify the results of our human aggregation that we shall approach most nearly the condition of safety for life which we find still in greater measure in the country.

Man's mastery of his environment is one of his distinctions from the brute, which can adjust to but not control its surroundings. There seems to be no reason to doubt that the will to maintain unpolluted air, suitable light, water and food can be expressed almost as effectively in the city as in the country.

Man will remain his own greatest hazard in the cities, partly from the diseases he spreads and knows not how to control, partly from his ambition in the satisfaction of which, as expressed in wealth, luxury and power, he deprives his fellows of some of the indispensable qualities of environment. While the spirit and urge is upon man to seize and enjoy those qualities and substances of life which, he believes, are found only in the city, he will make sacrifices of his health and that of his children to acquire them. He will demand from the sciences and arts every possible adjustment which will bring him in the city the guarantees of survival which nature has abundantly provided in the open spaces.

When speed, and change and power over material things seem less valuable than those qualities and properties of life which man holds always within himself, regardless of his place of residence, we shall see, or our inheritors will, a redistribution of people where less effort will go to the creation of a safe environment by artifice, in an intimate and abundant contact with the invigorating realities of outdoors.

CONCLUSIONS

Apparently we pay and pay heavily in terms of loss of life for our inclination or rather determination to live in increasing numbers in cities. We have been for at least fifty years reducing the discrepancy between rural and urban death rates. Whether we shall ourselves be so modified or adapted that we can tolerate or survive, on equal terms with our country cousins, the conditions so far inherent in city environment, or whether we shall so alter and command the contacts and physical setting of our urban life that these no longer constitute a handicap, only the future can tell. But as long as the rush of people cityward continues, social and medical science will be concerned with watching end results and trends, with analyzing material, social and psychical elements of city life, until man can be sure of control of his environment regardless of place and association with his fellows, so that there may be no hindrance or limit to his choice of place or manner of life in seeking to satisfy his reasonable ambition to live to the limits of his inherited capacities.

The city dweller is in the majority. He will command and perhaps dominate as fanatically as the farmer often has ruled the city in the past. After the city dweller has learned to bend material things to his wishes with entire safety and to accommodate his body and life to the pressing throngs about him in street and store and factory, he will still require in all probability to make and keep contact with the elements, a relation which no amount of associations with similar men can replace. He will always need the sweetening influence of the uncontrollable sun and wind and rain which

he has been at such pains to ward off and limit in his urban life.

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Chapter XVI

ANTISOCIAL BEHAVIOR: DELINQUENCY AND CRIME

William Healy

IT is not possible to discuss scientifically antisocial behavior, such as crime and delinquency, according to the ordinary terms of social facts. What do we mean when we speak of crime, delinquency, criminal, delinquent? For the sake of sound generalizations there is very great need of good definitions and discriminations in this field.

It seems to be taken for granted by most writers that crime is behavior easily differentiated and quite set apart from all other conduct, so much so that very few have conceived that there is any necessity for defining it. But some do pay attention to this point, notably Garafalo, the jurist and criminologist. He cites many instances of laws making crimes of behavior which at other periods and under other circumstances has not been considered crime. To kill during a war is not criminal, and yet killing at other times, perhaps from much the same motives, is a crime. In one place bribery is hardly an offense; in another country it is a serious one.

Garafalo calls for understanding of what constitutes a real or "natural" crime; behavior that would be recognized anywhere and among all peoples as really crime, which, as such, may be contrasted with legal or made crime. Real or "natural" crime is a violation of the fundamental altruistic sentiments, namely, those of pity and probity, in the average measure in which they occur in civilized humanity. However, as Ferri suggests, it should be remembered that social sentiments have changed during the ages; they have been and are being evolved, together with alterations in social conditions. Colajanni very well says that punishable acts are those which, determined by individual and antisocial motives, disturb the conditions of existence and shock the average morality of a given people at a given moment.

The ordinary dictionary definitions of crime are: "An omission of a duty commanded, or the commission of an act forbidden, by public law." "Gross violation of human law—in distinction from a misdemeanor or trespass or other slight offense." Procedure under the criminal law generally makes no attempt to define crime, but the New York Penal Code says that a crime is an act or omission forbidden by law and punishable by death, imprisonment, fine, or removal from office. Delinquency, as the term is used in America, means offense against the law committed by an individual of juvenile court age, up to seventeen or eighteen years in most states.

One of the most important points for consideration by those who study delinquents and criminals scientificially for the purpose of correlating physical or mental peculiarities with special conduct proclivities is that criminals, after all, are only the caught and convicted offenders against the law. Who or what are those who commit crime and remain for long or even permanently undetected, hence figuring very little or not at all in any studies of persons rated as criminals? Some suggestion of what the answer to this might be is in the following: I remember once in the Juvenile Court of Chicago a mentally defective boy appeared in court for the third or fourth time, having been readily apprehended each time after a minor burglary in his neighborhood. Next came two active high school boys who together had perpetrated some fifty or sixty burglaries or larcenies without apprehension. They had hugely enjoyed their adventures; their stories were corroborated by discovered loot.

Then, next, for the sake of more fundamental considerations in the science of human nature, it is worth everything steadily to insist on the very plain fact that, compared to crime, much that is not rated as crime is as injurious, or even more injurious, and bespeaks as much deviation from the ideals of social welfare. Those who have to deal with the problems of family life come to know of many cases of frightful misbehavior that are not punished and that are hardly punishable under the law. Cruel dominations and frictions in the family that bring about great unhappiness,

resulting in life failures and in mental upsets, are some examples of what I mean. Or injuries done to one's fellow beings in more public ways often represent behavior that is worse than crime. We may remember Shakespeare's "He that robs me of my good name" as a case in point.

This is a matter of vast importance if we are really to get at the relationship of antisocial conduct to biological conditionings. Injurious to the person and rights of others is, for example, the action of the landlord who maintains premises conducive to immorality and ill-health, or the attitude of employers who have such wage scales that decent standards of living cannot be upheld by their employees. Then what witness we could give, from hundreds of case histories, to the harm done by extreme moral neglect of young boys and girls, or by pernicious teachings, resulting not only in sex misconduct but also in other forms of delinquency, the real offender not being convicted or perhaps convictable by legal process. Or to go to history for representative examples of terrible misconduct to be contrasted to legal crime, what a huge material is available, ranging from the kiss of Judas to the wholesale slaughterings of Napoleon.

It becomes plain enough that the portrayal of the causes in human nature of tendencies towards antisocial conduct, one artificially differentiated variety of which is called crime, must be undertaken upon a much larger canvas if the true perspectives and backgrounds of antisocial conduct are to be shown.

In considering statements of what criminals are in terms of human nature, it is an important point to remember the differences in the laws and in the facilities for detection and apprehension of offenders in various countries, and even in different parts of our own country. It appears highly probable that the undetected and unapprehended may represent in average make-up a very different group from those who relatively easily fall into the toils of the law. There are a hundred ways in which we might suggest possible differences; a very picturesque comment on the whole problem is afforded by the immediate situation in this country with regard to murder. Apropos of the recent so-called gangster murders, we are informed by the press,

probably with some approach to correctness, that in the last two years there have been over two hundred such murders in Chicago alone, with almost none of the murderers brought to trial. While this is an outstanding example of the main point we have in mind, in regard to less lurid offenses almost equally baffling conditions confront one who would generalize about human nature as related to criminalistic behavior.

CRIMINOLOGICAL THEORIES

For our own orientation, some mention of older conceptions of criminology will be advantageous. Any outlining of the various ideas that have been held in this field leads to the realization that they, all of them, are bare theories. Even the concepts of the law, based though they are upon "the accumulation of human wisdom during the centuries" are but theories concerning the fitness of certain punishments and the effectiveness of deterrency and reformation. It shows that only the first beginnings of the application of scientific method, of experiment and the observation of results, are as yet discernible in the treatment of criminals.

Until some fifty years ago the generally held notion in regard to crime was that it always results from a fiat of the individual's free will. Nothing further was needed by way of essential explanation, nothing pertaining to specific biological or sociological features concerning the individual or his environment. The latter part of the last century witnessed the rise of the biological and sociological schools of criminology, captained respectively by Lombroso and Ferri. They and their followers constituted the Positivist or Italian school of criminology, as set over against the earlier classical school whose tenets have been mentioned. Enrico Ferri drew up the following orienting diagram of theories:

Crime is a phenomenon of either:

A. Normality: biological or social

B. Biological abnormality:

(a) Atavistic: organic plus psychic, or psychic

(b) Pathological: neurosis, neurasthenia, or epilepsy

(c) Degeneracy
(d) Defect of nutrition of the central nervous system
(e) Defect of development of the inhibitive centers
(f) Moral anomaly

c. Social abnormality:
(a) Economic influences
(b) Juridicial inadaptability
(c) Complex social influences

d. Biologicosocial abnormality.

The scholarship of this diagram is substantiated by the citation of some forty authorities. Ferri himself is the proponent of the biologicosocial abnormality theory which holds that the criminal tendency is conditioned by elements in both the individual and his environment.

From our present-day standpoint, we realize that the anthropological observations upon which earlier theories are founded represent not only merely caught offenders but very partial studies of human individuals. The mental life, as it is viewed by modern psychiatry and psychology, was almost entirely neglected. The work of Lombroso and his adherents, for example, with their discriminations and measurements of the physical structure, and particularly of physical anomalies, represents one pole of investigaton. To my thinking the greatest weakness of their findings is in lack of any correlations of such physical findings with the study of mental capacities. It seems very likely that the Lombrosians were often dealing with essentially feeble-minded individuals, who, because of certain social circumstances, became criminals. This might account for the well-recognized difference between their findings and those in other countries where mental defectives have from early life been taken care of in institutions. As representing the opposite pole of investigatory method, we might take the recent studies of Bjerre, the Swedish lawyer, who constructs pictures of the motives and characteristics of criminals through prolonged and repeated interviews with them in prison, an intensive piece of interpretive work with little attention to the theoretical consideration of the schools of criminology.

THE PLACE OF SCIENCE IN THIS FIELD

It is certainly pertinent, after this cursory review of theoretical criminology, to ask by what right, or for what reason, science invades this field. At least one may inquire why the biological or psychological sciences should play any part in the study of treatment of offenders against society. It will readily be granted that sociology is involved; indeed, the law itself as social regulation belongs to the data of sociology. Or put it otherwise, why not leave the whole matter of dealing with antisocial conduct, particularly crime, to the law and, in order to meet the needs of society, call for a finer development of legal procedure?

One answer to this is that individuals showing certain deviations from the norm, such as mental defect, nervous disease, or mental instability, more easily succumb to influences conducive to antisocial behavior than the ordinary run of mankind. There are, then, some definite correlations between what biological science can discern and the exhibition of specific conduct tendencies, making for some predictabilities which may be the bases of good social therapeutics and prophylaxis.

A second answer might be that the law, in undertaking measures for the protection of society, is provably a very considerable failure in what it essays to accomplish. If it be argued, in turn, that it is only the modern and more humanitarian law and the weakness of modern judges that prevents the law from being successful, we have only to consult the annals of history and find that the harshness of a Lord Jeffries, or hangings for sheep stealing, or lopping off ears and hands, by no means stamped out crime. Statistics of recidivism (repetition of offense after the law has dealt with the individual), wherever they are available, show that penalties inflicted by the law are, very commonly, no effective deterrent to criminal proclivities on the part of the offender punished. Few figures are available for the United States because of the backwardness of any attempt on our part to look with scientific spirit into what is accomplished with criminals, but it is well known that the amount of recidivism is appalling; a tremendous number of those who are punished have been punished before. An English jurist,

Justice Rhodes, some twenty years ago turned to the medical profession in an article in the *British Medical Journal* and asked whether this dealing with offenders was, after all, altogether a job for the law. Do not the facts of recidivism prove that it is for scientists to cure criminal propensities? He quoted English criminal statistics, showing that in an ordinary year upwards of 10,000 of those convicted had been previously convicted more than twenty times each.

SIZE AND COST OF THE CRIME PROBLEM

And perhaps another reason why scientists should be interested in crime is the enormous size of it as an unanswered problem in our civilization, especially in our modern American life.

If we reckon costs in terms of money the Missouri Crime Survey is worth considering, a careful piece of work showing that the bill for crime in that state is about $100,000,000 a year, and Missouri is probably fairly representative, not much better or worse than other states. Mr. Prentiss of the National Crime Commission estimates the direct cost of law enforcement alone at $4,000,000,000 a year in the United States. If we need to say anything more about the cost of actual crime, we could generalize and state that in times of peace the greatest public expense, next to that of education, is by far that of combating crime, and this cost does not take into account the various big losses sustained through crime.

Notwithstanding the enormous number of criminals who are not apprehended or convicted, over 1/10 of 1 per cent of the population of this country at any given time is under commitment for delinquency and crime. That certain crimes form almost a national pastime with us is shown by such proportionate figures as the following: During 1919 in St. Louis there were 1087 highway robberies, and in Chicago 1862 were recorded. In the whole of France that year, it is said there were but 29 such robberies. Homicides with us have been statistically treated by Hoffman who shows their enormous relative occurrence, not only in Chicago, which figures so greatly in our newspapers as a center of

crime, but also in other American cities, some of which show greater proportionate figures. The average of 28 American cities for a number of years showed about 9 homicides per 100,000 inhabitants, while in England there were only 0.7. Prentiss calculates that 12,500 persons were murdered in 1926; he estimates that there are 2,000,000 criminals in this country; he states that the police and other law enforcing bodies employ 400,000 persons.

Our daily reading makes it rather banal, perhaps, to offer the observation that the amount of space given to crime in the newspapers proves the extent of crime. Parenthetically one might speak of the definite advertisement of crime and the fact that it has no mean value for newsgatherers.

NATIONAL COMPARISONS

The well-known fact that in several European countries the crime problem is vastly less in proportion than with us in America requires for its explanation much more than is usually offered. Those who propose remedies for our crime troubles usually cite some one possible cause, in line with their own interests or views, as explanatory of the better conditions in several of the older countries. But the fact is that everywhere the social background involves complexities that have to be taken into account when considering the incidence of any social problem or the results of dealing with it. For example, legalists are prone to attribute the relative lesser amount of crime in England to the swiftness with which offenders are brought to trial and disposed of. While we have no doubt that this is one factor, certain other immensely important considerations are forgotten in any such reasoning. The total situation is entirely different from ours because of such conditions, among many variations from our national circumstances, as the following: Vastly greater homogeneity of population; politics playing no part in most appointments, whether of judges or other officials dealing with offenders, the police and indeed whole city administrations being free from politics; the national government representing an integrated regime so that laws concerning crime are the same for the entire country and

there is a centralized effort to know and deal with crime and criminals, identification of criminals being vastly easier on account of this; the temper of the people in general being totally different with regard to its feeling about law breaking, a more subtle but a most important factor. Or if we take Germany, another country where crime is much less a problem than with us, we have conditions similar to those of England, plus such facts as the universal registration of population and the development of a specially well-trained police force.

From the foregoing, it should be clear that our own national situation with regard to crime and delinquency is *sui generis*, and that the extent of crime with us can be accounted for by some conditions and sets of conditions that are conceivably modifiable and by some that are not. As a matter of social environment, we might think of our present immense handicap of politics as in so many places it permeates the field of dealing with crime, and consider whether or not this might be changed. And then the facts that our judges are so untrained in criminalistics, that there are great weaknesses in our police systems, that there is so much ineffective, half-spirited and uninstructed parole and probation work which should be constructive and preventive, that there exist miserable moral contagions in prison life—these are to be pondered over. Are they alterable, if a different spirit were breathed into our national combat against crime?

But on the other hand, we cannot change the fact of the newness of our civilization, nor immediately modify traits and habits of the various races and nationalities that make up our population, traits and habits that among a mixed people so readily engender antisocial behavior, nor can we easily diminish the spirit of restlessness and recklessness that is inevitable in a fast growing country, so rich in its resources that many opportunities are given for changing occupations and moving about. Then the size of our country is an unescapable circumstance, bearing on the crime problem, especially in this age of rapid transportation and easy chance for flight, in most important ways. The independence of our separate states in dealing with crime and criminals

is another cause for the extent of crime, which, very plainly, at least through national registration and identification, must be met by centralized federal effort.

The facts of criminology, even those belonging to biology and psychology, certainly include environmental conditions as they exist in any particular community. Crime is conduct-reaction of a given person to a given environment. The crime problem, whether of any individual or of a statistical series, includes variables of personality and environment. In etiological studies, the latter, as well as the former, is bound to have its place.

Indeed this is so true that the influences which make for crime in one city and state may be found to be utterly unlike those in another part of the country, and differences of racial origins may be insufficient to account for this. In our own comparative studies of Chicago and Boston offenders we discovered most notable contrasts in crime tendencies, even among peoples of the same racial standards, such as the southern Italians. Concerning, for example, these Italians, in Boston there is the comparatively stabilizing influence of police and court work almost entirely free from politics, and much social effort of other sorts. This is challenging in its results and may be compared to what has so unfortunately met the same type of immigrants and their children in the other city.

With many things similar in two communities, there are, nevertheless, great possible differences in influences in the same country and under the same laws. By investigating the after-careers of 420 boys, repeated offenders, handled in the Juvenile Court of Chicago, it was ascertained that no less than 209 of them were in court as adult offenders for the more serious offenses, and 157 were committed to adult penal institutions; at least 13 (possibly 16) of these became murderers, and 39 are known habitual or professional criminals. Coming to the Juvenile Court of Boston during the same years were 400 young repeated offenders who produced only 84 appearing in the adult court and with offenses relatively so minor that only 25 were sent to adult penal institutions; there were no murderers, and almost none became habitual criminals.

These are facts which must make us for some of the explanations of crime turn from theoretical considerations, whether of the schools of criminology or of the legalists, to these very practical issues which confront our civilization. Some of the causations lie right in the spirit of the communities themselves, as exemplified by their patterns of political and other community behavior, and in the different modes of treatment of offenders. The social environment is a very large part of the story of crime.

LAW VERSUS SCIENCE IN TREATMENT OF CRIME

The lack of understanding between science and the law with regard to the knowledge of and treatment of the problems of crime has not been very favorable to the development of any satisfactory liaison between the two. Jurists and other legally trained people, so far, have shown but slight awakening to the possibility of the application of scientific method to the great task of protecting society from criminalism. Indeed, one can fairly say that there has not been the introduction of even any business-like methods of taking account of profits and losses, successes and failures, that accrue through treatment of crime by the methods in vogue under the law. One has yet to see any study coming from a jurist which undertakes to set forth the results of what has been accomplished by what he has prescribed. Such a tracing of results or outcomes is fundamental, of course, in the sciences which aim to have control of material or of situations, but since the law has grown to what it is through slowly developing theory and tradition, it has found no reason for introducing the methods of business or science.

On the other hand, science has never advanced to the stage of undertaking any thorough-going treatment of offenders with the aim of ascertaining, perhaps by experiment, what can be accomplished through any treatment. Very meager attempts have been made here and there to do something concerning some one feature of the total situation in individual cases, such as attention to the health or to trade training of offenders, but there have been practically no well-rounded efforts to check the careers of criminals

through attention to all the complicating factors of causation which will have to be met, even in individual cases. Science, up to the present, has been concerned mostly with theorizing about criminals and the causations of criminality, and almost nowhere has entered into the effort for control of the crime situation.

It is true that in the Germanic countries and in Italy the training for jurists to administer the criminal law has included acquaintance with what of science has been developed under the head of criminology, and this is a step in advance of anything that goes on in this country. Here, even in most law schools there is no training in criminology. Elected, or in a few places appointed, to positions where they have to deal with delinquents or criminals, we have judges who are, almost all of them, totally unacquainted with the principles of any science that makes for the understanding of human nature. I have never even heard of a conference of jurists and scientists in this country on the important subject of how best to deal with criminals. Regularly in Germany, judges, psychologists, and psychiatrists gathered for such conferences which were found to be most valuable. Nowadays we should also include sociologists.

The only time when any science of human nature comes in close contact with the bench in regard to criminal affairs is when the question of mental disease that bears upon responsibility is to the front. With the introduction of alienists in criminal cases, testifying from an *ex parte* standpoint, a not inconsiderable and very understandable distrust of mental science on the part of the legal profession has grown up. Yet when specific attempts have been made to better the situation, the legal profession has often stood in the way, as in the celebrated Leopold-Loeb case. In this instance, the psychiatrists who studied at great length the young offenders and the causes of their terrible deed were willing to put every bit of information, including their knowledge of many other crimes committed by the accused, into the hands of the experts retained by the state. The latter were willing, and indeed made a strong effort to go on with the case on the basis of such a consultation, one of

them making the notable statement that if all in conference had the same facts there would be no reason for disagreement. (Incidentally, it should be remembered that the psychiatrists were not acting merely as alienists. The question of insanity was not brought up in the court, and indeed under the law it is the jury in Illinois which decides the question of insanity, that is, properly speaking, legal irresponsibility. But there was no jury in this case, and no trial. It was merely a hearing before the judge, after the plea of guilty had been made.) The state's attorney refused, probably on account of possible criticism of his office, to allow the experts he had engaged to enter into such an arrangement and consultation. Here came out in strong demarcation the difference between the standpoints of the law and of science: Any appearance in court is regarded as high contest, there is short shrift for any idea that digging out the whole truth for the sake of society is an end to be aimed at. The usual procedure is that the prosecutor seeks to prove guilt, the defending lawyer to prove innocence or as near it as possible, and neither seeks to establish the exact truth. What might have been a historical event of importance for progress was blocked in the above case by legalism, science was not allowed to have fair play in the situation. It is only through a fair-minded attempt to study the *total situation* and present it in court (it was finally very largely done in the above case by the psychiatrists) that respect for what science has to offer in criminology will grow among the legal profession.

The main points to be made are that American judges and other officials of the law are very slightly indeed acquainted with criminology. Secondly, the older criminology, represented by many volumes on library shelves is mainly theoretical and by no means well developed from the standpoint of treatment of offenders. In consequence of both these facts the application of the modern methods of science to the individual case is exceedingly limited as affairs now stand. This appears surpassingly strange, since treatment is the one big issue: how to protect society, how to handle the offender so that he will cease his criminalistic tendencies. The legal therapeutist who prescribes some treatment, such as a period in jail, has little or no

notion of what this will do for the offender or for society. I am warranted, from what I know, in saying that many a judge has never been inside the institution to which he sends offenders, and practically no judges have any knowledge of the effects of the regime to which they consign offenders. This chasm between prescribing treatment and diagnosis followed by the observation of results is anti-science; the law appears to be very little concerned with results, and if obtaining results is not the main business of the law, then it is a strange phase of human endeavor.

But this statement of lack of cooperation between science and the law in criminal affairs must not stand alone and be taken merely at its face value. As we said above, there is no real distinction between crime and delinquency; the fact is that the delinquent is an offender against society who has committed offenses of just the same nature as the criminal, only at an age arbitrarily determined as juvenile. Now, in connection with the study of delinquents as such, and working hand in hand with juvenile court authorities, science has been playing recently a very considerable part. Medical, psychiatric, psychological, and social investigations of delinquents have been growing apace, undertaken in scores of places by well-organized clinics. Sometimes, and very properly, this extends beyond the mere examination of the offender to study of the etiology of the offense. It is true, however, that science has had, even in connection with these clinics, very little to do with the treatment under the law. Perhaps one reason for this is that science has not advanced far enough to be able to offer enough to create confidence in what it might do. However, its chances for carrying out experimental therapy, such as science everywhere undertakes, have been so slight that lack of progress in discovering effective treatment is readily understandable. The next step must certainly be therapy scientifically prescribed and administered, with close observation of results. It would seem easy enough to command the resources of probation departments and state correctional institutions for delinquents in order to demonstrate the possibilities of therapy and establish the causes and remedies of the weaknesses that now exist.

Treatment of any kind, either legal or scientific, applied to juvenile delinquents, must be understood to have very direct relationship to the whole crime problem. This is provable through many findings in all civilized countries that the careers of habitual criminals in the great majority of cases begin during youth and even childhood. This is an enormously significant fact, one that has not yet been fully recognized in its importance for the law and also for science.

Lest there be a mistake, it must be stated that a few courts and institutions dealing with adult criminals employ psychologists and psychiatrists, but this is almost entirely from a discriminatory standpoint, separating the sheep from the goats, mental defectives and those showing aberrational characteristics from the more normal. The "Briggs Law," providing in Massachusetts for the psychiatric examination and classification of those convicted of felonies, is the most advanced provision for this type of work. So far, only very limited modifications of treatment are offered as the outcome of such examinations. As an example of the tendency to a modern scientific approach, we may take, however, the work done with adults in the probation department of the New York City Court of General Sessions where attempt at social and individual diagnosis is regarded as prerequisite to treatment.

DOES CRIMINALITY BETOKEN ABNORMALITY

The reader of a work on human biology is, naturally, interested to know what statement science has to offer concerning the essential nature of those who are offenders against society. Is crime, or delinquency, the reaction of an individual peculiar or abnormal in any way to an environment that is either normal or abnormal? The preceding pages contain material essential for consideration before this question is answered. They offer fundamental criticisms of the data and conclusions that have been published under the title of criminology. It is hardly necessary to recapitulate the several points; such as the fact that only caught offenders are studied; that what is designated as crime does not differ in any respect from much other antisocial conduct;

that only very recently have the immensely important studies of mental capacities and aberrations and the more dynamic elements of mental life been introduced; that sociological science, as correlated with psychiatric work, is only just beginning and was almost entirely wanting in the picture presented by earlier theoretical criminology.

Noting the limitations which observations of incarcerated criminals represent, yet we find that recent better studies of them go far towards deciding for or against some criminological theories. And studies of juvenile delinquents, a goodly proportion of whom go on to adult criminality, as we indicated above, offer a very much better range of facts upon which to base conclusions.

In considering the theory that "the criminal" is a peculiar type of individual from a biological standpoint, "a degenerate," "an atavistic phenomenon," etc., it can be said at once that with practical scientific workers in the field this older idea finds almost no place. The anthropometric investigations of Goring in England on a large group of inmates of a prison of the penitentiary type seem quite to upset the notion that the criminal, even the caught criminal, represents an abnormal type biologically. Having been educated in the Lombroso tradition, I myself undertook a very careful survey of young offenders as they came to us in the Chicago Juvenile Court, many of them very serious delinquents, from the standpoint of biological anomalies. To my utter surprise, I found nothing in the least corroborative of the biological theory. Indeed, the proportion of stigmata of degeneracy among these offenders appeared little, if any, greater than among the general population. It is true that if one observes the inmates of certain penitentiaries filing past, one certainly sees an inordinate number of peculiar appearing men, but again I assert that these are highly selected groups. We cannot fairly draw conclusions concerning criminals in general, to say nothing of the make-up of those who are otherwise serious social offenders, by observing such a group. Without any idea of being merely cynical, I insist that penitentiary sentences are being served for the most part by those not endowed with shrewdness enough "to get away with" crime, not well enough off to

have good legal defense, not energetic enough to move off to another state after they have committed a crime, and that, above all, they probably represent an undue proportion of mental defectives, as compared to criminals in general. That biological anomaly exists among mental defectives in greater proportion than among the mentally normal is an acknowledged and easily observable fact.

Taking up mental defect next as possibly representing a biological anomaly (perhaps imperfect structure or functioning power of brain cells) correlated with criminality, we may say that here, too, we are at once introduced to complexities far greater than were earlier seen. Some critics have recently called attention to the ludicrous differences in findings of mental defect among groups of delinquents and criminals as made by various examiners. This is thought by Sutherland to be due largely to the varieties of attitudes and training of the mental examiners, showing that mental tests are not yet to be utilized as entirely safe criteria. I hardly think he is on safe ground in this opinion because different groups as selected for imprisonment, for example in different communities, vary tremendously according to the attitude of the community toward probation, reformation, and other modes of treatment, and may thus well vary in average mentality. But still one must acknowledge that probably the earlier large statements of the proportion of mental defect among delinquents and criminals was the result of unskilled and uncritical work by mental testers. (As a matter of fact, the significance of good mental testing rests largely on the frequency with which findings are corroborated by different examiners, perhaps in different institutions and at later periods.) At any rate, the upshot of the whole matter seems to be, fairly stated, that among caught delinquents and criminals, there is, undoubtedly, a much greater proportion of mental defect than among the ordinary population. Suppose we say that 1 to 3 per cent of the population would rate as defective according to the standard age-level tests now in vogue; then we find by the same criteria from 10 to 15 per cent of delinquents defective as they appear in the juvenile court. As might be supposed, there is at once a process of selection going on. In the correc-

tional institutions for juvenile offenders there is a much larger proportion of defectives. But the curious discovery was made by Doll, a very careful investigator, that in the penal institutions in New Jersey there is a smaller proportion of mental defectives than in the juvenile correctional schools.

The essence of the figures now available from many sources is that while mental defect in an undue proportion is found among inmates of prisons and correctional institutions of the several types, nevertheless we cannot conclude that feeblemindedness is at all the large factor in the causation of criminality that at one time was supposed.

To come back, as we must in scientific spirit, to the problem of antisocial conduct in general as not differing fundamentally from crime, we can easily believe that no such biological defect as may be implied by feeblemindedness plays any great part in it. Further, in the discussion of crime itself, we are bound to consider those who commit larcenies and other crimes, but who "get away with it." The thieving that goes on from transportation companies and warehouses in this country, amounting, if Prentiss is right, to over $100,000,000 a year, is certainly crime, but as I have already said, extraordinarily few of those who commit such offenses are taken into custody. Can anyone suppose that in a criminal practice apparently as common as this, the perpetrators represent much else than the average run of the population, that they are individuals peculiar from any biological standpoint?

But another important problem of biological import has to be met concerning criminals. Among them is there not an undue proportional representation of other varieties of deviations from the mental norm? We can at once say that some exceedingly important facts bearing on this matter have been brought to light recently as we have gained better knowledge of certain types of such deviations. I speak, particularly, of the finding that among delinquents and criminals there are many cases of what, in general terms, might be called abnormal personality. The interest in abnormal personality lies not only in the statistical findings, but also in the facts of the incorrigibility of this

type of offenders, the continuity of their careers, and the severity of the offenses they perpetrate. Psychiatry is gradually coming to know better this class of individuals, which comprises several sub-types, and to be challenged by the eccentricities of their mental and characterial deviations, by the possible biological bases of the condition, by the curious mental dynamics exhibited in lack of inhibitory powers which lead to impulsive delinquency and criminality, with evidence in some instances of an underlying feeling of a strange need for punishment.

With what we have, even so far, gained in understanding of abnormal personalities, there has come about much better appreciations of the part they play in crime. Birnbaum in Berlin has for some years been calling attention to the terrific offenses and the long careers of the constitutional psychopathic inferiors, as he designates them, among offenders. Many recent studies in the United States call attention to similar types of individuals and to their antisocial conduct tendencies. However, while our classifications and our definitions remain on the loose footing that they now are, with different observers using terms in very different ways, we are not in any position to give percentages of the abnormal personalities among offenders. But it is very significant that psychiatrists, working systematically in the large penitentiaries of Illinois, classify from 60 to 90 per cent of the inmates as showing traits of abnormal personality. One cannot here open the question whether the characteristics these observers speak of may or may not have been induced by environmental experiences of any kind, or by the absorption of any one of several toxic substances which may have caused malfunctioning of nervous cells. But it is highly probable that in a not inconsiderable share of the cases of this kind a biological anomaly was present. Birnbaum attributes nearly all of the trouble to defective germ plasm, but apparently without good proof on his part, especially since there are encountered nowadays effects of a very similar sort upon character and conduct that are the after-result of encephalitis lethargica (a disease occurring or only recognized as such in the last decade or so in America) and of some cases of concussive brain injury.

No students of conduct deviations can afford to forget that very many mental defectives have sound and wholesome character traits, the result of good upbringing. On the other hand, we have to recognize that in instances of abnormal personality, arising as the result of anyone of the several biological causes mentioned, the influence of attempts at educative control are often very slight indeed. Our own experience with treatment of individual cases shows this, and the careful regime undertaken for a group of post-encephalitic conduct disorder cases at the Pennsylvania Hospital also proves it.

The part that mental disease as ordinarily spoken of plays in criminality is, statistically considered, not great. But the borderline between abnormal personality and mental disease is not easy to draw, and psychiatry has not yet entered into enough researches on personality problems to have said its last word on the subject. Some of the most notorious murder trials have centered about this question of what constitutes mental disease; the problem sometimes has arisen because of the vague but obvious mental or personality abnormality of the murderer. Coming under the head of the ordinary groupings of the psychoses, there are comparatively few inmates of penal institutions, and almost none among those in juvenile correctional schools.

Our own years of study in the field of conduct disorders have led me and my co-workers to perceive very plainly that if we are to discuss at all the relationship of the biological make-up of individuals to their conduct tendencies, we must include not only inferiorities, weaknesses, and degeneracies, but also superiorities of physical structure and deviations from the norm in the way of overdevelopment and physical precocity. A very real cause of "breaking over the traces" socially and committing offenses, in our particular era, is to be found in unusual and premature general strength and development, as well as more rarely in unusually early sex maturity which may or may not accompany precocious or unusual general structural development. Anent this, we may cite the fact, well known by this time, that girls appearing in the juvenile court for sex offenses tend to be larger for their age than the norm.

Our findings on this seem conclusive, and indeed, it has been noted as a common sense observation by various judges in juvenile courts. The implications of such over-development are obvious. The girl's over-size or over-development of secondary sex characteristics plays its part in her own mental and emotional life, as well as in her social situation. Precocious puberty, taken alone, is much less a factor than this one of structural development, the possession of an unusually good physique.

Any student of young offenders comes to know the incentives to social misconduct that there are in the possession of a strong body without sufficient chances for satisfactory outlets in exercise, adventure and excitement. With the increasing development of our close urban life, the correlation between delinquent activity and the need for physical adventure and excitement becomes very apparent. It is safe to say that many of the criminal offenses of later adolescence, even some of the more desperate ones, are due to need for activity and adventure on the part of young men. The biological background of this situation is plain to us in many cases, particularly where the individual has a physical structure displaying more than ordinary energy and development.

EMOTIONAL LIFE AS RELATED TO CRIME

The part which the emotional life plays in the production of antisocial behavior of many sorts is entirely understandable. It has become a matter of deep interest, not only for the psychologist and psychiatrist, but also for the physiologist. Something of the biological, structural as well functional, foundations of emotional life are becoming known through researches of great import. The work of Head, Cannon and others, for example, in demonstrating the optic thalamus as, at least, one center of emotional activity, is immensely important for understanding, not only the human body, but also the human personality.

Endocrinology, to the front so much just now, has made great claims in explanation of personality characteristics and conduct trends. There seems to be a modicum of truth in the enthusiasm. Conservative scientific endocrinologists

who have undertaken very careful and prolonged special examinations of offenders for us, in their reports account for very little indeed of the antisocial behavior, and in spite of the existence of the much-advertised and much used extracts of glands, offer very few suggestions for treatment. I have come to the conclusion that the environmental life and experiences, which all biologists must include when they are studying an organism, are too often left out of account in the enthusiasm for endocrinology. Perhaps this is because many of these environmental experiences are only to be known at all through analysis of the mental life and content.

Some of us who are a bit older have seen rise and fall many biological, particularly medical, theories concerning the causation of criminality. We may remember that it has been successively regarded as a manifestation of epilepsy, of degeneracy, of feeblemindedness, of abnormal intracranial pressure which was to be relieved through opening the skull. Then trauma of the hypothetical moral center was held responsible, and so were tonsils and adenoids, and more recently, focal infections, while to be really up-to-date, we must include abnormal functioning of the glands of internal secretion.

HEREDITY AND CRIMINALITY

Readers in biology should very properly have the matter of heredity presented to them, even here in our section on human conduct. Behavior disorders, though having such a multiplicity of possible causation factors, are regarded often by the laity and sometimes by scientific men, perhaps because they are not brought face to face with all the facts in individual case studies, as proof of an outbreak of inherited tendencies. In contrast to this it is interesting to note that everywhere in actual clinical work with delinquents and criminals, very little explanation is offered in terms of heredity. Discussions on this topic have been undertaken mainly without careful scientific work being offered in proof that there is any such thing as the inheritance of criminal tendencies. Again, neglect of the deeper influences of

the environment, particularly the social and mental environment, constitutes the main weakness in any such attempt to draw conclusions about the origin of delinquent or criminal behavior.

Actual experiments with delinquents, such as we detail in a recent study, show that individuals removed to better community conditions from an environment easily seen to be productive of criminalism, with very great frequency change their conduct tendencies, if they are normal in mental make-up. From our findings we see no reason for offering a bad prognosis to child-placing agencies in cases even of severely delinquent children because there has been criminalism in the forbears. Even in studying the outcomes of our Chicago series of youthful recidivists, for the most part very inadequately or poorly treated cases, we could see no reason for regarding inheritance of criminalistic tendencies as playing any known part in careers. Looking in any way at the findings when statistics of other factors are taken into account, heredity, except of abnormal mentality, seems to be of little significance. For example, among either the failures or the successes, nearly as great a percentage came from criminalistic as from normally behaving families.

We may not want to go as far as the ultra-behaviorists do and allege that given an infant one can make either saint or sinner out of him but it does seem certain from our observations that what influences the mental life, even among the feebleminded, vastly out-weighs in effect on conduct tendencies anything that we know that comes through inheritance. It still remains that the conclusions of Spaulding, who showed, in working with a large series of our cases, that there was no proof of the inheritance of criminal tendencies as such, hold good.

IDEATIONAL LIFE AND CRIME

Adding to the foregoing suggestions of the richness of the field that is ploughed up if case after case of conduct disorder is carefully studied, we are led further to make perhaps the most important observation concerning the more positive and constructive aspects of investigation into the causative

background of antisocial behavior. It cannot be too strongly stated that the dynamics of conduct tendencies within the human individual include not only the emotional and affective phenomena which we have already discussed, but even more strongly center in his ideational life. More provocative of conduct and more directly causatively antecedent to it than anything else are ideas. This is a fundamental consideration. The nature of the ideational life or, at least, of parts of it and the manner in which certain ideas are handled by the individual, these are what immediately create conduct norms and deviations. It is to the mental content, then, to what notions or ideas are held by the individual, and to what, through his emotional life, he does with his ideas that we must essentially turn for understanding his delinquent or criminal activities.

All conduct, as being behavior related to one's fellow beings, is a social phenomenon. All conduct is the direct result of mental life. These are truisms too often neglected. Whether as the result of sudden impulse or deliberate intent, human action, which is called conduct, follows upon mental representation. The idea is there before the act. The biologist perceives that some physical deviations or pathologies, structural or functional, particularly in the central nervous system, are conducive in some measure to antisocial conduct, but it is to be noted that even in such cases the path to action must lead through the ideational field of mental life. It is these considerations that lead us to see clearly that delinquency, crime, and antisocial conduct in general are psychosocial phenomena.

METHODOLOGICAL CONTRIBUTIONS

At this point it may be fairly asked: What have the sciences of human nature so far mainly contributed to the understanding of antisocial conduct, or more particularly, to the understanding of delinquency and crime? The best answer seems to me to be that they have contributed a new methodology, based on case studies. The earlier general theorizings when brought face to face with the special problems in an individual case generally failed entirely to

answer them. This is because the factors producing the results always proved to be many more than any theory suggested. One of the greatest of medical clinicians used to say that for therapy it is generally not so important to know that a man had some particular disease as to know what particular man had the disease. Just so for the effective handling of conduct disorder; only it is necessary to go a step further and to ascertain, if possible, not merely what was the special make-up of this given individual who committed the offense, but also under what environmental conditions he lives or has lived, and what have been and what are his mental experiences. Now, reactions between the individual and his environment, back and forth, are not so simple, and involve an immense amount of circular response, that phenomenon so familiar to biologists. It becomes a highly complicated affair when the mental life and conduct tendencies of human beings, under the complex conditions of the human social environment, are the matters under consideration.

The methodology which is evolving in the modern case studies of antisocial behavior takes the best possible cognizance of the structural and functional physical make-up of the individual; his mental make-up from the standpoint of normality versus defect or aberrational tendency; his ideational life; his outer circumstances, present and past; his many mental and emotional experiences derived through family life, education, companionship; and the inciting circumstances of the special antisocial offense which may be the immediate problem.

It is a far cry from the many theories of crime and classifications of criminals to modern case-study methods, and from general assumptions concerning treatment, such as have led to the building of institutions and whole penal systems, to careful observation of the outcomes of different forms of treatment in series of differentiated cases. The latter represents the approach of science to any problem of control. To develop remedies for crime and delinquency we need adequate diagnoses and research into etiology, case by case, and the closest study of results. Beginnings of this

are to be seen already in work with juvenile delinquents, but even here science, so far, is having very little chance for trying different plans of treatment. The best of correctional institutions receive a motley aggregation of individuals, and in the main, treat them without regard to individual diagnosis and etiology. These institutions are really hospitals or colonies for the treatment of delinquency, the social disease, but in their regime and after-care, which is as important, and in some cases more so, than detention, they are not awakened to the advantages of a scientific methodology. Anyone acquainted with the ordinary management of our public affairs knows plenty of reasons for this, but with a better understanding of the possibilities and a more educated public sentiment the situation certainly should be alterable.

In present day endeavors to get better understandings, there are healthy signs of much cooperation between sociologists, psychiatrists, psychologists, with here and there other medical men, anthropologists and educators taking some part. Already nothing stands out any clearer than that the more effective handling of the problems of antisocial conduct, an end so utterly desirable, depends upon the extension of scientific method in this field. Observing the demonstrable high values of the case method study of juvenile delinquents, the diagnoses made, the uncovering of the varied etiological factors, the adequacy of well directed treatment based on scientific fact, observing these things no one can doubt the possibilities of checking very many anti-social careers. The main effort should be in the direction of applying this early therapy. While the bent twig, the older offender, presents a harder problem we may be assured that coordinate methods more scientifically constructed, could vastly better protect society from delinquency and crime.

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Chapter XVII

ADJUSTMENT TO INFECTIOUS DISEASE

Hans Zinsser

WHEN one living unit implants itself on the surface or within the tissues of another, the result of the association must be either a mutual adaptation, degrees of which are spoken of as "commensulism" and "symbiosis," or a struggle determining the deftruction of one or the other of the reacting organisms. The processes which are initiated and by which the invaded unit depends itself have been analyzed particularly in connection with infectious diseases of man and animals. But in order to understand them properly it is important to remember that the powers of adjustment and defense which are set in motion have a biological significance far broader than its application to the accidents of infection. They represent a deep-seated emergency mechanism latent in the normal body, an ancient heritage of the cytoplasm by which living cells and tissues are enabled to meet abnormal metabolic conditions of any kind and to preserve themselves from injury by the entrance into their substance of any materials that cannot be utilized nutritionally. Since many of these methods of defense are shared in common by the higher animals and plants and the simplest living units like protozoa, Ehrlich has picturesquely spoken of them as *Uralte Protoplasma Weisheit.*

Infection is in itself a distinctly abnormal process, or perhaps better, an accident in the plan of nature. The term "normal," when applied to the physiological processes of the higher animals, is of course, like "infinity" in mathematics, an entirely abstract conception. Nevertheless, it is necessary to formulate it as a working basis, for the purpose of properly defining deviations. Thus, it is a normal tendency in nature to preserve the integrity of biological units, and the parasitism of one living individual upon the substance of another may be regarded as an abnormal occurrence which implies either struggle or adaptation; and here,

as in human economic relations, the parasite, if the condition becomes habitual, pays for the situation by the loss of one or more of the functions no longer needed, a sort of biological degradation. If the cohabitation becomes mutually advantageous, as in the root tubercles of the leguminosae, in the symbiosis of green algae and certain flagellates, or perhaps in the case of colon bacilli and various animals, there is a sort of shrewd metabolic opportunism in which the loss of biologic liberty pays for the comforts of predigestion, or in other words civilization. Such perfect, even mutually helpful adaptation, however, is relatively rare and in most instances the entrance of one living unit into the substance of another is either entirely prevented, or resented by the initiation of a struggle, as a result of which one or the other participant is destroyed. Little is known regarding the conditions which ordinarily prevent such invasion except that it is intimately bound up with the property of life and closely associated with the activities of the various enzymes by which the host maintains his metabolic equilibrium and by which the invader attacks the substance of the host. It is not, at any rate, the unsuitability of the environment within the jelly of a mass of frog's eggs which keeps the bacteria in the puddle from swarming into it; for, let a sudden frost kill the eggs over night and, as Bail has pointed out, the mass swarms with invaders before the following morning. In general, then, living things, though surrounded by innumerable other living things which could readily make use of their body substances, are preserved during life from such invasion.

The majority of microorganisms, of the same classes and orders as those which can cause fatal infection, are economically independent, living on dead organic and inorganic materials, and delicately adapted to many different types of environment. A relatively small group have developed the capacity of living in or upon the animal body, and the nasopharynx, the intestines, the conjunctivae and other parts of the accessible body have all developed their characteristic flora. It is out of these in most cases that the pathogenic or disease-producing groups have arisen, a process of evolution which it is easier to conceive in the case of bacteria

than in other living forms, because the artificial production of changes or mutations, both as to growth characteristics and infectious power, can be easily and rapidly accomplished in the laboratory.

As a matter of actual observation we may subdivide bacteria into definite classes according to the degree to which they developed parasitic properties, as follows:

1. Those which under no circumstances will grow, except in the saprophytic state, upon dead organic and inorganic materials.

2. Those which have become adapted to an environment supplied on the physiologic exterior of the bodies of other forms where the reaction and the substance of secretions and waste products supply them with a suitable environment.

3. Those which, living on the exterior of the body, may produce powerful poisons by which the host is injured both locally and generally. To this class, which still may be regarded as purely saprophytic, belong some of our important pathogenic organisms, the diphtheria and the tetanus bacilli, which do not actually enter the tissues and may therefore be spoken of accurately as pathogenic saprophytes. Unless the toxin production in these forms is in some way related to the creation of suitable metabolic conditions for the organism itself, its biological purpose is quite obscure. It is not impossible that by the destruction of living tissues these toxins create the conditions that permit development.

4. Bacteria which ordinarily lead a purely saprophytic existence but which, given suitable circumstances, may invade the tissues of another form. This is the most widely distributed class of the pathogenic organisms, and includes most of the ordinary intestinal infectious agents and many of the so-called surgical infections; and the bacteria of this class, because of their saprophytic attributes, are easily cultivated on artificial media.

5. The relatively strict parasites which cannot be cultivated at all, or only by the use of specially adapted methods, and which seem to have developed a more or less strict parasitism for the conditions prevailing in the living bodies, often of a particular animal species.

Any classification of this kind must be regarded as representing points on a curve along which many gradations of saprophytism and parasitism are recorded. In regard to speed and delicacy of biological adaptation, there is no class of living things more worthy of study than the bacteria.

Every species of higher animal has its peculiar invaders, which rarely or never cause spontaneous infections in other species. Many diseases of man cannot be inoculated to any animals except the higher apes; and domestic animals suffer from fatal infections which often have no power whatever to invade man. Moreover, in certain instances, rabies for example, where an invader can afflict many different species, continued passage through one type of host (rabbits) will increase the virulence for this one, considerably diminishing its invasive power for man. Organisms like the gonococcus, which spontaneously infect man only, exhibit a distinctly nutritive adaptation by refusing to grow on anything but human protein in the first generations of artificial cultivation, rapidly losing this fastidiousness after a short time of test-tube existence.

While these and many other examples that might be given illustrate the delicacy of adaptation to the invasive from the saprophytic condition, still more remarkable is the speed and ease with which, in the laboratory, we can increase or decrease the virulence or invasive powers of certain bacteria by the simplest expedients. With the pneumococcus, for instance, we can readily, by successive mouse passage, enhance virulence until one-millionth of a broth culture will kill; and by properly manipulating this same culture, we can obtain individual so-called "rough" colonies, which are typical in most of their biological properties, but will no longer kill mice except in large doses. It is becoming increasingly apparent that the study of bacterial mutation is promising to develop facts of profound biological importance since, together with the loss of virulence, changes may occur in cell chemistry and immunological properties.

Since every infection is of course a process in which the two chief variables concerned are the pathogenic microorganism and the host, it has been necessary to discuss briefly the factors influencing the invader. We are chiefly concerned in this chapter, however, with the conditions of the host by which invasion is either permitted or prevented. The higher animals all possess in their normal state a so-called "natural" resistance against many bacteria. This natural resistance can to some extent be analyzed into

a coöperation of the blood plasma, the circulating nucleated cells and certain fixed cells largely represented by units of the reticulo-endotheial system, so that even when considerable amounts of bacteria which cannot by themselves gain entrance are experimentally injected into such animals, they are promptly disposed of by a process not identical with, but similar to that which is active in acquired immunity.

Many possible balances in the reaction between the invader and the host are conceivable, and for this reason it is not surprising that in the natural evolution of infectious disease many different types of relationship have been established. Thus, when hemolytic streptococci, pneumococci, anthrax, plague or typhoid bacilli, or many other bacteria, invade the body, they set up a violent reaction—an expression partly of their own toxic properties, partly of the energetic effort of the host to get rid of them—and these together constitute disease. In other cases such as the treponema pallidum of syphilis, the organism, probably because it has for centuries, been directly passed from body to body, without intermediate external existence, is so perfectly adapted to the tissues of man that it creates little acute disturbance. Injury is manifest only after considerable accumulation, and we have a chronic and slowly destructive disease. This state of affairs approaches the quasi symbiotic conditions observed in certain sarcosporidial and spirochetal diseases in mice and in trypanosome infections in rats, in which it may be said that infection has developed into an adaptation so perfect that the host no longer reacts, and manifest disease does not follow. At opposite ends on the series, then, we may have disease without infection, as in diphtheria and tetanus, where the bacteria do not invade but manufacture externally a toxin which is absorbed; and infection without disease, as in the last cases mentioned.

When bacteria that are capable of causing a fatal infection in an animal or in a human being enter the body, immediately a struggle is set up in which the bacteria grow and elaborate any poisonous substances which they are capable of producing. Both by their presence in the intercellular spaces and by the toxic inflammatory effects of their constituents and products, they injure the cells of the immediate neighbour-

hood in which they are lodged, as well as remote areas to which their toxic products are carried. The body responds by a process which, in its main lines of strategy, includes both a neutralization of the bacterial poisons and a destruction of the invading cells by the blood plasma and by the phagocytic action of the white blood cells and of certain fixed tissue cells. If the body survives, a subsequent invasion of the same bacteria encounters a considerable enhancement of all these properties, which results in a much more rapid disposal of the invaders. When we say that the reaction is "specific," we approach the most mysterious biological fact in the process, and mean thereby that this entire train of events is strengthened by the first infection only in regard to the same or to closely related infectious agents.

The simple observation that a body which has survived an infection is thereafter resistant to reinfection by the same agent for periods from fractions of a year to the remainder of life, is as old as history, was known in ancient China and India, was recorded by Thucydides in regard to the plague in Athens, and was generally familiar to clinicians when Jenner applied it experimentally in smallpox. It was scientifically formulated by Pasteur with bacteria, and its analysis has constituted the material of the science of immunology.

Briefly summarized, the basic facts of the analysis, as far as it has gone, are as follows: Normal animals, whether they possess a demonstrable degree of resistance or no resistance whatever to a given infectious agent, may be rendered highly resistant, sometimes even completely immune, by a variety of methods. These are:

1. The survival from an infection with the particular microorganism administered either in small doses or in an attenuated (weakened) form.
2. Systematic dosage with the dead organisms.
3. Similar treatment with the products of the organism (toxins).

When the resistance has been achieved, the animal has changed profoundly in its reaction to this particular infection and to no other, and its immunity can to a large extent be referred to the blood plasma and to certain special cells. If, as in diphtheria or tetanus, the toxins are the important

factors of injury, treatment with the toxins alone will induce the formation within the animal of a neutralizing constituent in the blood, the specific antitoxin, which will not only protect the tissues of the immunized animal from injury by any absorbed or injected toxin, but can be used, by taking the serum from such an animal, to protect others, i.e., antitoxin treatment. And to emphasize that these so-called bacterial toxins are merely a special group of a larger class of similar things in nature, it is well to state here that what we have said about bacterial toxins applies as well to snake poisons, spider poisons, the vegetable poisons (ricin, crotin and abrin) and to certain enzymes.

In cases in which the invasive power of the bacteria is relatively more important than their toxin production the immunity is antibacterial rather than antitoxic, and the blood serum of the animal treated with the attenuated or dead bacterial bodies acquires a substance which specifically unites with the bacteria (sensitization) and alters them so that they are more susceptible to a number of destructive effects. Bacteria mixed with such an immune serum will rapidly clump into masses, precipitating to the bottom of the tubes. By suitable experiments (absorption tests) it can be shown that in the course of this phenomenon the bacteria have absorbed out of the serum the substance responsible for the reaction. Also, it can be shown that the actual clumping of the bacteria is due to the fact that union with this immune constituent of the serum has rendered the cells susceptible to electrolytes in the fluid, probably altering their suspension-equilibrium, so that they are precipitated by the electrolytes just as are colloidal suspensions. At the same time the union with this antibody or "sensitizer," as it is called, has rendered the bacteria susceptible to an enzyme-like normal constituent of the serum, the "alexin" or "complement," which can often kill sensitized bacteria of varieties which it cannot injure in the unsensitized state. Again, the wandering and fixed phagocytic cells of the body, leucocytes and various endothelial cells, can take up and destroy virulent bacteria much more effectively after their union with the serum antibody than in their native condition. Thus the immunization has induced the formation of a specific reaction body which becomes free

in the serum, which has a specific capacity for union with the particular bacteria and which, by uniting with them, changes them so that they are more easily destroyed and removed.

There are, of course, many other factors involved, but for the purpose of making thoroughly clear the remarkable capacity of the body to adjust itself to an abnormal condition which threatens its destruction, it is best to follow only the main lines of occurrence, rather than to confuse the primary issue by an abundance of less important detail. This dormant capacity of the body to meet specifically an abnormal condition which threatens its survival would be difficult to understand if the described train of events were confined to infection. But, although the "antibody" mechanism was discovered first in connection with infectious diseases and, in this relation, has its most immediate practical interest, it is important to realize that this inherent capacity of specific response applies broadly to the entrance of a multitude of extraneous materials, of which bacteria are only a small and relatively unusual class. To make this clear it will be necessary to consider the processes that go on in the metabolism of higher animals and the chemical nature of the substances which normally penetrate within the physiological interior of the body.

In the lower forms of animal life digestion is intracellular, and within specialized vacuoles solid particles of the foreign substances are broken down into forms in which they can be incorporated into the protoplasm of the cell. In the lower metazoa the digestive process remains intracellular, but is gradually being relegated to special endothelial cells. Throughout the upward scale of the animal kingdom there is a gradual substitution of extracellular for intracellular digestion. In the higher forms of animal life normal digestion is so exclusively the task of certain specialized intestinal enzymes that the materials, which eventually enter the circulation and are distributed to the cell units for assimilation, have been converted into diffusible form, chemically adjusted to cellular needs. Thus, it is likely that in the completely normal body, a condition which probably never exists except for short periods, no foreign fats, proteins or complex carbohydrates penetrate into the circulation, the fats being split

in the intestine to fatty acids and glycerine, the proteins to amino-acids and the carbohydrates to simple sugars. Should unaltered fats of foreign origin get into the circulation, abnormal conditions may ensue of which we are more or less in ignorance but which, at any rate, have no bearing on processes of immunity to infection. The same is true of most of the carbohydrates, except certain specialized ones produced by bacteria. In regard to the proteins, however, conditions are different. Complete proteins, including the materials of the bacterial body, form a class of substances which cannot enter the circulation and come into contact with the tissues of the higher animals without arousing reactions by which these tissues are specifically and in all probability permanently changed. For this reason, these materials are grouped together and designated by the word "antigen."

Since the purpose of this chapter is to explain a rather complex state of affairs with as little use of technical phraseology as possible, we may be permitted to explain the term "antigen" in greater detail. It is a functional term which, irrespective of chemical structure, designates any substance which can arouse tissue cells to this specific reaction. If materials of this class, whether animal or vegetable proteins, bacteria, or various poisons, or enzymes are administered to the animal body in such a manner that preliminary digestion is avoided, for instance by injection with the hypodermic syringe, there appear after a time, in the circulation of the treated animal, substances which specifically react with the injected "antigen." Almost the entire structure of the science of immunology consists in the detailed elaboration of this simple law of antigens. Thus, to illustrate by an ordinary example, horse serum fed to a normal individual is broken up in the stomach and upper intestine into its component amino-acids, and these are absorbed, distributed and utilized by the cells. The same horse serum, obtaining unchanged access to the circulation, may be demonstrated in the blood, unchanged but gradually diminishing in amount, for a considerable time—days and weeks. As it disappears, however, the blood serum of the injected individual acquires a property not previously possessed, namely, of specifically

precipitating horse serum. By "specificity" in such a case we imply that the serum of an individual so treated precipitates horse serum only, and not, to any extent, any other protein. Since the precipitating property appears to depend upon some newly produced cellular product, it has been assumed that the blood contains a substance absent from the animal originally, conveniently spoken of as an "antibody," in this case "precipitin."

That there is an actual substance in the serum upon which these reactions depend and that they are not merely the consequences of a change of state is made apparent by the fact that the antigenic substances absorb out of the serum their individual reaction bodies. Thus, if an agglutinating or a precipitating serum is mixed with the bacteria or other antigen upon which this serum exerts its action, the supernatant fluid of such a mixture will be deprived of the capacity to produce the particular effect, and this power can be shown to have been transferred to the precipitate. For to some extent the precipitate can be washed, its unit combinations partially dissociated and the so-called "antibodies" recovered.

It is this property possessed by substances of a given chemical and physical structure to arouse a specific response on the part of the tissue cells which constitutes the basic fact of immunology. For the bacterial body and many of the bacterial products, toxic or otherwise, belong to this class of antigenic substances, and an infection is therefore nothing more than the entrance of an antigen into the physiological interior of the body, differing from a similar penetration of undigested egg white, milk or any other protein chiefly in that, in the case of bacteria, the antigen is a living cell which can multiply at the expense of the host and often possesses general and specific toxic properties, together with selective powers of localizing or penetrating particular organs or tissues of the host. These differences from ordinary antigens and the fact that, in regard to these variables, no two species of bacteria are entirely alike, has of course necessitated the assembling of a formidable volume of precise information, a good deal of which is of practical value in diagnosis and treatment. The science of immunology, therefore, is one

which has developed innumerable intricate ramifications. But when all is said and done, they all take ultimate root in the antigenic properties of bacterial materials—just as the chemical sciences are basically founded on the electrical laws governing atomic and molecular structure, except that we know considerably less about the antigens and their reactions.

In regard to the nature of the antigenic substances and in an analysis of the responses aroused by them in the cells of the body we must therefore seek for light concerning one of the most fundamental laws of function of the living cell, physiological in the sense that it is possessed by all of the higher animals as a latent capacity and in that it invariably is called into play in one way or another in the life of any individual; abnormal only in the sense that it is probably never in action under conditions of perfect metabolism, a state which, however, cannot be expected to prevail except for short periods in the course of any existence. Whether this emergency reaction capacity should be regarded as a survival of the more primitive properties of a less specialized cellular cooperation, or a function acquired to meet the inevitably frequent entrance of foreign proteins into the animal body is an interesting subject for speculation, but quite unanswerable at the present time.

Although the term "antigen" was first devised, on an erroneous etymological construction, to designate all substances which were capable of inciting the animal body to the production of antibodies, there is little doubt that the meaning of the word should be more comprehensive than this. At the time when it was introduced investigations upon "hypersensitiveness" were in their infancy and the power of a foreign substance to arouse a specific reaction in the cells of the body was recognized only by the discovery of antibodies in the circulating blood, either by the technique of agglutination, precipitation or "sensitization" to complement. It has since become clear that many substances may alter the specific reaction capacity of the cells without actually leading to the formation of circulating antibodies.

The recognition of this state of affairs has come largely through investigations of the strange phenomena of "ana-

phylaxis" and "allergic hypersensitiveness." These occurrences can best be explained by examples. Antigenic substances like horse serum and egg albumen when injected into normal guinea pigs may cause no reactions whatever, though given in considerable amounts. The material itself is entirely inocuous. If, however, the first administration is followed in the course of two or three weeks by a second injection of the same material, severe injury of the animal may result. Since the original material was harmless, it is obvious that some change was brought about in the animal as a result of the first contact; and the state reached is known as "specific hypersensitiveness" or, in the case of the complete proteins, "anaphylaxis." An animal so sensitized will react only to the particular material with which it has been prepared. If, for instance, one guinea pig is given egg white and another horse serum, a subsequent injection of horse serum into the "egg white animal" will be entirely uneventful, and vice versa. But a repetition of the identical material into the same animal will arouse a response apparent both by local edema, possibly tissue destruction, and by systemic symptoms which may cause death within a few minutes. It is quite impossible to summarize these reactions by any generalization since they vary with the several animal species and are subject to differences dependent upon dosage and the intervals between injections. Physiologically the point of attack appears to lie chiefly in the capillary endothelium, which is rendered permeable as a result of the reaction, and there is reason to believe that the further complex train of events which is set in motion in other parts of the body is secondary to this primary injury.

But while there is much that is obscure about the actual causes of injury and death in such cases, it is quite clear that the process is set in motion by union of the reinjected antigen with antibodies that were formed in the animal as a result of the first injection. These antibodies, remaining to some extent incorporated in the cells that formed them, have acquired, in consequence, a greatly enhanced capacity for union with the antigen; and this sudden introduction of a foreign protein into or upon the surface of the tissue cells, particularly of the reticulo-endothelial system, results in

injury. We can, for instance, inject antibodies against horse serum into a normal guinea pig and, allowing time for a penetration of these reaction bodies into the cells, render the an mal "passively' sensitive to horse serum. Quantitative exper ments indicate that the power of an "antihorse serum" thus to sensitize a normal animal "passively" is proportionate to the contents of "antihorse" antibodies. And it is a logical deduction, therefore, that, knowing the reactions to be cellular, the cells have absorbed the specific antibodies, now containing, in the jargon of our trade, "sessile receptors or antibodies" for horse serum. For many reasons it is clear that a similar mechanism underlies most of the other forms of hypersensitiveness which are concerned in important pathological conditions of man, namely, asthma, hay fever, serum sickness and perhaps drug idiosyncrasies. And in many of these conditions, although the fundamental phenomena are identical with those encountered in hypersensitiveness to horse serum and other proteins, circulating antibodies have not been demonstrable. For many reasons which it is quite impossible to analyze in this connection, it seems probable that in several of these conditions the antigen is quite capable of arousing a specific change in the reaction capacity of the cells analogous in every way to that aroused by the proteins but not followed by the production of circulating antibodies. We would, accordingly, define the term "antigen" today not as representing only substances that lead to antibody formation, but as any material which, introduced into the physiological interior of the body, leads to a specific alteration of the reaction capacity of the cells, detectable now not only by the presence of antibodies, but by the development of local or general hypersensitiveness to the particular substance. Nevertheless, while it is, of course, important to recognize that there is a difference between those foreign substances which give rise to antibodies and those for which no circulating antibodies appear, it is quite as necessary to remember that the fundamental occurrences in all forms of hypersensitiveness are alike in indicating specific alterations in cell responses, identical in all phases except in those which depend upon the presence of the circulating antibodies.

The change in cell capacity therefore is the essential fact and the discharge of the reaction substances into the circulation purely secondary, depending in some manner upon the chemical and physical properties of the particular antigen.

The most perfect antigenic substances are the proteins and it is from the study of these that most of our knowledge is derived. It would appear that the antigenic function may be in some manner related to non-diffusibility, since the nature and molecular size of antigenic substances seem to imply reaction with the cell surfaces. Teleologically regarded, this may mean that substances that can penetrate into the cells and undergo intracellular digestion may not require the development of a special antibody mechanism. The second criterion necessary to the possession of antigenic function seems to be an inability of the healthy body to eliminate these substances promptly by the ordinary means of excretion. Take the case of egg white. This antigen is eliminated by monkeys almost quantitatively within a few hours, little or no antibody is formed and hypersensitiveness develops only to a slight degree. And when in animals like rabbits, or even in man, antibodies are studied in response to the injection of horse serum, the horse serum may be found circulating for days, disappearing only gradually as antibodies begin to form. Thus, the most effective antigens are substances which are not easily eliminated, which are not removed from the circulation with facility and which, presumably on this account, form a slow union with the cells of the body.

It seems quite clear that the antigenic proteins, besides possessing the essential physical properties mentioned above must undergo a very definite chemical union of some kind with the responding cells, which is, indeed an inevitable conclusion from investigations on the nature of specificity.

It is in this matter of specificity that the immunological reactions illustrate, more than any other physiological phenomena, the exquisite powers of adjustment of the animal cell. In no other group of biological observations is specificity so finely differential and so manifold. The response of any given species of animal in essential mechanism to the

injection of all foreign proteins is alike. But in every case, limited only by the available number of protein antigens, the response is specific for the particular variety injected. Thus the immunological response is so exact differentially that the antibodies elicited by the several proteins vary with every animal and plant species from which the antigens are derived and, in their overlapping, follow with considerable accuracy zoological and botanical relationships. Antibodies to horse serum, for example, react partially with that of zebra, mule and donkey, and the kinship of man with the higher apes may be more fundamentally determined by the similarity of the serum antigens than by any of the more superficial characteristics.

Of the greatest importance to the biological principles we are discussing are the investigations planned to reveal the properties of the various protein molecules which determine specificity, and which have been authoritatively reviewed by Wells who himself has added much to the understanding of these conditions. There is no longer any question about the fact that immunological specificity is a function of the chemical structure of the particular protein antigen. Immunological similarity is, as Wells has repeatedly shown, based on chemical similarity, while immunological differences are coordinate with chemical differences.

While the protein nature of the substance as a whole seems essential to its antigenic function, it is nevertheless not the entire molecule which determines the specificity. This has been variously demonstrated by Pick, Landsteiner, Wells and others who have shown that by the introduction of simple radicals, e.g. iodine, diazo and nitro groups which combine with the aromatic ring of certain amino acids, or even by alteration of certain salt-forming groups of the protein, the specificity of the particular protein may be shifted from its original species relationship to another depending on the chemical change. In this way an iodized horse serum produces antibodies that react with other iodized proteins, but not as well, at least, with the original native horse serum. It is quite beyond the scope of this chapter to enlarge upon this most important phase of immunology, and the reader whose interest has been aroused

had best consult the thorough and critical discussions of this subject by Wells in his "Chemical Aspects of Immunity."

The chemical facts which we have outlined make it quite plain that in stimulating the cellular responses the so-called antigenic substances unite primarily, because of their non-diffusibility, with the cell surfaces; but it is rendered likely by a number of experiments that the antigenic substance may secondarily be incorporated in the cell substance. Since, as we have seen, a relatively small part of the protein molecule is associated with the specificity, it may well be that the union with the cell is something like an orientation of the foreign protein molecule in the cell membrane, reacting through the group which carries its specific affinity for the cell substance. What happens after this is entirely mysterious. That the cell should be capable of responding by an individually different reaction product to almost any number of foreign proteins and, in addition to this, to a large variety of chemically altered products of each of these proteins is an easily demonstrable fact for which no theory is at present adequate. The only explanation of this state of affairs which has ever been ventured is the side chain theory of Ehrlich, which is actually nothing more than a restatement, in theoretical language, of the fundamental observations. It states, in substance, that after the antigen has united with the cells, the particular radicles of the protoplasm which possessed the specific affinity for the antigen are thrown out of action and must be reproduced by the cell for its functional purposes. It is assumed that continuous stimulation of the cell in this manner, by repeated saturation of the particular cell constitutents involved, leads to an overproduction of these substances, which finally takes place to such a degree that they are discharged into the circulation. These so-called "cell receptors" become the circulating antibodies. Since they possess a specific affinity for the antigen, they now unite with it in the circulating blood. The theory is spoken of as the "side chain theory" because, by analogy with organic chemistry, Ehrlich conceived the cell receptors as "side chains" of the protoplasm which could cover many specificities because of the great complexity of this material.

It would be quite impossible to follow the intricate ramifications into which this theory has led and which, though not demonstrable in many of its details, is still the most intelligent analysis of the conditions that has been offered.

The body cell is, of course, a complex laboratory in which a great many different chemical processes can take place side by side. Bayliss, summarizing the activities of the cell, describes it as "a complex of substances of varying chemical natures and in various states of aggregation, associated together by forces of surface tension electrically charged, etc. In these, the liquid state enables an elaborate play of forces to take place. Chemical reactions can effectively proceed simultaneously in different parts of the cell, so that there is some mechanism by which one part is temporarily isolated from another." It is quite conceivable, of course, that a great many complex reactions of entirely different nature may take place in a heterogeneous system of this kind, separated from each other by semi-permeable surface layers, but it is hard to conceive the mechanism for a train of events in which, let us say, a molecule of horse serum will arouse a specific antibody response which in principle is exactly like, but in specificity distinctly separate from that aroused by a molecule of horse serum into which a methyl or a diazo group has been introduced. Moreover, it must be remembered that after the reaction is over, after antibodies have been produced, have circulated and, in time, have disappeared from the blood stream, the cell still retains an increased reaction capacity for the particular protein molecule with which it has once reacted. This it is impossible to explain on a physicochemical basis, and yet is most easy to demonstrate. For instance, a human being once injected with horse serum will, years later, on the intracutaneous administration of a minute amount of horse serum, react with a rapid formation of a large wheal, whereas in the perfectly normal subject no reaction whatever may take place. And guinea pigs sensitized with horse serum by a single injection may retain a hypersensitiveness that will result in severe distress of breathing, and perhaps convulsions, months after the first injection of horse serum, which in the normal guinea pig had no effect whatever,

though given in large amounts. This latent reaction capacity with or without formation of antibodies is a mystery. Its recognition has explained many abnormal conditions in man and has led to much exact analysis, but it has remained in its fundaments utterly unexplained.

In order to obtain a proper physiological understanding of infectious processes, therefore, it is simplest to remember that the body cells of bacteria are composed of protein materials, largely nucleoprotein-like substances, which possess this antigenic function. As soon as bacteria that have become biologically adapted to entrance and survival in the animal body have invaded either through the skin, the respiratory or intestinal tracts, and have penetrated into the physiological interior they become foreign antigenic substances in the same sense in which this would apply to egg white or horse serum which had been experimentally injected. In the case of bacteria, however, the antigen is a living cell which, because of its development of parasitic properties, is capable of increasing in quantity at the expense of the host. Also, these bacterial invaders often produce poison which, in different bacteria, possess varying selective pharmacological affinities for definite parts of the body; and these poisons often are in themselves antigens. The nature of the disease, therefore, depends upon the manner of entrance, the amount of local inflammation aroused at the point of entrance, the distribution of the organisms in the body and the particular tissues of the host which are selectively injured by the poisons. Upon these factors depend the manner of infection, the incubation period and the nature of the symptoms; and if we know what the biological properties of the various bacteria are in these respects, we have a logical basis for diagnosis and can often state by which particular microorganism or type of microorganism the disease is caused.

The antigenic substances which are liberated from the bacteria and come in contact with the cells give rise to the specific increase of reaction capacity for this particular antigen. In some cases this, let us call it "increased specific irritability," remains purely a cellular function and may be

observed by various methods, the most important of which we can illustrate best in connection with tuberculosis.

When an animal or a human being is tuberculous and we reinfect the skin with tubercle bacilli or inject a small amount of tuberculin, the tuberculous animal will react with a violent inflammation to a dose which would have aroused little or no response in the normal. This means that the body is on a hair trigger in regard to the specific response which is set in motion by contact with this antigen, and many of us believe that this specifically irritable condition is a direct manifestation of the protective armament of the cells.

In most cases, however, the specific reaction aroused by the antigen expresses itself not only by an increased cell reaction, but by the appearance in the circulation of cell products which we speak of as antibodies. Efforts have been made to isolate these antibodies and although we have no definite knowledge of either their exact chemical nature or structure, we do know that they are associated with the globulins of the blood plasma. We know them by their activities rather than by their chemical and physical properties, in that we can easily demonstrate, by test-tube experiment, that in the serum of an immunized animal the particular bacteria with which the animal has been treated undergo certain changes; and that by contact with the bacteria the serum loses this particular property, that is, the bacteria specifically absorb these substances.

The changes which contact with an immune serum produces in bacteria as a consequence of this union are simple and easily described:

Bacteria which will remain finely suspended in a normal serum will aggregate in clumps in a homologous immune serum.

Similarly, an extract of bacteria filtered clear and added to a normal serum will leave the serum entirely unclouded, whereas a similar extract of the same bacteria added to a homologous immune serum will give rise to the formation of a flocculent precipitate.

In both of these cases an analysis of the mechanism has shown that by union of the antibody and the bacterial

substance the molecular equilibrium of the bacterial suspension is altered, so that precipitation occurs, just as many colloidal suspensions may be precipitated in the presence of electrolytes. If we allow bacteria to absorb their particular antibody out of a serum and wash this united complex in distilled water, these so-called "sensitized" bacteria will remain unprecipitated; but add an electrolyte by resuspending them in salt solution and rapid precipitation or agglutination will occur.

Furthermore, by the absorption of the antibodies the bacteria become vulnerable to two effective influences in the body. One is an enzyme-like constituent in the circulating blood which is easily destroyed by heat and deteriorates on standing, but which is always present in fresh blood. It is called by immunologists "alexin" or "complement." This active serum constituent of normal animals exerts a destructive, sometimes even a solvent effect upon bacteria, relatively slight in the case of normal bacteria, but materially enhanced after the bacteria have in some manner been changed by the union with their antibodies.

Again, there are in the bodies of all animals definite cells usually spoken of as the "white blood cells" and certain wandering cells of the reticulo-endothelial system (clasmatocytes and phagocytic endothelial cells of various kinds) which have retained the primitive capacity for intracellular digestion. These take up foreign particles that gain access to the body. The particular type of these cells that we are capable of studying in the test tube, namely, the leucocytes of the blood, will not take up bacteria to any extent if washed leucocytes are brought together with bacteria in physiological salt solution. In the presence of normal serum they can take up many bacteria of the less virulent varieties, but will often entirely fail to ingest bacteria of very virulent strains, like pneumococci or virulent anthrax bacilli. After such bacteria, however, have united with antibody, they are so altered that the phagocytes can take them up and destroy them actively and in large numbers.

The mechanism by which the union with specific antibody modifies bacteria is still, to a great extent, obscure. By the absorption of antibody there is a reduction of electrical

charge and, as far as agglutination is concerned, Northrup has shown that there is both a decrease of potential (below 13 millivolts) and a reduction of cohesive force by the combined action of the serum constituents and the salts. There is undoubtedly a surface change in the bacteria as a consequence of their union with the specific serum constituent which profoundly alters their relationship to the environment. But this we know empirically rather than by any clear understanding of the mechanism.

It is therefore plain that the specific response of the cells stimulated by contact with the bacterial antigen has resulted in the formation of substances which render the cell itself more sensitive to the antigen. Free in the circulation, these antibodies can unite with the homologous bacteria and thereby change them. By agglutination, the bacteria are caught in the finer capillaries and more easily ingested by endothelial phagocytic cells, such as the Kupffer cells in the liver, and functionally similar cells in other organs. At the same time, an increased susceptibility to the destructive action of the complement or alexin, and an increased susceptibility to phagocytosis (processes quite actively defensive) are initiated.

It must not be assumed that by the analysis of the relationship of antigen to the production of circulating antibodies we have covered the entire story of the adjustment of the body to infection. It is quite clear from numerous observations that in addition to this mechanism there is also a more deep-seated resistance of the cells of the tissues, and a capacity for bacterial destruction by such cells, which cannot be brought into relationship with antibody production. There are, in naturally immune animals, cellular activities like inflammatory response and phagocytosis, which seem to go on independent of the presence of antibodies. And in animals that have been immunized and allowed to rest until all antibodies have disappeared there remains a powerful capacity on the part of the tissues to respond to infection in which, again, no cooperation of antibodies can be demonstrated. Moreover, animals that have been nonspecificially rendered resistant by the injection of broth or ptopene solutions into the peritoneal or pleural cavity

some time before the administration of virulent organisms may be shown to react with an energetic formation of inflammatory granulation tissue which protects them in a manner fundamentally different from that involved in the antigen-antibody mechanism which we have described. Too little is known about the nature of these reactions to make it possible to discuss them intelligently, but it must not be forgotten that they exist and that while they are much more difficult to investigate, gradual progress is being made in their comprehension.

It is hardly necessary to state that no adequate presentation of the problems of immunology can be made in the brief space available. The study of the adjustment of the human body to infection is in that transitional stage in which a great volume of insufficiently correlated information, much of it purely empirical, must be subjected to a more definite analysis by physiological and chemical methods. It must be clear, however, even from the superficial review which we have presented that, in its broader conception, the study of infection offers data and material that are far more significant for the investigation of cell reactions than is indicated by their relationship to infectious disease. The phenomena outlined represent deep-seated capacities of cell adjustment which should receive as much attention from the general physiologist as they do from the immunologist.

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Note. For obvious reasons no attempt has been made to give references to any but the larger treatises and summaries which deal with this subject.

Chapter XVIII

WHAT MEDICINE HAS DONE AND IS DOING FOR THE RACE

Sir Humphry Rolleston

IN the past medical men, being those chiefly interested in natural science, played no insignificant part in the spread of general culture. This is hardly surprising for the doctor is or should be a biologist, and medical science is practically synonymous with human biology. Although at one time medicine came within the province of the encyclopedic scholar, the scholar-physicians were not without their influence on classical learning; Thomas Linacre (1460–1524) was largely responsible for the introduction of the study of Greek into Great Britain, and by founding the Royal College of Physicians of London in 1518 encouraged the pursuit and raised the standard of learning among its Fellows, who as scholarly physicians set an example in extending the cult of the classics. Since the birth of physiology in 1628, when William Harvey published his discovery of the circulation of the blood, the observations and the needs of medicine have illustrated and stimulated research in physiology and chemistry; though medicine owes an ever-increasing debt to these sciences, the account is not entirely one-sided: statistical science too owes much to the stimulus given by the requirements of medicine, as realized and carried out in its earliest days by Sir William Petty (1623–1687) and later by Dr. William Farr (1807–1883).

In primitive races the priesthood supervised the care of the body as well as the cure of souls, a combination with an evil influence in fostering superstition and engendering belief in magic; but the advice given then and by medical men since with regard to manner of life, the use of alcoholic stimulants and of narcotics, and sexual conduct has made for good morals. The medical missionary, the modern successor in the functions of the primitive priest-doctor, gains potential leverage for his moral and religious teaching from

his reputation in relieving the ills of the body. As a general rule far-reaching medical reforms tend to bring about social reforms and improvement in the material and moral condition of the people; the healthy body favors a healthy state of the mind; the destruction of insanitary and overcrowded slums and the substitution of well-lighted and properly drained tenements, as the result of the Medical Officer of Health's activities, must help the poor to a more happy as well as a more healthy life; freedom from epidemics and chronic disability enables self-respecting work to be done and thus banishes worry, discontent and starvation. As Medicine became more rational and entered on a scientific stage it gradually freed itself from gross superstitions, belief in the supernatural origin of disease, demoniac possession, and magic; in this way it influenced mankind to take a logical view of natural phenomena.

Passing from these general ways in which medicine has influenced humanity to its more obvious and special effects: the death rate of England and Wales fell from 20.6 per 1000 living in 1868 to 11.7 in 1928, and the infant mortality rates from 155 to 65 per 1000 during the same period. Further in 1854 the expectation of life at birth for males was 39.9 and for females 41.85 years, whereas in 1922 the corresponding figures were 55.6 and 59.58 years. Other European countries show changes on the same lines, which in the main must be ascribed to improved conditions of sanitation and the influence of medical science. As was proved in the European War (1914–1918) the practical applications of advances in medicine and surgery, sanitary precautions, a pure water supply, and generally in preventive medicine diminished in an unprecedented degree the toll of disease and life exacted by war and pestilence. Medicine has of course greatly influenced veterinary practice and thereby improved the comfort and well-being of mankind.

Unfortunately the art of healing may lag long behind the scientific milestones; thus Harvey's discovery of the circulation of the blood in 1628 was not followed by any modification in practical medicine for many years; for example, transfusion of blood, first performed in the seventeenth century, did not become a routine practice until the

Great European War (1914–1918), and the intravenous injection of drugs, originated by Christopher Wren about 1656, did not come into general use until Ehrlich's arsphenamine was employed about 1910; Humphry Davy's discovery in 1799 of laughing gas (nitrous oxide) as an anesthetic, though demonstrated again in the following year at Guy's Hospital by W. Allen, remained unutilized until Crawford W. Long (1842), and the dentists Horace Wells (1845) and William Morton (1846) employed ether as an anesthetic, and James Y. Simpson of Edinburgh introduced chloroform in 1847. James Lind showed in 1754 how scurvy, which was a constant and most serious cause of incapacity on long voyages, could be prevented, but it was not until 1795 that this simple means was put into general use in the Royal Navy of Great Britain and at once banished this ancient scourge. Herbert Spencer instanced this long delay of forty-one years which the Admiralty allowed to elapse before acting on Lind's recommendation as an apt illustration of the inertia and torpor of administrative bodies. Some years passed before Lister's (1827–1912) antiseptic method (1868) conquered the conservative opposition in his own country and transformed surgery, so that it may be regarded as the greatest material benefit ever conferred on humanity. The fight against childbed or puerperal fever, begun by Charles White of Manchester in 1773, Alexander Gordon of Aberdeen in 1795, Oliver Wendell Holmes of Boston in 1843, and I. P. Semmelweis of Vienna in 1861, has saved many lives and, with the later knowledge of infection and how to avoid it, should certainly be more successful in the future. The last fifty years have seen the most notable changes that have ever occurred in the history of surgery; as the result of Lister's work operations on parts of the body which previously were seldom attempted have become commonplace, and the gain to humanity in freedom from suffering and imminent death has been incalculable, for example in conditions such as appendicitis, gallstones, other abdominal diseases, and brain tumors, which were previously too dangerous to remove and therefore were treated by palliative measures only.

Specialism. During the same period the intensive study of diseases of certain parts of the body, such as the eye, the throat, the nose and ear, the genitourinary organs, and the skin, to mention a few only of the numerous specialties, has greatly increased the efficiency of the healing art, for such specialists acquire a degree of technical skill which is otherwise impossible. In addition to the instances just mentioned the benefit derived from prolonged experience in manipulative and delicate operative procedures is seen in some other branches of surgery, such as orthopedics and plastic operations by which deformities and crippling due to congenital malformations, injury or disease are remedied. The utilization of natural agencies in the treatment of disease and disability has been much extended; thus rest, fresh air, and sunlight (heliotherapy) or, when the latter is not available, artificially produced ultraviolet rays, have largely superseded the previous routine surgical methods in tuberculous disease of bone and joints. Massage and re-education by exercises and gymnastics in old injuries, particularly in stiff joints, though not unknown to the Greeks and Romans, have been much expanded. Treatment by baths, douches and sprays (hydrotherapy), long employed at spas, has been elaborated and is being placed on a more scientific basis much to the advantage of patients with chronic arthritis and allied affections.

THE BENEFITS FROM KNOWLEDGE OF THE CAUSES OF DISEASE

By recognizing the existence of separate diseases (diagnosis) in the first place, and then discovering their respective causes (disposing and immediate or directly responsible) medicine has supplied the means for their prevention or, if it is too late for this, for their cure or relief. An accurate knowledge of this branch of medical science (etiology) is essential for any but the empirical, namely that derived from experience, treatment.

The disposing causes of disease render the individual liable to contract an illness, such as influenza, which he might otherwise escape; thus an unhealthy environment, such as foul air, working in ill-ventilated rooms, improper food, alcoholism, worry, insufficient sleep and exercise,

may reduce the bodily resistance; an inherited constitution may render the onset of certain diseases, such as those of the kidneys, heart and blood vessels, or lungs, a definite danger; and one disease may favor the onset of another, for example measles and diabetes mellitus may both be followed by tuberculosis (see Chap. xx). Realization of these various tendencies enables precautionary steps to be taken. Epidemiology, or the study of the conditions responsible for the great epidemics, such as bubonic plague and cholera, has provided knowledge bearing on the prevention and control of their occurrence, as is shown by their practical disappearance from civilized countries where preventive measures are adopted, and by their occurrence in India and China. Investigation of the factors favoring the onset of chronic disabling disease, such as was advocated and begun by the late James Mackenzie, still awaits completion. In order to understand and remove the disposing factors an exhaustive study must be made not only of the earliest symptoms and signs of disease, but of the patient's environment; circumstances in the patient's life which are unfavorable to a healthy existence may be obvious to the medical man, who may thus be able to benefit other members of the family.

The earliest indications of disease, such as undue fatigue or a sense of ill-being, are manifestations of disordered function, and often precede any gross structural change which can be detected by ordinary physical examination of the patient. In the past the decision whether or not there was anything the matter with a person largely turned on the presence or absence of gross physical changes. The study of functional efficiency of different organs of the body has much advanced the recognition and treatment of disease; chemical examination of the contents of the stomach after a test-meal may show absence of the hydrochloric acid normally present and necessary for the digestion of proteins (meaty foods) and this deficiency should be corrected by acid given by the mouth. Chemical analyses of the blood, the air expired from the lungs, the urine and the excreta provide evidence of the manner in which the changes in the living body producing heat and energy (metabolism) are being carried out; examination of the blood will show

whether or not the kidneys are doing their work properly and so decide whether or not it is safe for the patient to undergo certain operations, such as the removal of an enlarged prostate; examination of the amount of sugar in the blood may reveal a tendency to diabetes mellitus; the functional efficiency of the kidneys and of the liver can be estimated by their ability to deal with certain dyes; graduated exercises throw light on the efficiency and reserve power of the heart and on the state of general physical fitness.

Microscopical examination of the blood may, by revealing an increase in the number of the white corpuscles (leucocytosis), make it highly probable that the infection in a case of fever is due to a microorganism likely to cause an abscess. By the bacteriological method of blood-culture the bacteria causing some infective diseases, such as septicemia and pyemia (commonly spoken of as blood poisoning), can be isolated; further, special, so-called serological, reactions point to the presence of certain infective diseases, such as typhoid fever (Widal's reaction), Malta fever, syphilis (Wassermann reaction); by means of a somewhat similar method it is possible to decide whether a blood-stain is due to human or animal blood. By examination of the blood (Hijmans van den Bergh reaction) a distinction can be drawn between some forms of jaundice and so a decision can be made whether or not the cause can be removed by operation. Examination of the blood is also essential in the recognition of diseases of the blood-forming organs, and differentiates the various forms of anemia and leukemia.

A new development auxiliary to the diagnosis and treatment of the poor, especially those attending hospitals, is the medical social service; by investigation of the environmental conditions in the patient's own home much light may be thrown on the factors responsible for early disease and so indicate the lines on which efficient treatment should be carried out. In order to treat the ailing child or mother without any evidence of gross organic disease, knowledge of the home conditions is most important. Further, in the case of infectious maladies, such as tuberculosis, other sufferers may be detected; the factors lying at the root of

functional neuroses and early mental disorder can thus be elucidated; mental hygiene is a branch of the preventive medicine which is essential in connection with the neurological and psychiatric out-patient clinics of a hospital.

The immediate or directly responsible causes of disease include the numerous infections, the various forms of mechanical injury, and negative factors such as the absence of an internal secretion or of a vitamin essential to the maintenance of health. The knowledge of the immediate exciting causes of the infectious diseases is due to the sciences of bacteriology and later of protozoology, and is one of the greatest milestones in the history of medicine. In the sixteenth century Hieronymus Fracastorius of Verona spoke of the "seeds" of contagion passing from one person to another, and was the first to compare infection with vinous fermentation; but the real founder of bacteriology was Louis Pasteur (1822–1895) a chemist and not a medical man, and with his the name of Robert Koch (1843–1910) of Berlin will always be associated as a pioneer in its advance and in the methods of specific treatment for diseases due to a known microbe. The epoch-making discoveries of the microorganisms responsible for diphtheria, tetanus and typhoid fever, and so of measures for their prevention and, to take a more modern instance, the successful elaboration of insulin in the treatment of diabetes mellitus, would have been impossible without animal experiments. Yet many well-meaning but ill-advised people, unmindful of our Lord's words "Ye are of more value than many sparrows," have bitterly opposed the practice of vivisection; it is perhaps best, and certainly most charitable, to assume that they know not what they do, and will not realize the truth until it is revealed to them by seeing their young child gasping for breath and dying for want of antidiphtheritic serum. Pasteur did not see the virus of canine rabies or human hydrophobia, but following in the footsteps of Edward Jenner (1749–1823), who in 1798 made public the vaccination with the material of cowpox (vaccinia) as a protection against human smallpox, he gave an emulsion or vaccine of the virus of rabies, at first weakened or attenuated and then gradually intensified, to persons bitten by mad dogs

and still in the incubation stage, namely the interval that elapses between the bite and the onset of symptoms, and so averted the distressingly fatal disease hydrophobia. The success of protective vaccination with the killed micro-organisms responsible for typhoid and paratyphoid fevers was shown in the European War (1914–1918) by the freedom from these diseases, unparalleled in previous wars, by the troops treated with the vaccine originally introduced by Almroth Wright. These are outstanding instances of infective diseases in which a scientific knowledge of the exciting cause has enabled prevention or cure to be effected.

Tropical medicine provides some of the most impressive examples of the beneficial results of scientific investigation in the prevention of disease. In 1877 Patrick Manson discovered that mosquitoes carry and convey from man to man the parasite of filarial disease, which while in the mosquito undergoes a cycle in its life history, so that the mosquito is the intermediate host necessary for the development of the filarial organism and the spread of this parasitic disease. The idea that blood sucking and biting flies play a part in infecting man is not new; it was a belief among savages, and Beauperthuy (1807–1871) thought it responsible for malaria and yellow fever; Manson's suggestion that the mosquito was the vector of malarial infection was proved to be correct by Ronald Ross working under his direction, and in 1900 Walter Reed (1851–1902) and his colleagues proved the correctness of Beauperthuy and C. J. Finlay's hypothesis; this was the necessary step to the control and prevention of malaria and yellow fever. Similarly the African sleeping sickness has been shown to be due to infection with an animal parasite *Trypanosoma gambiense* transmitted by the tsetse fly. The proof that bubonic plague, due to the *Bacillus pestis*, is conveyed to man by the bites of fleas carried by rats, and that typhus, formerly known as gaol fever, is due to a rickettsia carried by lice, provided an obvious guide to the prevention of these diseases. Hydatid disease of the liver and other parts (which is not a tropical disease) is due to the entrance into the alimentary canal of human beings of the ova of a tape worm common in the intestines of dogs.

Malaria is probably the commonest and most disabling disease in the tropics; in India alone more than four million victims apply annually for treatment on this account. The mortality and economic loss thus produced are enormous and now fortunately are preventable. The deteriorating effect on national health and morale is very real, and W. H. S. Jones has brought together evidence to show that the decadence of Magna Graecia in 400 B.C. was largely due to the prevalence of malaria. Cinchona or Jesuit's bark, which contains quinine, owes its name to its successful use in the treatment of the Countess of Cinchon in 1638, and is said to have been accidentally discovered by the natives of South America before the Spanish invasion of 1630–1640. Writing in 1897 Sir William Osler (1849–1919) regarded its introduction as not only one of the greatest events in medical history but as one of the great factors in the civilization of the world. It did much to cure the disease and to mitigate the evils of the disease by destroying the parasite when it has gained entrance to the circulation, and small doses may protect persons from becoming affected. In 1880 a French military surgeon C. L. A. Laveran (1845–1922), first observed the malarial parasite; in 1894 Patrick Manson (1844–1922) applied to malaria the hypothesis, based on his previous discovery that mosquitoes conveyed the filarial parasite to man, and in 1898 Ronald Ross proved that mosquitoes conveyed the malarial parasite to man. It thus became evident that mosquito-borne diseases could be prevented by making it impossible for mosquitoes to bite human beings; this can be done by keeping the mosquitoes off by netting and screening, but the most satisfactory means is the complete irradication of mosquitoes. Anti-malarial campaigns for the destruction of mosquitoes by various methods have in many places, as was notably shown in Havana and the Panama Canal area under General W. C. Gorgas' (1854–1920) direction, entirely changed the sanitary conditions in tropical regions previously deserving the epithet of "the white man's grave." As already mentioned, yellow fever, which formerly levied a terrible toll of human life, is also conveyed to man by the bites of a mosquito, *Aedes aegypti* or *Stegomyia fasciata*, and has now been almost completely

suppressed; it is indeed one of the best examples in medical history of an acute infectious disease which can be prevented by scientific sanitation.

Prognosis, or forecasting what will happen, is a very important function of medical men, as it supplies what everyone is anxious to know when illness overtakes them or their relatives. The power of predicting the duration and outcome of a given case of disease depends on several data: first an accurate knowledge of the nature of the illness (diagnosis), secondly on knowledge of its natural history, course and significance, of the complications that may occur, the sequelae or results that may follow, and how far treatment can influence it beneficially, and thirdly on acquaintance with the individual patient's constitution, family history, inherited characters, mental traits, previous health and habits of life. Prognosis thus involves problems all of which may not be capable of solution, particularly during the initial stages, and is probably the most difficult part of medicine. It may be vitally important for a man with many responsibilities to know if he must face death at no long interval, and in these circumstances he should share the medical man's honest opinion, but a fatal prognosis must be given only when there is absolute evidence. In cases of doubt an optimistic view is better for all concerned, and even when there is every reason to anticipate the worst, the unasked warning may be harmful, and many patients know, though they do not really wish to be told, what is before them. Of course reticence must not delay or interfere with the proper medical or surgical treatment of the disease. The foretelling of the physical future of the individual is not confined to conditions of illness, for a medical survey is an essential part of life insurance, and apart from this there is much to be said for the wisdom of a periodic overhaul of the man's body as well as of his business affairs and stock, so that he may be warned in time of any early indications which make it desirable to change his manner of life.

As a result of the application of statistical methods the occurrence of epidemics can in certain instances be foretold so that preparations can be made in advance. Thus J. Brownlee (1868–1927) pointed out that after a pandemic of

influenza, recurring outbreaks may be anticipated at intervals of thirty-three weeks, provided that the thirty-third week does not fall between June and December. Measles tends to recur every two years in large communities or three years in small communities, apparently depending on the accumulation of susceptible children. Protective measures, such as education of the public to pay special attention to colds in children under three years of age and to call in medical men at once, to segregate all contacts of cases, and the offer to immunize young and delicate children by the injection of the blood serum from a convalescent patient, can then be taken to prevent the spread of disease and minimize the mortality. The study of epidemics of infectious diseases artificially induced and experimentally controlled in laboratory animals carried out by Simon Flexner at the Rockefeller Institute in America and Topley in England may be confidently expected to throw much further light on the factors influencing the occurrence of epidemics, and thus to point the way to their prevention. This again is an example of the value of animal experiments as a means of providing the knowledge necessary to diminish human disease and suffering.

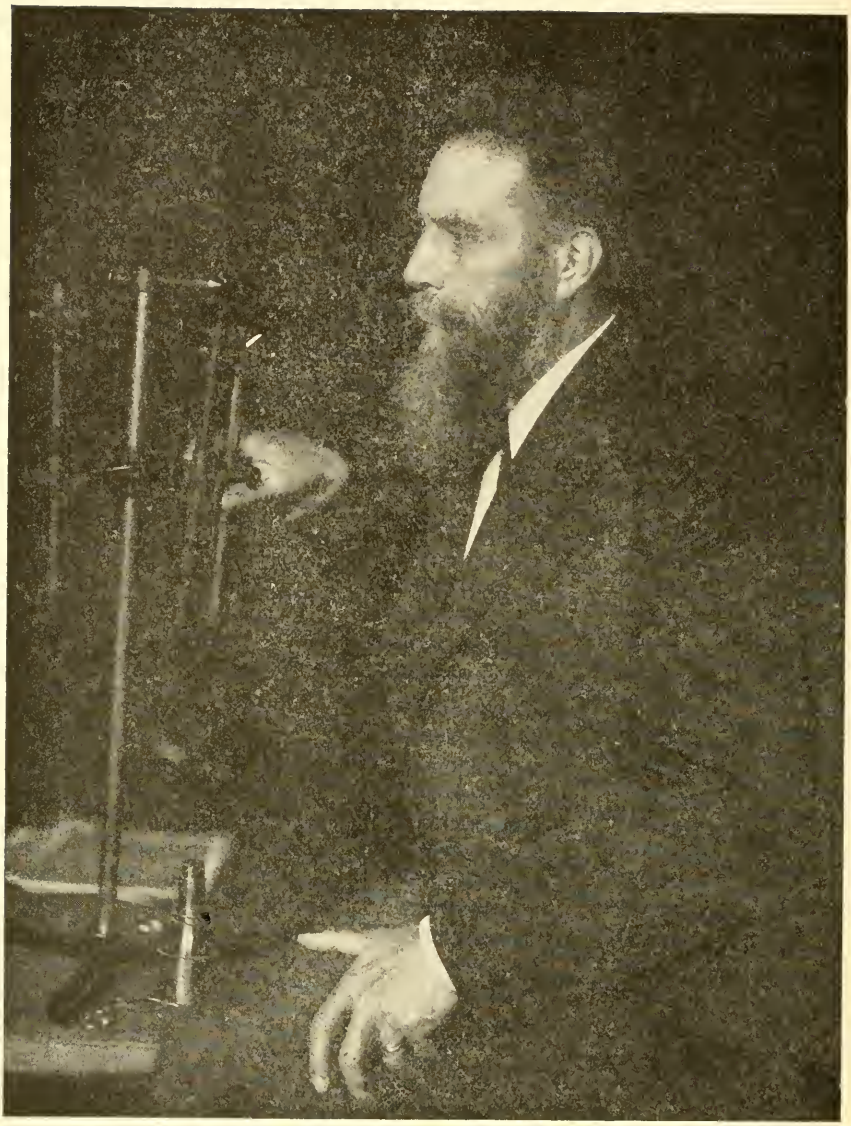
Protective Vaccination against Diseases. Edward Jenner's discovery in 1798 that smallpox, a disease which in the past levied a heavy toll in death and disfigurement, could be prevented by introducing under the skin material obtained from cows with the modified disease of cowpox (vaccinia) was a great improvement on the previous method of inducing an attack of smallpox by inoculation of healthy persons with material from patients suffering from actual smallpox in the hope that by producing a mild attack further risk from a virulent form would be obviated. Jenner's discovery laid the foundation of protective immunization against infectious disease; this method arouses the same defensive mechanisms that ordinarily follow a non-fatal attack of the disease but without actually making the inoculated person ill with the ordinary manifestations of that disease. Such active immunization was employed with complete success by Pasteur in the prevention of hydrophobia in human beings who had already been bitten by a mad dog, and would after a latent or incubation period have developed this constantly fatal

disease. Its adoption against infection with enteric (typhoid and paratyphoid) fever, due to the work of Almroth Wright, was as already mentioned, crowned by phenomenal success in the Great European War (1914–1918) and has been employed in other diseases.

Prophylactic or protective serums render the individual into whom they are hypodermically injected immune to the diseases caused by the viruses which have set up changes in the animals from which the serum is obtained. The blood serum of the animals thus treated contains so-called antibodies which antagonize the toxins or poisons produced by the viruses; in this way *passive* immunity is produced, and contrasts with the *active* immunity which results when vaccines or emulsions of dead viruses are injected, the tissues of the person so vaccinated being thus stimulated to produce the specific (i.e. corresponding to the particular virus) antibodies. Antidiphtheritic and antitetanic serums are well-established examples. Various other serums have been used in the same way (see Chap. XVII).

An important step is the method of being able to determine whether or not an individual is susceptible to certain infections, and therefore likely to contract them when exposed to them. This immunological reaction is in practical use in diphtheria (the Schick test) and in scarlet fever (the Dick test), and can be applied to the inmates of schools; those children who are thus found to be unprotected against either of these two diseases can then be injected with antidiphtheritic or antiscarlatinal serum, and so rendered immune to these infections for a time. In this way epidemics in schools can be prevented.

Curative Antitoxic Serums. The cure of diphtheria by the subcutaneous injection of the blood serum of an animal, usually the horse, previously immunized or rendered insusceptible to the bacillus of diphtheria, has largely robbed the disease of its terrors. This remedy was the result of careful bacteriological research involving animal experiments by Behring. Antitetanic serum, produced in an analogous way by Kieasato, is the best method of treating tetanus. Cerebrospinal fever (meningococcic meningitis) and one form of pneumonia (that due to type I pneumococcus



Wilhelm Konrad Roentgen (1845–1923).

are infections which have more recently been treated with success by the corresponding antitoxic serums.

X-rays, discovered by Professor W. K. von Roentgen (1845–1923) at Würzberg in November 1895, now constitute an essential aid not only in diagnosis or the detection of what is the matter with patients, especially those with internal complaints of otherwise obscure nature, but also in treatment, particularly that of skin diseases and cancerous growths. First employed mainly to determine the exact position of foreign bodies, such as bullets and needles, in the body and of the ends of fractured bones, its use was extended to the detection of disease in the organs of the chest and abdomen and the skull; by the introduction of substances, such as salts of bismuth and barium and more recently of tetraiodophenolphthalein, opaque to *x*-rays, the position, size, shape, and movements of the hollow viscera can be studied in life, and thus is obtained knowledge which previously could be supplied only by an exploratory operation. While medicine has benefited enormously by the help of radiology, surgery, which was made painless by the introduction of anesthetics, safe by the adoption of Lister's antiseptic methods and asepsis, has been assisted by the accurate localization of disease provided by *x*-rays. The rays of radium are employed for the treatment of skin conditions and especially small cancerous growths there and in some other accessible positions with great success.

INTERNATIONAL HEALTH ORGANIZATIONS

The Health Section of the League of Nations is an international organization in the interests of the control of disease throughout the world, in which more than fifty nations are cooperating. By this means early information about epidemics is broadcasted, and much-needed data about tropical diseases are made available. In addition there are governmental, commercial, and privately endowed agencies active in the fight against disease and the resulting economic loss. The International Health Board of the Rockefeller Foundation (established in 1909) which cooperates with government agencies and thus acts on the principle of helping those who can and will help themselves, has carried

on an extensive campaign against hookworm disease in the Southern States of North America and elsewhere, and against malaria and yellow fever in an international manner. Not only do these campaigns diminish the diseases against which they are directed and so are of great humanitarian and economic value, but by their educational influence in inculcating sound principles of sanitation, for example in hookworm disease the erection of latrines and the disposal of excreta, lead to improved health and a decrease in the incidence of other diseases, such as typhoid fever and dysentery. Hookworm disease occurs in agricultural laborers, the parasite gaining its entrance through the unbroken skin; it can be prevented by wearing shoes, even when the soil is heavily contaminated by fecal pollution; the infected individuals can be cured by the oral administration of new drugs, such as chenopodium, carbon tetrachloride, and ascidol.

ORTHODOX AND IRREGULAR MEDICINE

One of the duties of the British Minister of Health, as defined by the Ministry of Health Act 1919, is "the avoidance of fraud in connection with alleged remedies;" this cautiously worded sentence brings up for consideration the relation of orthodox medicine and the medical man to quackery and their obligation to protect the public from exploitation by irregular practitioners out purely for gain at the expense of the patient regardless of any harm which he may suffer. The problem is delicate, for a new method employed by a man without any qualification to practise and little knowledge of medicine may be good in virtue of special knowledge, experience, or manipulative skill in one direction; and on the other hand quackery may be practised by a graduate in medicine. Individually medical men can and do protect their patients against fraudulent methods of treatment, but concerted action has not been general. In North America, where cults of medicine, such as Christian Science, osteopathy, chiropractic, and patent medicines with flaunting advertisements are much in evidence, action has, as far as is possible in the circumstances of the legislature's arrangements,

been taken by the American Medical Association and other bodies.

SPECIAL FORMS OF DISEASE

Tuberculosis, called by John Bunyan "the Captain of the Men of Death" and more recently "the white plague," has greatly diminished in its mortality; thus in England and Wales tuberculosis of the lungs in 1847 carried off 3189 of every million living, whereas in 1928 this death rate had fallen to 755. Many factors have played a part in this change: improved conditions of living and more wholesome food, better ventilation, more open-air life, less overcrowding, education of the public in general hygiene and in particular as regards the risk of spread of infection. The control of milk from tuberculous cows is most important in preventing infection of infants and young children with the bovine form of tuberculosis. The open-air treatment, though advocated in 1840 by G. Bodington of Sutton Coldfield, Warwickshire, England, and by Henry MacCormac of Belfast in 1855, and put in practice by Brehmer at Göbersdorf in Silesia in 1859 and by E. L. Trudeau in the Adirondacks in 1884, did not meet with general adoption in Great Britain until the end of the last century, long after the fall in the tuberculosis mortality had begun. Its influence in educating tuberculous persons in a proper manner of life has been most beneficial, but otherwise it has its limitations; it is not easy to get the poor to go to sanatoriums in the earliest and most curable stages, and it must be realized that in order to consolidate the cure begun at sanatoriums tuberculous patients should continue to lead a protected life in a colony or village settlement where they can earn their living in hygienic workshops and other favorable conditions; a beginning in the establishment of such permanent industrial colonies for ex-sanatorium tuberculous persons has been made at Papworth Hall near Cambridge and at Preston Hall near Maidstone, Kent, in England, under the direction of Dr. P. C. Varrier-Jones who has organized industries on a self-supporting basis. During the years that the Papworth Colony has been in existence no case of tuberculosis has occurred in the children living in the cottages with their formerly

actively tuberculous fathers. Numerous associations, such as the American National Tuberculosis Association organized by E. L. Trudeau in 1904 and the National Association for the Prevention of Tuberculosis founded in Great Britain in 1898, have undertaken antituberculosis campaigns for the education of the public so as to prevent infection and, if this has already occurred, to popularize treatment at the earliest possible time; by way of propaganda they have arranged travelling exhibits, lectures, and cinema films, such as that of the American National Tuberculosis Association which toured all the States east of the Mississippi from 1906 to 1912. It is satisfactory to notice that the death rate from tuberculosis in the United States, which was 201 per 100,000 in 1900, has been reduced to 86.6 in 1925. These campaigns, especially by their insistence on the gospel of open-air, have also led, as a kind of by-product, to improvement in the general health of the human race.

In 1882 Robert Koch demonstrated the microorganism, the tubercle bacillus, responsible for widespread disability and death, and thus opened the way to the prevention of infection, both from human and animal sufferers, for example by inhalation of the expectoration and by ingestion of milk containing bovine bacilli. Thus the spread of "the seed" can be minimized by education of the public, laws against spitting, and special care and measures to be taken about those with the fully developed disease, such as destruction of their expectoration, efficient ventilation and disinfection. The importance of preventing the spread of tuberculosis by milk from cows suffering from the disease has already been mentioned. Without "the seed," or the tubercle bacillus, the disease of course cannot occur, but it is so ubiquitous that in towns avoidance of exposure to its infection cannot be insured, and yet it is comparatively few who fall victims to its obviously evil effects. The factor of the "soil" or constitutional power of resistance of the individual was somewhat cast into the background in the early days of bacteriology when much was hoped from the discovery of the responsible germ and specific treatment by tuberculin; but its importance is now fully recognized in the hygiene and open-air methods of treatment and in the care of

delicate children. Systematic surveys of school children thus act as a prophylactic measure by providing a remedial change of air and rest to those in a pretuberculous or in a very early stage; and further, by the detection and segregation of children so affected as to be a source of infection to others, these surveys by medical men combat the insidious spread of the disease.

Venereal Disease. Of the two, syphilis and gonorrhea, the first is more far-reaching and devastating in its effects; whereas gonorrhea is locally more effective in causing sterility and chronic ill-health in women, and in infants ophthalmia and blindness from infection at the time of birth, syphilis may attack any and every part of the body, and is now known to be the cause of locomotor ataxia, general paralysis of the insane and other disabling conditions which supervene years after the original infection has been thought to be cured. Statistics show that the mortality from locomotor ataxia and general paralysis has recently diminished—a result which may fairly be correlated with the knowledge that they are late results of syphilis and with the improved and earlier treatment of syphilis. By means of a blood test, the Wassermann reaction, introduced in 1906, the existence of syphilis, although there may not be any other evidence of its responsibility, can be determined, and thus point the way to curative treatment which has been made much more complete and effective in the last twenty years. Syphilis is a killing disease not only of adults but of innocents yet unborn, and is a most potent cause of abortion, miscarriage, still-birth, and infantile mortality; it is said that one third of all syphilitic infants die before birth, and that of the remainder 34 per cent succumb during the first six months of life—an appalling total mortality of 77 per cent (Kassowitz); but fortunately treatment of pregnant women with the disease prevents these fatalities. In England and Wales the establishment of free treatment centers for venereal disease, of which in 1928 there were 188, was at once followed by diminished incidence; in 1920 85,531 persons were treated and in 1924 54,380, the progressive diminution in the number of new cases being due to the successful treatment of syphilis. But in 1928 there were 65,931 new cases. Schau-

dinn's discovery in 1905 of the *Treponema pallidum*, the cause of syphilis, rendered it possible to make a certain and early diagnosis of this enemy of human life and efficiency. By treatment with Ehrlich's (1854–1915) organic arsenical preparations (salvarsan, arsphenamine, "606") and by drugs of an analogous nature, the infective power of the primary sore is rapidly abolished, and thus the spread is prevented of a disease which otherwise damages or destroys the individuals who have contracted it and also their unborn offspring. Not only is the propagation of the disease prevented but a well-marked curative effect obtained in the individual.

The ideal of Ehrlich's chemotherapy is that by means of a drug the virus of a disease should be destroyed in the body of a patient without doing any harm to the patient. Although the second essential has not been entirely achieved, the outstanding success of organic arsenic preparations in protozoan infections of man is a great tribute to Ehrlich's labors; thus the treatment of syphilis by arsenobenzol preparations (arsphenamine), of trypanosomiasis by analogous drugs, and of amebic dysentery by emetine has revolutionized the aspect of these killing diseases.

Acute rheumatism or rheumatic fever has long been recognized as a most serious cause of crippling heart disease, especially in children, and of early death. Campaigns to educate the public and so to diminish its effects are actively maintained; the objects are to remove its causes, such as bad teeth and infected tonsils, which may be summed up as focal sepsis, to obviate the disposing environmental circumstances, such as damp dwellings, and to bring rheumatic children under medical observation at an early stage. Experience has shown that the cardiac damage due to acute rheumatism in children may be minimized by prolonged rest in bed. Before the introduction of treatment by salicylates in 1877 rheumatic fever tortured its victims for six weeks; now the fever and pain can be banished in a few days, but salicylates cannot be relied upon to prevent the heart complications.

Chronic arthritis (rheumatoid arthritis), fibrositis, and chronic rheumatism exact an enormous toll of disability and economic loss mainly from adults, though the heart is not

damaged, as in rheumatic fever. These chronic rheumatic affections are in large measure due to focal sepsis somewhere in the body, a state of affairs which naturally tends to become more frequent with the passage of years. The prevention of such causes by attention to dental disease and infected tonsils is therefore on the same lines as in rheumatic fever, but other methods of treatment, such as that at spas and forms of radiant heat and light, have recently been more widely employed.

Malignant Disease. While infant mortality has fallen in a most remarkable manner, many epidemic and infectious diseases have been controlled, and the average duration of life greatly increased, there is much yet to be accomplished in the conquest of disease. This was shown by the pandemic of influenza in 1918-1919, by the outbreak of encephalitis epidemica, practically a new disease, in 1917, and by the lack of efficient control over acute poliomyelitis, known since 1840. Perhaps the outstanding example is cancer, the mortality from which is increasing, though this may in part be due to the survival of a larger number of people, as a result of improved hygienic conditions, to the age when malignant disease most commonly occurs. The British figures of the mortality from cancer and tuberculosis are instructive in this connection: in 1884 the annual mortality rate per million persons living was 563 for cancer and 2574 for tuberculosis, whereas in 1928 the corresponding figures were 1425 for cancer and 755 for tuberculosis. Cancer occurs in all parts of the world, no country or race is exempt, for the old statements that primitive uncivilized tribes are not affected were due to want of accurate knowledge; it has been estimated that 1 out of every 7 persons reaching the age of thirty years will die of cancer. The urgency of the prevention of cancer has led to intensive investigation in special institutions all over the civilized world of the various problems concerned, and an enormous amount of information bearing on its causation, pathology, incidence and statistics has been accumulated; but so far the essential cause has not been indubitably established, and until this much sought for discovery is made, the means of prevention is yet to seek. But although this final achievement has not been accomplished, the way has

been prepared, and in the meanwhile much has been done; conditions which favor the incidence of cancer, such as chronic irritation and inflammation, have been recognized and so can be obviated, such as irritation of the tongue by a sharp tooth or of the skin by materials such as soot, paraffin and other agents in industrial occupations. To take an example in which medical men have been the main sufferers: more than a hundred radiologists have now died from cancer of the skin caused by *x*-rays; standardized methods of protection against the dangers of *x*-rays and radium exposures have now been formulated, so as completely to obviate them.

Educative campaigns to instruct the public about the importance of seeking medical advice about the earliest symptoms of possible malignant disease, so that if present a growth may be removed at a period when cure can be obtained, have done much good. The progress of diagnostic methods, such as *x*-rays, enabling a decision to be made at a stage not previously possible, has given the sufferers the benefit of cure by early operation; the improvement of surgical technique and *x*-ray and radium therapy are other advances which have been of service in the treatment of cancer. Before 1890 the operative removal of tissues and lymphatics around malignant tumors was not sufficiently wide, and as a result recurrences were more frequent than after the more complete and extensive operations now performed.

One of the great triumphs of applied physiology was the exact localization of tumors in the brain so as to indicate the exact position where the surgeon should trephine the skull for their removal.

Diseases of the Heart and Blood Vessels. Except aneurysm, or pathological dilatation of the arteries of the limbs with a tendency to rupture which was known to Galen (130–200 A. D.), little in connection with the circulatory system was recognized until long after Harvey's publication of the circulation of the blood (1628). The reason for this was that the methods of physical examination of the heart were not practised until the beginning of the nineteenth century when J.N. Corvisart (1755–1821) in 1808 resuscitated Auenbrugger's

(1722–1809) neglected discovery of percussion and R.T.H. Laennec (1781–1826) in 1819 published his classical work on auscultation. The alterations of the heart sounds (murmurs) which characterize valvular disease were elaborated throughout most of the nineteenth century, and, as is now apparent, attention was directed too much to the more obvious evidence of valvular disease and not sufficiently to the condition of the muscular efficiency of the heart. The signs of cardiac disease were regarded as far more important than the patient's symptoms and sensations. The new cardiology began with James Mackenzie's (1853–1925) elucidation of the irregularities of the pulse, and the more accurate indications for the use of digitalis in cardiac affections, derived from instrumental investigation; this advance was continued by Thomas Lewis' observations with the electrocardiograph. By these means the actual changes in the heart revealed by special methods were correlated with more obvious signs; the latter have thus in most instances become a reliable guide to the underlying condition without recourse to the more elaborate methods of the original pioneers. More accurate knowledge of the causes of heart disease, such as acute rheumatism, infections and especially syphilis have made curative treatment more rational and successful, and prevention more possible. The accurate instrumental estimation of blood pressure which enables its abnormal characters to be detected before symptoms have made their appearance, is most valuable as a warning to start preventive treatment in an early stage.

A brief reference should be made to the advances made in the recognition and treatment of the various *diseases of the blood-forming organs*. Anemia may be due to many causes; one form is due to the presence of a parasite in the alimentary canal, as in hookworm disease (see p. 442); the destruction of these worms or better the prevention of this infection is the logical and successful sequel of this new knowledge. Another form of grave anemia, the pernicious or Addisonian, has now been shown to be benefited by an administration of liver substance which also has a most satisfactory influence on the tropical disease known as sprue. Anemia due to loss of blood, such as occurs as the result of disease, wounds or

operation, can be most successfully remedied by introducing into the patient's veins the blood of a like nature, previously tested to show that it is compatible, from another and healthy person (the donor); blood transfusion is an old idea, but it is only within the last twenty years that its technique has been so improved as to make it safe. Anemia may be due to the action of substances used in industries, such as lead, benzole, some explosives, or of *x*-rays or radium in persons exposed to their influence for long periods in the course of their occupation; knowledge of the causes makes it comparatively easy to anticipate and prevent regrettable results by periodical inspection of the employees. Another form of anemia associated with enlargement of the spleen, known as chronic splenic anemia, has been proved to be curable by surgical removal of the spleen, an operation which has also been found to be an effective cure for chronic hemolytic jaundice.

NEUROLOGY

The remarkable progress in physiology since the second half of the last century has influenced the practice of medicine in many directions, but probably in none more than in bringing about a clearer insight into disorders and diseases of the nervous system. Morbid physiology, which is part of pathology, has thrown much light on the causes of nervous diseases, as have the new developments in psychology; thus it has become possible to apply more rational and effective treatment to functional disorders (neuroses, psychoneuroses) as well as to structural diseases of the brain, spinal cord and nerves. The needs of the numerous cases of war neuroses led to much psychotherapeutic practice, and the experience thus gained has borne fruit and modified in some respects previous conceptions. The recognition of the effect of syphilis in producing degenerative diseases of the nervous system has emphasized the urgency for thorough early treatment. Recently one of these diseases, general paralysis of the insane, has been much benefited by the artificial production of malaria. The importance of heredity in mental disorders has aroused eugenic activities for the

protective segregation of the mental defectives and limitation of their propagation.

Reform in the Treatment of the Insane. The efforts of Pinel (1745–1826) in France from 1792, John Connolly (1840), the Tukes and others in Britain led to the abandonment of barbarous methods, a relic of the time of demoniac possession, and changed the character of asylums from that of prisons to that of mental hospitals. By the modern study of the factors responsible for mental disorder and the early treatment of mental instability great benefit has been effected in both preventive and curative directions. This movement of mental hygiene has been an actively efficient method of correcting faulty habits of life, removing injurious environmental influences, and of correcting abnormalities of conduct, and thus preventing deliquency and mental disorder. By the arrangements made for the care and segregation of the mentally defective, their well-being has been promoted and the liability of their multiplying has been minimized.

ENDOCRINE DISEASES

Certain glands in the body pour their secretions into the circulating blood and are spoken of as the ductless or endocrine glands or glands of internal secretion (see Chap. x). The substances they supply are necessary for the normal functioning of the body and are called hormones and spoken of as chemical messengers. Absence, deficiency, excess, or alteration of these hormones upsets the so-called endocrine balance and produces various disorders of health or diseases. The secretion of the thyroid gland contains the active principle, thyroxin, which can now be artificially made or synthetized in the chemical laboratory; it is a stimulant and increases the changes, or metabolism, of the body so that they take place more rapidly. If, as the result of disease or removal of the thyroid gland, the secretion of thyroxin is absent, the individual becomes apathetic, slow in body and mind, puffy and somewhat fat; when this occurs in an adult it is known as myxedema, when in a baby as cretinism and then, although the years pass, the individual remains in an infantile state. These patients can be restored to practically a normal condition by the administration of

the extract of the thyroid gland of an animal; but this substitution treatment must be continued indefinitely as the individual's own thyroid cannot supply the hormones. Excessive and probably also altered secretion of the thyroid gland causes a condition (exophthalmic goiter or Graves' disease) which is the opposite of myxedema and is characterized by extreme nervousness, protrusion of the eyes, enlargement of the thyroid gland (goiter), sweating, palpitation and rapid action of the heart; this disease is greatly benefited by removal of part or almost the whole of the gland, and is, at any rate temporarily, improved by the administration of iodine. The thyroid gland is concerned with the metabolism (or changes connected with the presence) of iodine in the body, just as the small parathyroid glands in its immediate neighborhood regulate the metabolism of calcium. In certain regions, such as the basin of the Great Lakes and the valley of the Mississippi in North America, parts of Switzerland, and some valleys of the Himalayas, enlargement (goiter) of the thyroid gland is endemic; this has long been connected with the water supply. According to McCarrison simple goiter is due to a number of causes, viz. deficiencies and excesses in food, polluted water, gastrointestinal infection, insanitary conditions of life, and deficiency of iodine. This simple goiter, which is not accompanied by the symptoms of Graves' disease, occurs much more frequently in young girls than in males, and according to D. Marine is due to a lack of iodine; he has found that it can be prevented by the administration of small doses of iodine twice a year, a striking demonstration of scientific preventive medicine.

The pituitary gland at the base of the brain exerts a well-marked influence on physical growth; deficiency of its internal secretion leads to a form of obesity, with, in children, arrest of development so that the changes of puberty do not appear. Overactivity of the anterior lobe of the pituitary causes excessive growth which in early life is responsible for giants, and in older people, whose bones can no longer grow in length, for a characteristic increase in size of the extremities known as acromegaly. An extract of the posterior lobe of the pituitary has been found to prevent for some hours the excessive excretion of urine which so disturbs the

rest of the subjects of diabetes insipidus; but, just as in myxedema and cretinism, and in diabetes mellitus, in which the injection of insulin temporarily transforms the patient into a normal person, so also must this form of treatment be continued, for the relief is not permanent and therefore not a cure. The adrenal or suprarenal glands, which lie in close contact with the kidney but are not concerned in the excretion of urine, are, like the pituitary, composed of two parts; the internal or medulla has an internal secretion, adrenaline or epinephrine, which is a tonic to the vascular system, maintains the blood pressure by constricting the arteries, and so is much used in the arrest of bleeding. It is also employed for the relief of asthma. It can be manufactured in the chemical laboratory. Other glands, such as the parathyroids and gonads (the sex glands), have internal secretions which keep the body in a normal condition, and when altered bring about morbid manifestations.

An international agreement as to a standard composition of therapeutic substances (including endocrine preparations, serums, and vaccines) has been a valuable measure in insuring their proper preparation, strength and purity.

Advances in medical science dealing with diet have so greatly promoted human welfare that a whole chapter (Chap. XIV) is devoted to their discussion.

PREVENTIVE MEDICINE

Towards the true ideal of medicine—the prevention rather than the cure or relief of disease—there has been more advance in the last fifty years than in any similar period of the world's history. Preventive medicine is closely bound up with the practical application of physiology, for, as Sir George Newman points out, it must deal with the causes of health so as to be able to discover the causes of disease, and thereby effect the "removal of the occasion of disease and physical inefficiency combined with the husbanding of the resources of the individual."

According to G. E. Vincent, President of the Rockefeller Foundation, the activities of public authorities can prevent, wholly or in part, not more than 20 per cent of the diseases causing death or disablement; there is therefore the most

urgent need for education of the lay public in "the laws of physiological righteousness;" for if the people do not know or understand properly the principles of personal hygiene, they will neglect them or carry them out imperfectly, in fact "the people perish for want of knowledge." Sir George Newman has insisted that health education is an essential part of any national health policy, that instruction should be given in schools, and has facilitated this by the issue from the Board of Education of "A Handbook of Suggestions on Health Education." In this education medical men have taken the pioneer part, and for its right guidance and success must continue to give this service.

Infant Welfare. As about 80 per cent of the population are born free from disease, it is obviously most important to protect them against the various dangers in the way of infection, improper feeding, and neglect that may assail them. Antenatal care and instruction of the mothers, infant welfare centers, and infant treatment clinics provided by the state are obviously of great value in this respect. In 1871–1880 out of every thousand infants 149 died during the first year of life, in 1928 this number had fallen to 65. The infant welfare centers should continue to supervise the health of the young up to the age of school life.

The school medical service, started in 1907 in England and Wales, is part of the public health service of the country, and employs more than 1800 medical men and women. This step in preventive medicine has been followed by a substantial degree of physical and mental improvement.

Disease of the teeth, pyorrhea alveolaris and dental caries, are an extremely common cause of ill health, rheumatism and fibrositis, neuritis, disease in the abdomen and other parts. The frequency of dental disease may have increased with the cooking of civilized life, but, be this as it may, the great importance of oral sepsis, including tonsillitis, in causing widespread bodily disease, especially rheumatic fever and heart disease, has only recently been fully recognized. The institution of dental clinics for the inspection of school children, as part of the systematic school medical service in Great Britain, is a most valuable element in preventive medicine. Logically a similar *periodical medical examina-*

tion of adults should be available in order to give timely warning of the tendency to disease and to detect the early evidence of insidious disorders of which there may not be any conscious suspicion, such as high blood pressure, kidney or nervous affections. Comparatively few consult their medical attendants in the same way that they visit their dentists in order to anticipate trouble. But that this is worth while has been shown by the action of some American Life Insurance Companies in offering their policy-holders periodical medical examinations by the Life Extension Institute; the results have shown that it is a good business proposition, for there was a substantially lower death rate among those who availed themselves of the offer as compared with the policy-holders who did not. If this step is economically sound from the statistical point of view, it is surely worth consideration by the individual.

Preventive Physiological Tests. A recent example of the application of physiology and psychology to practical life is seen in the examination of candidates for aviation work, and periodically of pilots to see if they are fit to continue or need rest. The tests evolved during the European War proved of great value in deciding questions which an ordinary medical examination cannot do with such certainty. The human machine has to adapt itself to the changing conditions of temperature and oxygen tension depending on rapid alterations of altitude; and to estimate the capacity of the individual in these respects and to determine the state of the nervous system and the sense organs special methods of testing are necessary. By these tests loss of life and disabling crashes were diminished.

Preventive Bacteriology. The comparatively new knowledge that otherwise normal people may carry in their bodies the germs of disease, such as typhoid fever, pneumonia, diphtheria, and cerebrospinal fever, and thus unconsciously give the disease to others, explains the apparently spontaneous outbreaks of disease. The detection of these "carriers" by bacteriological means supplies the obvious way of preventing disease, namely isolation of the carrier.

Preventive Surgery. Examples of the preventive influence of internal medicine are mentioned elsewhere in this chapter,

and it is therefore unnecessary to repeat them. But attention should be drawn to the way in which surgery acts in a similar way; the removal of local centers of bacterial infection or septic foci, such as an inflamed vermiform appendix or a small abscess on the finger, may prevent a severe peritonitis or a general infection which would otherwise prove fatal. Complete removal of a cancerous growth is another obvious example.

Dentistry, which until the end of the last century was mainly mechanical in its conceptions, is now recognized as a most effective means of preventing general ill-health and disease in other parts of the body, such as rheumatism.

INDUSTRIAL MEDICINE

In preventing disease among those employed in various occupations, which were formerly known as dangerous trades, medicine has done much and is progressively doing more for the well-being of the race. In Great Britain as long ago as 1832 Dr. Turner Thackrah and in 1857 Dr. E. H. Greenhow enquired into the influence of industrial occupations on health, and since then these problems have been widely and intensively investigated; since 1917 a special section of the physiological department at Harvard University, Boston, Massachusetts, has been devoted to scientific research into the causation of industrial diseases under the direction of Dr. C. K. Drinker. The poisonous effects of lead which attend a number of industries, such as white lead workers, printers, potters, have long been known, and as the result of carefully planned protective measures, including periodical examination of the employees, based on investigations of the circumstances of the industry, the evil effects have been largely obviated. But other metals, such as nickel, zinc, manganese, copper, and mercury (in hatters, thermometer and mirror makers) may be responsible for industrial poisoning. A number of occupational diseases are due to the inhalation of dust, especially among miners, as in the "gold-miners phthisis" in which particles of silica are particularly harmful.

As examples of the value of arresting the incidence of toxic effects from dangerous occupations, reference may be

made to the rapid effect of skilled medical advice in connection with the occurrence of jaundice and hepatic disease in aeroplane workers who used tetrachlorethane ("dope") to paint the wings of aeroplanes in England at an early stage of the Great War, and later on in the War in the care of workers in munition factories where trinitrotoluene ("t.n.t.") was used. It may be pointed out that the exigencies of the War stimulated efforts in the direction of industrial hygiene. The practical application of experimental psychology, which investigates the responses of individuals to definite prescribed conditions, has proved to be of great economic value in increasing the output of work in factories and workshops by modifying the conditions of work, particularly by the introduction of intervals of rest, maintaining good atmospheric conditions so as to obviate fatigue, and by minimizing monotony and boredom.

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Chapter XIX

THE RELATION OF SCIENCE TO INDUSTRY

R. A. Millikan

A WELL-KNOWN public speaker of fifty years ago once remarked ruefully after disastrous consequences had followed misplaced humor, "I rose by my gravity and fell by my levity."

I use this incident as an introduction to my chapter for the sake of calling attention to the fact that what is absurd or ridiculous today was perfectly good science, or at least good philosophy, not more than 350 years ago, that the very existence of the "law of gravity" was discovered as late as 1650 A.D. and that "levity" and "levitation" have through all recorded history up to Newton been just as acceptable scientific ideas as gravity and gravitation, so recently have we begun to understand just a little about the nature of the world in which we live.

Nor do I need to go back 300 years to make my point as to the newness of our knowledge. It is within the memory of every man of the age of sixty that in the great Empire State of New York the question could be seriously debated, and in the most intelligent of her communities too, as to whether Archbishop Usher's chronology, computed by adding Adams 930 years to Enoch's 365 years to Methuselah's 969 years, etc. gave the correct date of creation. Recent election returns from Arkansas indicate that the same debate is at this very moment going on there.

But what has this to do with "Science and Industry?" Everything! For mankind's fundamental beliefs about the nature of the world and his place in it are in the last analysis the great moving forces behind all his activities. Hence the enormous *practical* importance of correct understandings. It is his beliefs about the nature of his world that determine whether man in Africa spends his time in beating tomtoms to drive away evil spirits, or in Phoenicia in building a great "burning fiery furnace" to Moloch into which to throw his

children as sacrifices to his God, or in Attica in making war on his fellow Greeks because the Delphic Oracle, or the flight of birds, or the appearance of an animal's entrails bids him do so, or in medieval Europe in preparing for the millennium to the neglect of all his normal duties as he did to the extent of bringing on a world disaster in the year 1000, or in burning heretics in Flanders or drowning witches in Salem, or in making perpetual motion machines in Philadelphia, or magnetic belts in Los Angeles, or soothing syrups in New England.

The invention of the airplane and the radio are looked upon by everyone as wonderful and pre-eminently useful achievements, and so they are, perhaps one-tenth as useful as some of the discoveries in pure science that I shall presently discuss and hence worthy of a moment or two of consideration.

As I listened in Pasadena to the Presidential candidates presenting in their own easily recognizable voices from the platform in Madison Square Garden to the people of the United States the issues of the election, or at least its shibboleths, I found myself aglow with enthusiasm for the future of representative government. The few thousand citizens of Athens gathered about the Acropolis to hear the problems of the city discussed and then to cast their ballots. The 120 million citizens of the United States in this recent election had precisely the same opportunity and in my judgment they used it judiciously. These public discussions addressed to the ears of the nation represent, I think, a stupendous advance. No such step forward in public education has been taken since the invention of printing.

But this new achievement of the race, this new capacity for education was after all only an inevitable incident in the forward sweep of pure science, which means simply knowledge, knowledge of the nature and capacities of the physical world, the ethereal world (to which the radio belongs), the biological world and the intellectual world; for this knowledge, as man acquires it, necessarily carries applied science in its wake.

Look for a moment at the historic background out of which these modern marvels, as you call them, the airplane

and the radio, have sprung. Neither of them would have been at all possible without 200 years of work in pure science before any bread and butter applications were dreamed of, work beginning in the sixteenth century with Copernicus and Kepler and Galileo, whose discoveries for the first time began to cause mankind to glimpse a nature, or a God, whichever term you prefer, not of caprice and whim as had been all the Gods of the ancient world, but instead a God who rules through law, a nature which can be counted upon and hence is worth knowing and worth carefully studying. This discovery which began to be made about 1600 A.D. I call the supreme discovery of all the ages, for before any application was ever dreamed of, it began to change the whole philosophical and religious outlook of the race, to effect a spiritual and an intellectual, not at first a material revolution, this was to come later. This new knowledge was what began at this time to banish the monastic ideal which had led thousands, perhaps millions of men, to withdraw themselves from useful lives. It was this new knowledge that began to inspire man to know his universe so as to be able to live in it more rationally.

As a result of that inspiration there followed 200 years of the pure science involved in the development of the mathematics, and of the celestial mechanics, necessary merely to understand the movements of the heavenly bodies, useless knowledge to the unseeing, but all constituting an indispensable foundation for the development of the terrestrial mechanics and the industrial civilization which actually followed in the nineteenth century; for the very laws of force and motion essential to the design of all power machines of every sort were completely unknown to the ancient world, completely unknown up to Galileo's time.

Does the practical man of today fully realize that the airplane was only made possible by the development of the internal combustion engine, that this in its turn was only made possible by the development of the laws governing all heat engines (the laws of thermo dynamics) through the use for the hundred preceding years of the steam engine, that this was only made possible by the preceding 200 years of work in celestial mechanics, that this was only made

possible by the discovery of the laws of force and motion by Galileo and Newton. That states the relationship of pure science to industry. The one is the child of the other. You may apply any blood test you wish and you will at once establish the relationship. *Pure science begat modern industry.*

In the case of the radio art, the commercial values of which now mount up to many billions of dollars, the parentage is still easier to trace. For if one's vision does not enable him to look back 300 years, even the shortest-sighted of men can scarcely fail to see back eighteen years. For the whole structure of the radio art has been built since 1910, definitely and unquestionably upon researches carried on in the pure science laboratory for twenty years before anyone dreamed that there were immediate commercial applications of these electronic discharges in high vacuum.

It is precisely the same story everywhere in all branches of human progress. I suspect it would be difficult to find a single exception. Here is the latest illustration that came to my attention less than a week ago in a letter from the Air Reduction Sales Company. It reads as follows: "We take pleasure in handing you herewith a complete set of luminescent tubes, each containing in the pure state one of the elements of the air, namely, nitrogen, oxygen, argon, hydrogen, neon, helium, krypton and xenon. It seems to us worthy of note that at the beginning of this century these gaseous elements as such had practically no commercial significance. Today the estimated value of the plants and equipment that have been created either to manufacture or to use and handle these gases in industry amounts to three hundred million dollars."

The writer of this letter might have added that the chain of discovery which led up to this result started in the most "useless" of all sciences, astronomy; for helium, as its name implies and as everyone knows, was first discovered in the sun with the aid of the spectroscope, and thirty years later it was its discovery in minute amounts in our atmosphere, also with the aid of the spectroscope, that set us looking for the other inert gases of which the letter speaks and which have recently found such enormous application in neon tubes and the like.

But why continue these recitals, for no intelligent man today needs to be convinced that our material prosperity rests wholly upon the development of our science. It is as to the broader values, intellectual and spiritual, that even intelligent men sometimes express doubt. Let me then start with the foundations that I have already laid and try to show to what these beginnings are leading, whither we are going, not materially, but as feeling, thinking and willing beings.

Was Pasteur only a scientific enthusiast when he wrote: "In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring discussions of politics seem to be our guide—empty appearances! What really leads us forward is a few scientific discoveries and their application."

Or was H. G. Wells, himself not a scientist at all, merely talking nonsense when he wrote: "When the intellectual history of this time comes to be written, nothing, I think, will stand out more strikingly than the empty gulf in quality between the superb and richly fruitful scientific investigations that are going on, and the general thought of other educated sections of the community. I do not mean that scientific men are, as a whole, a class of supermen, dealing and thinking about everything in a way altogether better than the common run of humanity, but in their field they think and work with an intensity and integrity, a breadth, a boldness, patience, thoroughness, fruitfulness, excepting only a few artists, which puts their work out of all comparison with any other human activity. In these particular directions the human mind has achieved a new and higher quality of attitude and gesture, a veracity, a self detachment, and self-abrogating vigor of criticism that tends to spread out and must ultimately spread to every other human affair."

These may be extravagant statements, most of us scientists are sure they are, but I should like to attempt to picture a little of what I think was in the back of the minds of their authors when they made them. I shall do it by drawing an analogy between the life of mankind as a whole and the life of man as an individual. But first let me answer the question as to what we know about the duration of the life of mankind. A hundred years ago we knew practically nothing about it, as

my opening remarks on Archbishop Usher's chronology showed. But since then we have made some scientific discoveries, discoveries that are not usually listed as of industrial importance at all, but which in my opinion outweigh by far in practical value to the race, either the invention of the airplane or of the radio, and that simply because they change fundamentally our ideas about the nature of the outside world, and hence change also the nature of our acting in relation to it.

We have learned within the past half dozen years through studies in radioactivity that this world of ours has in all probability been a going concern, in something like its present geological aspects as to crustal constituents, temperatures, etc. for more than a billion years, and hence that the human race can probably count on occupying it for a very long time to come, say another billion years; and further, that mankind has been doing business on it in something like his present shape for about 20,000 years, perhaps 50,000, but in any case a time that is negligibly small in comparison with the time that is behind and also that is presumably ahead of him; in other words, we have learned that mankind, speaking of him as an individual human being, is now just an infant a few months old at the most, an infant that up to about a minute ago, for the 300 years since Galileo are but a minute in the geological time-scale, had been lying in his crib spending his waking hours playing with his fingers, wiggling his toes, shaking his rattle, in a word, in simply becoming conscious of his own sensations and his functions, waking up, as he did amazingly in Greece, to his own mental and emotional insides. Just one minute ago he began for the first time to peer out through the slats in his crib, to wonder and to begin to try to find out what kind of an external world it is that lies around him, what kind of a world it is in which he has got to live for the next billion years. The answers to that question, even though never completely given, are henceforth his one supreme concern. In this minute of experience that he has already had he has tumbled down in his crib, bumped his head against the slats, and seen stars, real ones and unreal ones, and he has not yet learned to distinguish with certainty between those that actually exist and those that only seem to

exist because his eye-balls have received a blow, and so he is reaching out his hands part of the time trying to grasp illusions, and yet slowly, painfully learning, bit by bit, that there *is* an external world, physical and biological, that can be known, that can be counted upon when it has once become known, to act consistently, not capriciously, that there is a *law* of gravity and that it is not necessary to be covered with bruises all the time because he forgets it, that there is a principle of conservation of energy, and that all constructive and worth-while effort everywhere must henceforth take it into account and be consonant with it, that it is not worth while to spend much time with sentimentalists who wish that that law did not exist and sometimes try to legislate it out of existence, that again there are facts of heredity that it is utterly futile to enveigh against, that our whole duty is rather to bend every energy to know what they are and then to find how best to live in conformity with them, that, in a single sentence, there is the possibility ahead of mankind of learning in the next billion years of its existence to live at least a million times more wisely than we now live. This is what Pasteur meant when he said, "What really leads us forward is a few scientific discoveries and their applications." This is what Wells meant when he contrasted the result of the objective method of learning used in the pursuit of science with what he calls "the general thought of other educated sections of the community." The one guesses and acts upon its hunches or its prejudices, the other tries at least to know, and succeeds in knowing part of the time.

We need science too in education, and much more of it than we now have, not primarily to train technicians for the industries which demand them, though that may be important, but, much more, to give everybody a little glimpse of the scientific mode of approach to life's problems, to give everyone some familiarity with at least one field in which the distinction between correct and incorrect is not always blurred and uncertain, to let him see that it is not always true that "one opinion is as good as another," to let everyone understand that up to Galileo's time it was reputable science to talk about gravity and levity, but that

after Galileo's time the use of levity became limited to the ridiculous, that "the town that voted the earth was flat, flat as my hat, flatter than that," had a perfect right to exist before 1400 A.D., but not after that date, that we are learning slowly through the accumulated experience and experimenting of the centuries, especially since 1600 A.D., more about the eternal laws that govern in the world in which we live. And for my own part I do not believe for a moment that these eternal laws are limited to the physical world either. Less than sixty years ago, to take one single illustration, there existed a large political party in the United States called the Greenback Party which jumped at conclusions and which conducted campaigns to induce our government to go over to a fiat money basis. I do not suppose such a party could exist today unless it be in states that passed anti-evolution laws, for there are some laws that have become established, even in the field of finance.

This brings me to a brief discussion of the current opposition to the advance of science, an opposition participated in even by some intelligent people, on the ground that mankind cannot be trusted with too much knowledge, by others on the ground that beauty and art and high emotion are incompatible with science. Now, fear of knowledge is as old as the Garden of Eden and as recent as Dr. Faust, and there is no new answer to be made to it. The old answer is merely to point to what the increase in knowledge has done to the lot of mankind in the past, and I think that answer is sufficient, for it has certainly enfranchised the slave and given every man, even the poorest, such opportunities as not even the prince of old enjoyed. Who would go back to the Stone Age because Stone-age man had no explosives? Of course every new capacity for beauty and joy and for accomplishment brings with it the possibility of misuse and hence a new capacity for sorrow.

But it is our knowledge alone that makes us men instead of lizards, and thank God, we cannot go back whether we would or no. Our supreme, our Godlike task, is to create greater beauty and fuller joy with every increased power rather than to turn our weeping eyes toward the past and fling ourselves madly, unreasoningly athwart the path of progress. Beauty

in the ameba's house disappeared when man cleaned up the miasmic swamp, but it was only because the ameba had not the capacity to adapt itself to modern sanitation.

No, the only real question in a nation like ours is not whether science is good for us materially, intellectually, esthetically, artistically. Of course it is, for science is simply knowledge and all knowledge helps. The only real question is how the forward march of pure science, and of applied science which necessarily follows upon its heels, can best be maintained and stimulated, for, as Pasteur said, "It is this alone that really leads us forward."

The answer to that question will depend upon the nature of one's whole social philosophy. If you think that social progress is best brought about by a paternalistic regime of some kind, by throwing upon a few elected or hereditary officials the whole responsibility for social initiative of all sorts, then you will say, "Let the government do it all; let it establish state universities and state research laboratories and state experimental projects of all kinds as it has done in most countries in Europe, and let the whole responsibility for our scientific progress lie in these institutions. But if you believe with the makers of our nation in the widest possible distribution of social responsibility, in the widespread stimulation of constructive effort, in the nearest possible approach to equality of opportunity, not only for rising to wealth and position, but for sharing in community service, if you believe with President Hoover that government should only step in where private enterprise fails, that it should act only as a stimulant to private initiative and a check to private greed, then the industries in the United States which are themselves the offspring of pure science, will join in a great nation-wide movement to keep alive the spirit of science all over this land of ours through keeping pure science going strong in universities, its logical home, and applied science going strong in the private industrial laboratories where it thrives best. No country ever had such an opportunity as ours, such a widespread stimulation of initiative, such a large number of citizens who had learned to treat financial power as a public trust, such resources to command, such results to anticipate. With our American

ideals American industry cannot fail, I think, to realize this opportunity and to support and keep in the finest possible condition "the hen which lays her golden egg." That, is my conception of the relation of science and industry in the United States.

Chapter XX

THE INFLUENCE OF EDUCATION

John Dewey

PROBABLY man's oldest tradition about himself is that he is different in kind from all other animals, so different that according to the version current in the Christian world he and he alone is made in the divine image. That this tradition is deep-seated and supremely cherished is made evident in the bitter opposition aroused by the theory of his animal descent. This theory is a challenge to belief in his unique status among creatures on earth. The conception was not arbitrary in its origin. There is a mass of facts which taken at their face value support the belief that a great gulf divides man from the animals. He alone is capable of morals, religion and science, invents tools, develops arts, employs language, transmits culture and envelops himself in institutions. His possession of ideals and of the sense of right and wrong, his consciousness of laws, are alone enough to give rise to the notion that his kinship to other animals is at most physical. Realization that these differences are due to the fact that man alone is an educable being in a pre-eminent sense of the word is the most extraordinary and complete proof of the significance of education. Of all the various definitions that can be given of man, that he is the educable being is that which goes deepest.

Man is not only educable but he educates. He has not only potentialities for the extraordinay modifications which seem to put him in a class far above other animals, but he has the constant desire to transmit all accomplished transformations to others. He is a propagandizing (to use the word for once in a good sense) animal as well as a propagating one. His zeal in social and moral reproduction matches that in physical reproduction. The course of culture has been slow and tortuous, exposed to accident and destruction. But it would have been still more so if man had remained merely a being capable of education but without the energetic

tendency to train, instruct and form others of his kind. Nor has the desire and ability been limited to his own kind. The history of civilization would have been very different without the domestication of animals; this domestication marks an extension of training to other species. In the case of his own kind, however, the need to educate is itself biologically imperative. Much has been said by John Fiske and others of the effect of the prolongation of infancy in the human animal in developing care of others and the reflex effect of this necessary care upon the growth of moral sentiments and ideas. But it testifies also to the fact that the young require education by others to an extent not paralleled among other animals.

EDUCATION A BIOLOGICAL NECESSITY

The human being is born feeble, impotent, needy in the extreme. He cannot survive without the attention and nurture of others who are capable and who supply his wants. Food and protection must be extended to him by others; this not a matter of choice but of necessity if he is to live more than a day or two. But the matter does not terminate there. He has to learn to do and fend for himself; he has to pass from the status of dependence to one of independence. And this he can do only as he learns from others. His native tendencies demand manifestation; he has eyes, ears, hands and vocal organs. Even these he has to learn to use. Much of their development is due to an intrinsic maturing of the organism itself. To that extent the young teach themselves. But such organic development does not take them far. Indeed, without direction from others, it leads to arrested development. Fortunately, although also in some respects unfortunately, others, more experienced and more initiated into the acquired habits and resources of a community, have an interest in giving native aptitudes direction. They see to it that natural tendencies are directed toward certain objects and attached to certain ideas and ideals. Interest in this process springs from sources over and above such affection for the young as may be entertained. For since death is as sure as birth, social institutions, beliefs and skills can be perpetuated

only as they are renewed; the customs of a group and civilization must be integrated into the habits of at least enough of the young to ensure their continuing reproduction. Not only does this general force operate, but that of direct utility; indeed, the latter is often more intense. The demand for aid and cooperation in carrying on the occupation of the group, whether tribe or family, is urgent. Children and youth are taught so they may be of assistance; their help is needed in savage tribes, for example, in the hunt and war, in making baskets, utensils, clothing, etc. The immature can be of use only as they learn the skills their elders possess. In multitudes of ways, the affection, the social interest and loyalty and the desire for direct aid interact with the dependence and the native tendencies of children to educate the latter. All the words that express the operation tell the same story, to rear, raise, form, nurture, cultivate.

If, then, one wished to sum up briefly the influence of education one can only say that it is a process of civilizing; of transforming a biological heritage into beliefs, abilities and aspirations consonant with sharing in social life, and this through the medium of what has already been achieved in the group and culture into which the young are born. Or, from the standpoint of mankind instead of that of the individual, the effect of education is to secure the perpetuation of culture in all the various phases in which the anthropologist uses that word, material, intellectual, moral and institutional. It is education that makes the difference between the mere original animal, in which respect the human being is inferior to most other vertebrates, and the human being with whatever of culture and civilization he possesses. If this claim for education is doubted, it is because education is taken too narrowly, being identified with schooling. Of education in the sense of schooling, the statement is of course not true. But the education of the schools represents a specialized mode; education itself is synonymous with all the ways in which native biological tendencies are shaped into formed abilities, attitudes and dispositions.

Before we consider the specialized mode (a consideration that is the main concern of this contribution) it is advisable to mention some questions, more or less controversial, that

grow directly out of the relation of biological and cultural factors. One of them is that of the relation of heredity and environment, or as it better stated since the days of Galton, of nature and nurture.

THE FUNDAMENTALS: NATURE AND NURTURE

It is not necessary, fortunately, to raise the question in its full scope. For in the practice of educative training it is necessary that the two factors should cooperate and not be set over against each other. In other words, they *are* factors, and *the* factors of education. The most ardent devotee of the importance of original nature cannot deny the necessity of the surrounding medium as the means of developing native capacities and giving them direction. The acquisition of language is a striking instance. Without a hereditary or "natural" equipment, an individual cannot learn to speak. But his speech would remain a mere babbling and lisping, mere cries probably not even well articulated and certainly without sense and meaning, except for the nurture given by interaction with other previously educated human beings. When we come to written language and literature, dependence upon nurture by social environment is even more obvious. Although even then native capacities of the hand and brain are involved, education signifies the process of *using* them in certain definite ways, ways that are expressed in nurture.

Thus with respect to education the problem reduces itself to one of greater or less emphasis. Some magnify one factor, some the other. None can deny the necessity of both. As a rule, the particular emphasis given depends upon arbitrary conditions; in part, personal temperament and previous training decide; in part, social creeds. Anyone who has read the literature on the subject is aware, for example, that those who incline to favor political aristocracy emphasize original hereditary differences as the dominant force; those inclined to a democratic faith put more emphasis upon the force of environment and its nurture. Ardent social reformers and revolutionists have often gone to the point of asserting, as did Helvetius, the omnipotence of education when that is taken in its widest sense. Extremists in the other direction hold that as you cannot make a silk purse out

of a sow's ear, so education can never seriously modify and transform original capacities. Their plea is always for recognition of individual differences of native ability and for selection (for anything beyond training for elementary utilities) of those inherently of superior gifts.

The issue thus raised is too complex and controverted to go into here. But it is something to recognize that we must have both factors in some measure. In addition, the testimony of biology to native differences is a valuable contribution to the educative process and is destined to become more so. But most persons who approach the matter from the side of education would utter a warning against too ready identification of native differences of traits with difference of ability. Sympathizing personally with this view, I suggest three considerations in support of it. In the first place, standards or norms of ability are much affected by convention. A strictly intellectual and professional class would take to measure abilities quite different capacities from those which would be taken by not only executive and mechanically minded persons, but also by those of strong esthetic tastes. Every social culture tends to exaggerate the value of certain qualities and minimize that of others. When we take school education into account, even more conventional factors come into play. The abilities that happen to be especially cultivated in the schoolroom are treated as if they were a universal measure. In short, while persons may be, in theory at least, compared with one another with respect to certain traits, determination of how these traits themselves stand with reference to a scale of superiority and inferiority of personality is a radically different matter. The latter involves judgments of values in respect to what sort of a person is to be socially desired and prized. And such judgments are exposed to all kinds of artificial influences.

In the second place, and as the counterpart of the first point, individuals are marked by all kinds of characteristics which do not form a straight one-way series. A person may be highly musical and not highly developed in some other respects; he may have conspicuous philosophical ability and be deficient in practical capacity. Children who

are judged at school to be laggards are found sometimes at home to be more helpful than their brothers and sisters more adept in studies. Are not these traits worthy of recognition in education? In any case, what is wanted as an educational product is, barring very unusual cases, a balanced personality, and balance is as a rule much more a product of nurture than it is of original nature.

Finally, contact and interaction between those more gifted and those less gifted is a normal condition of normal education, for one class as much as for the other. It takes all kinds of people to make the world, and as long as society at large is such an intermixture as it is, it is dangerous not to give all a chance to develop to the limit of their capacities. One can appreciate the force of this point by imagining himself as an adult confined to a circle of other adults all superior, and all selected because of native superiority. Most persons would, I think, dread the thought of such an exclusive companionship. To recognize all kinds of abilities and to give them all opportunity is desirable, but specialization on what is regarded at a particular time as superiority would be likely to develop a set of conceited prigs, who for lack of suitable contacts and knowledge of average human nature would be most unsuited for the task of leadership.

The conclusion at which these remarks are directed is that the greatest knowledge which can be obtained of native tendencies, endowments and shortcomings is of genuine importance to the educator, but it is something to be used within the educational scheme in determining proper methods and materials for each boy and girl, not something which can be employed in a general way to decide the scope and limits of education. The great value of such knowledge is, first, that it shows what education has to build with and upon; the recognition of native endowments is the perception of educative capital. Without knowledge of them education tends to become an external and hit and miss imposition. With such knowledge, the educator, parent or teacher, can cooperate with traits and forces that already exist. Secondly, such knowledge is a precondition of individualization of education; it is a safeguard against mechanical uniformity and regimentation. Thirdly, while original gifts constitute the

initial forces that make education possible, and also, it may be admitted, set a limit to what is possible in individual cases, yet our educational processes are still so defective that every normal individual has more capacities than as yet we know how to discover and develop by adequate educational methods. Moreover since only experimentation can discover just where the limits are located, it is fatal to define limitations rigidly in advance. Too many children have been judged dull and stupid merely because the right methods and materials were not presented and have later been aroused when rightly approached, to enable us safely to act upon the basis of antecedent judgments of inferiority.

INFLUENCE OF BIOLOGY ON EDUCATION

Increased biological knowledge has conferred on education the priceless boon of necessity of knowledge of original capital stock and of individual differences; it has also led to a specific study of definite original tendencies, impulses and "instincts." The significance of instincts for education is still, however, a controverted question. The theory that intelligence may be regarded as an organization of instincts cannot be maintained in the face of facts. The helplessness of human infancy is itself a sign that in human beings the definite organization of instinctive powers in lower animals has broken down, and it must also be recognized that even in them instincts are not as fixed and rigid as they were formerly supposed to be. Biologically, intelligence is conditioned by *failure* of instincts to meet the needs of human life; it represents the method of supplementation of their inadequacy for the work of life. To educate simply or mainly on the basis of original instinctive tendencies means at best and most only to secure specialized practical skills, not a development of intelligence itself. In reality, therefore, the study of instincts is not a study of fixed educational foundations but is a way of making knowledge of individual potentialities more definite and accurate. Instincts do not set the ends of education, but indicate in a more accurate manner materials to be dealt with. The educative problem is what may and should be done with them; what may and should be made out of them; and to find an answer to these ques-

tions we have to go outside of instincts to judgments of their relation to esthetic, cognitive and moral values as ends.

Finally, in this connection, our modern knowledge of biological equipment defines one of the fundamental unsolved problems of education. All our knowledge goes to show that man is not fitted by his biological heritage to live successfully in civilization. The more complex a civilization, the more "artificial," biologically speaking, are the conditions imposed upon its constituent members, and the greater the strain to which they are subjected. Statistics of disease and of nervous and mental disorders reveal their increase under modern conditions of life. It is for this reason that the problem of dealing with the organism so that it may adjust itself to take advantage of the resources of civilization is said to be an unsolved fundamental problem. While there is constantly increased attention paid to the body and its education, it cannot be asserted even by the most optimistic that its results as yet even offset the maladjustments created by our school practices, to say nothing of providing a positive and constructive basis for a general efficient and healthful meeting of the conditions of present civilization.

We now return to a consideration of the relation which the incidental education given to the young in early societies bears to intentional nurture, defining for our purposes "incidental" and "intentional" by the absence or presence of schools.

EDUCATION AND CIVILIZATION

Lack of systematic organization of educative processes was no doubt one cause of the slow progress of early society. As long as the process of transmission by nurture was accidentally carried on, much that was gained was inevitably lost. Yet knowledge of primitive societies discloses that even in them there was a certain amount of deliberate instruction given. There were even solemn ceremonies set apart for induction of the young into the most cherished traditions and rites of their group. The perpetuation of such culture as existed was not left at the mercy of accident. Although there were no schools, education was a conscious function, definitely and religiously taken care of.

The next stage of development appeared when tribal life became complicated because of marked divisions of labor, each demanding some special mode of skill and knowledge. Without going into detail, we may point out that there was a division in two directions. On the one hand, there were the medicine men, later differentiated into physicans and the priesthood, and on the other hand, the secular useful arts. The former possessed the "higher learning;" they were the guardians of the mysteries upon which depended personal health and the well-being and prosperity of the group. All the data show what pains were taken to select the young men who showed special aptitude for these callings, and the careful discipline they underwent. The other phase gradually developed into regular apprenticeship by which skill in making needed tools, utensils, furnishings weapons, etc., was transmitted. Even this brief account would be incomplete, however, if we did not note that the division of labor between men and women brought about a marked differences in the training of boys and girls.

This bare outline is intended merely to indicate how progress in civilization went hand and hand with and depended upon a corresponding advance in educational instrumentalities; because in indicating the background out of which schools finally developed at least among the peoples from whom we derive our own culture, it suggests how recent and new are the agencies we today associate with the word "education." For no estimate of the possible influence of education can be made that does not start from the fact that education as we know it today is an affair of almost the last century. The custom of apprenticeship in the mechanical and utilitarian arts for the mass, the reservation of higher education to the select few, the influence of "the mysteries" upon higher education, the sharp separation of educational aims, methods and subject-matter as between men and women, persisted almost to our own day. The idea of educational agencies and opportunities for everybody, having a common content, and the idea of an educational ladder by which, in theory at least, all could come to share in the higher skills and knowledge is a new thing in human history. Recollection of this fact would quiet some of our impatient

and harsh criticisms of the defects of our educational system. What is much more important, the fact has tremendous implications as to the future influence of education. It justifies hopes which otherwise might seem to be extravagant dreams.

From these considerations there emerges a rough definition of education, but one, it is hoped, adequate for our purpose. Education consists of all the influences which operate during the life of an individual to form and transform his attitudes and dispositions, whether of thought, belief or conduct. This statement, made from the side of the individual, has a counterpart in social and collective terms. So considered, education consists of all the agencies and instrumentalities by which society, through forming the mind and behavior of individuals, transmits its own cultural attainments and prepares the way for its own improvement. As already noted, the educative influences are of two kinds, the relatively informal, and those that operate through schools as a formal medium. Schools have not existed at most more than a few thousand years of the hundred of thousands of human history; while, if we contract the entire span to the measure of a day, public and universal schooling occupies hardly more than a moment of that day. The latter feature is that most characteristic of our time, and to its influence, actual and potential, the discussion will now be directed.

THE EDUCATION OF THE FUTURE

Under the first heading may well be put the increasing importance attached to those distinctive capacities that constitute individuality, the powers and interests that mark off one person from another. As we have already noted, education until comparatively recently was a class education. This fact meant that in practice the kind of education received was decided chiefly by the status in the social and economic scale of the families from which children came. Individuality was submerged in status. It was a virtue for persons to be content with the station in which it had pleased God to place them. Because there was no little opportunity for individuals to put into action the capacities that they possessed, they were

naturally subordinated in education to meet the requirements of the class to which the persons in question belonged. The development of public common schools marked the beginning of a change. The idea of universal education implies that all persons shall have at least the elements of an opportunity to develop whatever potentialities they individually have.

In some European countries, it is true that even with universal schooling there are at least two types of schools, designed from almost the first grade, for members of two different social classes who are thus regarded as predestined to different spheres of life. But in this country because of the conditions under which the country was settled this idea never obtained. There were the same elementary and secondary schools for all. Different types of courses were developed in the high school, but a youth found his place in one or another according to his own abilities and preferences rather than because of any external class standard. Economic status still largely decides how far in the educational scale individuals will proceed. But by the development of municipal colleges, training schools for teachers and especially state universities, an educational ladder was erected; the parts of it were so articulated that it was made easier for individuals of capacity to rise through its entire length. This tendency was reinforced by generous provision of scholarships; in many of our larger cities there are now organizations, some municipal, the greater number private, that make it possible for children of unusual ability, coming from homes that are not well off, to continue in school; these associations select promising children in the elementary schools and take them on into secondary education, when otherwise they would be obliged to go to work. By means of legislation raising the years of necessary school attendance and forbidding child-labor under these years, the ideal of equal educational opportunities for all approaches more nearly a reality. The fruits of this policy are beginning to be seen in the extraordinary fivefold multiplication of the number of pupils in high schools, colleges and professional schools within the last thirty years. It is impossible to judge the extent of release and development of individual abilities that would otherwise be lost to the world, due to this policy.

The point just made refers particularly to the external and administrative side of education and its influence. It is quite true that provision on this side is far from covering the whole ground of the discovery, selection and release of individual capacities. Within the schools, in spite of the opportunity they furnish, it is still possible for lock-step, mass instruction to persist. But there has nevertheless been a constant multiplication both of types of schools and a multiplication of courses, which render possible a closer approximation of education to individual needs and powers. What is more important is the fact that in the more progressive schools, there is much greater attention than there was even a generation ago to individuals as such, even when they are all together in the same school class. A definite effort is made to provide not merely a varied program of studies so that each pupil shall have scope for any special abilities he may possess, but to diversify material and methods even in the same study, so as to supply occasion for individual attack and response. While relatively this tendency is still backward, there is much evidence that its fermentation will gradually leaven the whole lump of mass education. In administration, the former quasi-military regimentation is quite generally giving way to a more liberal policy in such matters as discipline and promotions.

The second point under this heading is closely connected with that just made. In the better schools, personal initiative is prized and encouraged as it never used to be. Of course the main tradition of the school has been that of passivity. Minds were treated as blank pieces of paper on which information was to be stamped. Or they were empty reservoirs into which knowledge was to be poured by means of conduit pipes from text books and the teachers' words. Recitations and examinations were calculated merely to test and record the amount that had been poured in and not leaked out. Or, to vary the metaphor, the mind was like a gramophone plate where memory retained what was impressed, and the recitation and examination periods were times when the plate was set in motion to give out what it had taken in. Not even the most optimistic would hold that this tradition has died out in our schools; its baleful consequences in suppression

of intellectual and moral individuality remain. But it is generally weakening. Educational reformers from an early date have denounced the procedure. While perhaps their influence has not been great, the inherent development of universal education has worked against it. The more pupils there are in schools, the greater the heterogeneity among them, and the greater the difficulty in impressing the same stamp upon them all and in securing a uniform response. The disregard of personal individualized mental activity resulted in creating aversion to study. Mobile, active children rebelled against constant external imposition and mechanical repetition. Actual results were not correspondent with the efforts put forth. The conflict between the active nature of most children and the enforced passivity of study was so unfavorable to genuine learning that the idea arose, and still persists, that the mind is actually averse to learning. Intelligent teachers, perceiving the unsatisfactory result and perhaps themselves bored and nervously strained by the artificial monotony and uniformity sought out almost unconsciously methods that would invoke more active reactions from pupils. The idea of utilizing the interest of pupils in education may be degraded to the level of mere amusement, but in its reality it marks the sound principle of enlisting the *active* cooperation of pupils in what they are doing in school. Under such conditions of personal mental activity, it is found that most children like to go to school and enjoy learning.

As far as elementary schools are concerned the chief stimulus to a more active curriculum undoubtedly proceeded upward from the kindergarten. In higher education, it was promoted by the development of scientific laboratories in which methods of inquiry and discovery took the place of memorizing authoritative statements imposed from without. The method gradually spread to such subjects as literature and history where increasing emphasis was put upon collateral readings and library research. As kindergarten methods worked upwards, university methods worked downwards until they tended to meet. Aside from the general influence of scientific method in furthering a change from passive to active learning, the specific effect of a more

scientific study of psychology should be noted. The older psychology that was in the intellectual air and that was definitely taught in training schools for teachers, was a psychology of the reception of sensations and impressions from without, and of faculties inhering in the mind by which the material thus received was worked over. The entire development of psychology has been to reverse both these conceptions. On the one hand, the motor side of life has been brought to attention and the connection of sensory impressions with active motor adaptations. On the other side the whole hierarchy of ready-made faculties has been relegated to the scientific scrap-basket. With it has gone the vogue of the notion of "formal discipline" which was the theoretical foundation of the old idea of mental training by means of mechanical exercises constantly repeated. If attention and memories were "faculties," it was logical to hold that they would be developed and strengthened by a series of gymnastic exercises. What was attended to or memorized made little difference. If the mind was only kept at it, the inherent faculties of attention and memory would be built up. Moreover as mental faculties, they had an existence and mode of operation quite independent of any bodily activity, which indeed was thought of as hostile to their manifestation. The quieter the child was kept, the more prospect was there that his mental faculties would come into play as he was kept pouring over his text-books. It is hardly too much to say that every teacher in every training school is now taught a radically different psychology. He learns that the young child is primarily a sensory-motor being, and that his intellectual development, corresponding to the function of his cerebral structures, is brought about as coordinations and cross-connections are built up among sensory-motor activities. Psychology has been so revolutionized, in a biological direction, that the significance of the body and of organic activity is coming into its own. For the idea of faculties capable of separate training, obtained by means of set and uniformly repeated exercise, has been substituted the idea of the total engagement and response of the whole being in effective learning. Teachers indeed meet with many obstructions and embarrassments when they try to put their

theoretical psychology into effect in the classroom. But it is a great advance to have destroyed the theory that underlay and justified the old procedures. Gradually there will come about such a transformation of actual schoolroom conditions and equipment as will make it possible to carry the new scientific conceptions into practice. In the best schools, much progress in this direction has already been made.

OBSTACLES TO BE OVERCOME

A difficulty which amounts to an obstruction is the persistence of older scholastic traditions after the actual situation as respects knowledge has radically changed. It was inevitable at a certain time that chief emphasis should be given to the acquisition of the tools of learning. This tradition took possession of elementary schools during their formative period in our own country. For under pioneer conditions mastery of the three R's (reading, 'riting, 'rithmetic) was the key to all educational opportunity. Homes and neighborhoods were scantily supplied with reading material; letter writing was a special event, and so on. Moreover the school and neighborhood provided, in demands made upon the young, full opportunities for immediate contact with raw materials of nature and with such industrial techniques as existed. Now the situation is largely reversed, at least in urban and semi-urban communities which have constantly grown at the expense of rural districts. Yet upon the whole the tradition persists which makes the acquisition of the three R's, together with a somewhat miscellaneous body of information in history and geography and perhaps nature study, the main business of the eight years of the grades, that is, of the entire schooling which the mass of children receives. The case is made worse by the multiplication of bodies of learning. Modern languages now make their claim; to the new development of the physical sciences are added new and important social studies. The result is congestion of the curriculum, and a consequent superficial touching, in the higher elementary grades, the high school especially and even the college, upon a multitude of subjects with mastery of none. There is not even enough of any one of them to leave behind a

taste and thirst which will secure continuing development in some intellectual line after school days are ended.

Ideas formed in the days when it was reasonably possible for a man who had been studiously through the schools to master the sum total of learning too largely control the schools today. Complaints of lack of thoroughness and of intellectual discipline go back to this cause. Nothing which may be of importance at some time in life but finds its way into "courses" and textbooks. Meantime books and printed material have increased enormously, and it is possible for the adult to find information when he needs it with a minimum of trouble. Also opportunities for amusement and for culture have multiplied outside of school. The result is not merely congestion, overstrain and superficiality, but distraction. The burden is increased because well-meaning organizations who have some cause to serve seize upon the schools as the easiest way to reach the public and promote opinion favorable to their causes.

In consequence, the most serious of problems today as far as the course of study is concerned is that of reduction and simplification. Unfortunately attempts made in this direction are often atavistic. What is urged by way of simplification is merely return to some curriculum of the past, simpler in the sense that it consists of a smaller number of studies, but irrelevant to present conditions and conceived still in the encyclopedic spirit as far as it goes. What is actually indicated is surrender of the ideal of "covering the ground," and a substitution for full treatment of all subjects of limited groups of material that are typical, with a view to developing independent method of thought and inquiry on the part of students, instead of the now hopeless task of inculcating a vast mass of information, which in any case is readily accessible in an up-to-date form in books and periodicals when needed. In short, nothing but a revolution in aim would appear to meet the requirements of the situation. Such a revolution would make supreme the development of definite intellectual interests sufficiently varied to protect students from premature one-sidedness and sufficiently powerful to communicate to the minds of learners an impetus to go further. For one of the tragedies of present-day instruction,

even in colleges, is the extent to which subjects studied are dropped about as soon as the courses devoted to them are scholastically terminated. Along with the formation of such active and enduring tastes would go experience to inform students as to proper sources of information and ability to utilize them. As long as the idea of subject-matter for its own sake persists, instead of subject-mastered for the sake of developing inherent intellectual interest and method, no thoroughgoing reformation of instruction seems to be probable.

At present the conservatism of schools contrasts strangely with the readiness to scrap old machinery in industry, old beliefs in science, and old practices in the professions, when new conditions render better ones available. It cannot be truly stated that schools have not made an effort to re-adapt themselves to new social conditions. For the converse is true. But the adaptation has been made largely by procedures that defeat the purpose. For it has been attempted mainly by *addition*, with the result already mentioned. What is needed is a change of attitude and aim that takes advantage of the non-scholastic resources that have developed, and that recognizes that method which enables the mind to deal with problems as they manifest themselves is now more important in life than accumulation and cold storage of subject-matter. It would be absurd of course to suppose that method can be acquired except in actual dealing with subject-matter. But if the thought and energy that now go into a vain effort to record subject-matter and keep up with its growth were spent in selecting limited fields that are typical of present methods of intellectual inquiry and mastery the outcome would be very different. As long as the issue is regarded as lying almost exclusively between the limited and thorough curriculum of the past in classics and mathematics and spreading over the whole content of present-day knowledge and interest, the present situation of confusion will continue.

The large degree of failure to obtain, by our present system, fundamental intellectual achievement is seen in two marked traits of the popular mind: undue deference to any one who obtains popular prestige as an "authority" in any field, and an accompanying credulity of mind that undis-

criminatingly accepts for a time anything offered, only to turn soon to some newer topic. For the older tradition of universal scholarship has affected even the teaching of science, short of the small number who become capable of independent specialization. The essentials of scientific method, of a certain way of looking at things and seeking and weighing evidence, in short the development of judgment, are swamped in the acquisition of information, all the items of which stand on the same level and are equally subject to belief or unbelief. The mind is left more ready to seek for signs and wonders, and more ready to grasp at and swallow whatever is presented in print. The mere mass of what is offered daily, monthly and yearly, overpowers independent judgment and creates a state of intellectual impotence; the mind is oppressed rather then enlightened. Perhaps the most encouraging signs of improvement are now found in various branches of professional education. These have to deal with the problem presented by the enormous growth material in both bulk and complexity, and are correspondingly forced by the necessities of the situation to simplify, and to simplify not by arbitrary limitation to traditional portions of the field, but by emphasis upon subject-matter that is strategic in developing command of method.

There are many who are pessimistic regarding the ability of intelligence to take any considerable part in social direction. After a period in which psychology was conceived almost exclusively in intellectualistic terms, a marked reaction has set in. This is due in part to the influence of biology on psychology. For the former has revealed the large rôle of non-rational factors in the human make-up. Instinct, impulse, emotion, desire, habit occupy the position once held by intellect. Anthropological knowledge has disclosed the rôle of non-rational factors in the whole course of human life on earth. Study of mental disorders, great and small, has shown the extent to which what presents itself as reason is in fact an *ex post facto* rationalization dictated by desire and having only the semblance, the form, of rationality without its substance. This reaction has occurred during a period in which the need of direction by informed intelligence of social affairs has enormously increased. It is only

necessary to point to the rise of democracy that has brought the masses into possession of political power; the disturbance of old habits and institutions produced by new technological developments in industry and commerce; the elimination of distance and the barriers that formely kept peoples apart which has produced an intermingling and contact of peoples and races not prepared to understand one another, and so on. The effect has been both an immense expansion of educational facilities, and, as greater responsibilities were thrown upon the schools, a growing scepticism regarding what it is possible for education to accomplish.

In this connection the remarks made earlier about the newness of universal education find their pertinency. We are at only the beginning, not the maturity, much less the climax, of the experiment of affecting social life and giving it guidance through intentional education. And, as been summarily indicated, the experiment is still in large measure affected by customs and traditions that hang over from an earlier period. In consequence the problem of educational reconstruction by which these hang-overs will be eliminated and materials and methods introduced which will develop the type of mind and character adapted to contemporary movements is far more than a scholastic problem. It is the fundamental problem of society itself.

It is no part of this chapter to try to tell in detail the nature of the reconstruction that is demanded. Three conditions of its achievement may, however, be properly indicated. The new knowledge of psychology indicates the need of much more attention to emotional factors than they have received. Upon the whole, education has so far been concerned with forming practical skills and giving information, with incidental training of intellectual habits. The emotional factors that determine the set and channels of operation of practical abilities and of knowledge have been largely neglected. Such questions as more and better esthetic education, instruction in sexual matters, the place of religion, the formation of minds emancipated from racial and international prejudice, moral teaching that is vital and not merely formal, all find their proper place in this connection.

Secondly, the basic rôle of financial considerations in every serious attempt at successful execution of the great experiments must be recognized. All competent observers have testified that, aside from sheer inertia, the chief obstacle in the way of introducing into the school methods and materials that are known to be desirable is the matter of financial support. Instruction through the medium of books, reinforced by blackboards and a few maps, is the cheapest possible system. Introduction of shops, laboratories, etc., doubles the expense. And this is not the end. In order that they may be utilized successfully, the numbers in classes must be reduced. This fact requires more and better trained teachers. In order to attract and hold the type of person as teacher who can initiate and direct genuinely educative methods, pecuniary reward and compensation by way of social recognition and prestige must be increased; and meeting the second condition depends largely upon fulfilling the first. In spite of the great growth of public expenditures for schools (it is estimated that the annual cost of schools in the United States is now two billion dollars), much remains to be done to awaken the attention of the public to the necessity of greatly increased financial support.

The third condition is closely allied. What is called "academic freedom" is much more than academic matter. In fact, it is in the higher institutions about which the question is usually raised that there exists at present the most freedom of thought and discussion. Influences which tend to suppression, are most powerful in lower schools where the larger number receive their training. Objective discussions of social conditions, especially in their economic implications, is rare and difficult. The result of this virtual tabu on free and independent thinking on the part of both teacher and student is twofold. On one hand, an added premium is put on the formal and mechanical elements in training. Drill, practice to achieve skills, and inculcation and absorption of information, are what remain when inquiry and reflection are excluded. Or, if there is thinking it is confined to specialized technical fields. On the other hand, students are sent out into life without that kind of intelligent understanding of needs,

conditions and possibilities that is indispensable to social direction; confusion automatically piles up.

The foregoing bare outline emphasizes the point originally made. The standing problem of education is interaction of biological native factors with the factors that constitute culture in its broad sense: that is, the achievements and aspirations that actually obtain in the society within and for which individuals are educated. The essential point is that instead of conceiving nature and nurture as competitive rivals, we should treat nurture as the means by which nature and culture are brought into the fullest harmonious relationship with each other. This problem, which is the problem of securing the free satisfaction of individuals together with social order and progress, is equally that of both social life and education.

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PART V. THE FUTURE

Chapter XXI

THE INHERITANCE OF DISEASE

Paul A. Lewis*

CONSIDERED in a broad and untechnical sense, an individual's inheritance means all those attributes both actual and potential received at or before birth from the parents. This usage has of late years been given up by scientific men in favor of a more circumscribed one, namely, that the inheritance consists of those attributes actual and potential acquired at the moment of conception due to the intrinsic properties of the germ cells.

This distinction is of real importance to a clear understanding of the relations between inheritance and disease. The biblical dictum that the sins of the fathers are visited on their offspring for generations has been considered in recent times to be particularly applicable to one contagious disease, syphilis. Children suffering severely from this disease are frequently brought into the world at or before the normal birth period. It is now considered a certainty that in these cases the child is infected at some point in its fetal life definitely subsequent to its conception. In any event, it is infected with an extraneous microorganism carried by one or both parents. Many other similar and less obnoxious instances of "intra-uterine infection" might be cited from our knowledge of human and animal diseases. On the other hand, it is known, by animal experiment at least, that the offspring of an immune mother are apt to show more than the usual resistance to certain diseases for some time after birth. This, it is recognized, is due to the transfer of protective substances in a passive way from the mother either through the membranes separating the fetal from the maternal circulation *in utero* or in the milk during the first days of life. Under the older definition, these instances would be considered to be cases of inherited disease or inherited immunity

* Died of yellow fever at Bahia, Brazil, on June 30, 1929, while investigating the cause of the disease.

respectively, but are not so regarded under the more rigid definition of inheritance.

Even the circumscribed definition of inheritance as here given may not be wholly accurate. There is much reason to believe that injury to the parents by long-continued exposure to certain poisons such as alcohol or lead may affect the offspring unfavorably and it is also probable on the basis of animal experiments that exposure of the parents to roentgen rays may, under certain conditions, result in altered if not abnormal descendants. In so far as these influences may be manifest through action on the male parent it can only be by some affection of the germ cell itself and it would probably be impossible to frame an entirely adequate definition of inheritance in which these preconceptual influences are justly accounted for. These may for purposes of definition be recognized and passed over.

The outstanding achievement of genetic study has been to show that as a broad biological principal the most diverse general characters can be analyzed into an infinity, almost, of combinations of less inclusive specific unit characters which are inherited independently in principal. Actually they are inherited either separately or in small and apparently "chance constituted" linkage groups. There is every reason to suppose that the mechanism of human inheritance completely conforms to this "Mendelian" scheme. That it does so has been demonstrated for a considerable number of characteristics.

"Disease" is a general concept sufficiently defined for many purposes as any condition of body or mind which departs from "perfect health." A precise definition which shall be more critical than this and cover all the manifestations of morbid processes is extremely difficult to formulate. It would greatly simplify this, and many other discussions of a similar nature, if an all-inclusive definition could be framed, but the attempt would be hopeless and misleading in the nature of the facts. It is well to recognize this clearly at this point because there is a very general assumption or belief that people are quite definitely divided into two classes, those who are born healthy and of sound constitution, and those who come into the world otherwise. All

such conceptions, it should be clearly seen, are in fact untrue. A healthy person is one who has no gross anatomical or physiological defects and enough normal general health to get on with. Any refinements of definition must be entirely with reference to some ideal standard which will doubtless change with time and future evolution or achievements.

In fact the great progress made by medicine as an art and a science from the dawn of civilization down to today is based on the steadily developed recognition of the infinite complexity and relative nature of the phenomena included in the general term "disease." And especially the remarkable progress of the last two centuries is due to the extension of this general principle into the study of particular diseases. Even the most simple (apparently) of abnormal conditions is found on closer scrutiny to be of the utmost complexity. A common boil is spoken of in scientific terms as a simple inflammation and even moderately informed lay people know it as the result of some "germ" getting into an insignificant scratch. In reality the processes are complex far beyond our present understanding. Essentially the same process in the lungs gives rise to the acute and often fatal disease, pneumonia. But when pneumonia is examined, even in the light of our present imperfect knowledge, attention being paid to the particular germ giving rise to the infection, and the qualities and distribution of the reaction material in the lungs, it is easy to discriminate more than ten essentially independent kinds of extensive and severe inflammations of the lungs, which would be properly designated by the practicing physician as pneumonia.

It will readily be understood, therefore, that when as in this chapter an attempt is made to deal with the points of contact and mutual influence of two such all-inclusive and infinitely complex assemblies of phenomena as those of inheritance and of disease, it cannot profitably be done solely with reference to general principles. Nor would it be useful in this place to attempt a very detailed account of what is known. The plan adopted is to try to give an outline of principles where these are discernible and to illustrate them with such concrete examples as may be most informing to the general reader.

INFECTIOUS DISEASES

As previously pointed out there is in the rigid sense no such thing as the positive inheritance of an infectious disease. This lies in the nature of the case since the impelling incident in such a disease is the entry of an agency: germ, bacterium or protozoan, from the environment. None the less, the inheritance is of very vital significance and within certain limits absolutely controls the prevalence of these diseases. This is true when we approach the question from a wide biological viewpoint, regarding species lines. It then becomes in truth a matter of common knowledge. It is probably quite correct to state that each distinct species of animal or plant has certain diseases which are peculiar to it, and neither naturally nor artificially transmissible to any other species. Influenza and malaria are fair examples of such diseases of human beings. Asiatic cholera is another. Many cases may be cited in which species lines are not rigidly respected and are yet very influential. Smallpox is such a human disease. It may spread to milch cattle under suitable conditions, but in them produces a modified type of disease similar to the naturally occurring cowpox. Rabies is widely disseminated among the domestic animals, is very frequently transmitted to man but is not known as a disease of birds.

The questions at issue really become debatable when we consider the relation of the racial, familial or individual inheritances within the species. It is now clear that here the lines are much less rigid. There are very certain instances, particularly among plants, where families or strains within the race are quite immune to a particular disease from which the race as a whole suffers most severely. The rust-resistant varieties of wheat and asparagus are familiar cases. Similar cases can be made out among animals. There is no certain instance of an infectious disease affecting one or more races of the human species and leaving another untouched. There are a number of instances when it seems that certain races are less susceptible than others to particular diseases but even here it is impossible in the present state of knowledge to be sure of the significance of the cases. Racial habits as to diet, for example, and the continued state of contact

with the disease are apparently influential factors about which there is as yet insufficient information.

When we turn from the race to the individual, vision apparently becomes clearer, for there can be no doubt that with reference to most infectious diseases there are wide individual variations in resistance. These are made manifest in several ways. Most certainly perhaps in the varying severity of the effects of an established infection, but also in all reasonable probability in the "take or no take" as a result of approximately equal grades of exposure. It is again remarked that the matter is *apparently* clearer when the individual is considered. It is meant that the differences in resistance are more definitely discernible, they are in fact unmistakable. But in the individual case it is always open to question whether the exposure has in fact been equal; whether more or less immunity has been acquired from the mother, or actively accumulated through a succession of abortive exposures; or whether a previous mild attack of the disease may not have passed unnoticed and given an effective vaccinal protection. The great advance in medical science in the past fifty years consists in considerable part in the acquisition of the understanding of these fundamental features of the body's reaction to infections. It has seemed to many, perhaps to most, thoughtful physicians. in recent years that these near at hand factors were sufficient to account for all the differences in individual resistance.

But if we go back for a moment to an earlier period we find a fixed and universal opinion that certain infectious diseases follow family lines to a considerable extent. This is not true of measles or smallpox. It seems conspicuously true of tuberculosis. Most of us can doubtless call to mind families in which severe illnesses and deaths from tuberculosis have been common, and other families in which they have been rare. Large groups of family histories have been collected and submitted to the best available mathematical analysis and these have also given evidence of some difference in the inheritance. But it is also known that under conditions of universal exposure as in crowded cities, practically all individuals have some tuberculosis at some time or other. The disease is one which often lasts in individual cases for

years or even through a long lifetime. There is obviously unusual opportunity for infection to follow a family in which it is established. In the face of such considerations on the contrary side, it cannot be maintained that such studies of human family histories as have been made absolutely decide the matter. They do give evidence, however, that familial differences in resistance exist.

Some light has been thrown on this case by animal experimentation. Guinea pigs are very susceptible to inoculation tuberculosis. These animals have also been favored as subjects for genetic experiments. There exist a few families of the species which have been propagated for years by the closest possible inbreeding. With regard to certain characters, color, growth rates, fertility, etc., the family characters are distinctive beyond question. It has also been possible to show that the families differ in their susceptibility to inoculation tuberculosis. The differences are of degree only. That is, all are susceptible, but the disease advances much more rapidly in some families than in others. Animal experiments cannot in general be transferred to the interpretation of human phenomena without scrupulous consideration. But the laws of inheritance have been proved in other cases to be among the most fundamental of biological phenomena. Wherever there is sexual reproduction the laws of Mendel have been found to govern the inheritance. And wherever a certain quality has been found to be definitely inherited in any species it is found to be inherited in other species possessing the quality. The details governing the inheritance of the quality may differ from species to species, but this only means that the relative importance of certain qualities may be found to vary in relation to other qualities which may or may not be definitely heritable. The quality, to repeat, if subject to inheritance in one species will be similarly controlled in any other in which it may occur, although it may be a much more important and significant quality, in the one species than in the other. Also it may be considered certain, that, in its fundamentals, inoculation tuberculosis in the guinea pig reproduces the condition of spontaneous tuberculosis in man. There are doubtless important departures in the intimate nature of the disease

in the various species but these, however significant, must still be regarded as differences in detail. It would seem proper to consider therefore that the results of the animal experiments may safely be applied to the interpretation of what has been observed of the inheritance of the human disease to the extent, at least, that we should for the future be ready to accept the statistics and familial observations at the significance thay carry on their face, rather than straining all points of possible criticism and reservation. In other words, it seems established in all reasonable probability that important factors influencing the incidence of tuberculosis and the development of the disease in the individual are inherited.

The studies of human material from the pathological standpoint show, as has been said, that most individuals become infected with tuberculosis at one time or another and it may therefore be concluded that neither in kind nor degree are the inherited factors capable of preventing infection. They must, therefore, be exerted on the progress of the disease after the body is invaded by *Bacillus tuberculosis*. The direct evidence at present available from human sources does not carry us beyond this point.

What we know of the pathology of human tuberculosis, experience derived from animal experimentation with this disease, and consideration of our knowledge of other infectious diseases enables us to set up a series of surmises or hypotheses with regard to the possible nature of the inheritable factors involved but it would be difficult if not impossible to check these effectively by direct studies of the human disease. It has been possible to make a beginning in this direction on the basis of the guinea-pig experiments just mentioned.

It is found in the first place that there are a number of inherited factors involved. At least three and possibly four separately inherited factors or factor groups are indicated by the results with the available guinea-pig families. It cannot be assumed that these families assembled by chance for other purposes present all the possible variants. Nor can it be assumed that the most complete collection of guinea-pig material would accurately portray and relatively evaluate the human factors. What is presented is a minimum

statement of the number of factors involved and an indication of the way they may exert their effects.

In the guinea pig it is found that there are inherited factors which influence the quantity of antibodies (antitoxic substances) which are produced in response to a given stimulus. There are other inherited factors which influence the severity and precise quality of the ulceration which the tubercle bacillus and some other irritating agents produce in the skin, and in the character of the tuberculous inflammation in the lymphatic vessels and glands. There is also an indication of another group of separately inherited factors affecting the nature of the reaction to dietary deficiencies.

Granted that there are inheritable factors influencing the character of tuberculosis in the individual, any clue as to their dominant or recessive quality is a matter of great interest. Unfortunately the human material lacks the precision of detail necessary for an answer to such a question. The guinea-pig material suggests that where all of the characters favorable to resistance are combined in a family it presents a dominant combination. The first generation crossbreds are as resistant as the most resistant family. In the actual observations they somewhat surpass this mark, indicating the operation of those forces which make for heterosis or hybrid vigor. Where crosses are made between families of less than the maximum resistance the result varies. Some crosses produce offspring as resistant as the better family, another produces an intermediate resistance. In general, dominance of resistance prevails but it is imperfect.

The available information from all sources with respect to the inheritance of a variable degree of resistance to tuberculosis suggests some further comment in relation alike to its medical aspects and to the genetic point of view.

Belonging essentially to the prebacteriological era of pathology is the conception that susceptibility to infectious disease is more or less definitely related to fundamental inheritable qualities which find expression in physical conformation, that is, "physical type," and in peculiarities of function, that is "constitution." The terminology was on the whole very loose and interchangeably employed. Con-

stitution also was often thought to be expressed in physical characteristics. When functional characteristics were thought of as directly related to disease the term "diathesis" was frequently used. Thus people of a certain inherited "constitution" were regarded as especially liable to tuberculosis, particularly to that of the lymphatic glands on the basis of a "scrofulous diathesis."

When ideas were crystallized during and after the classical bacteriological studies of the latter quarter of the last century the conception of the scrofulous diathesis was first amplified in an attempt to harmonize it with new observations, and then almost, if not quite discarded, as being at best inadequately grounded. The considerations advanced in amplification of the conception are of considerable interest in the present connection.

It was first shown that the lymphatic lesions characteristically associated with the diathesis were tuberculous and that they had in general the same etiology as pulmonary tuberculosis. It was soon very evident that it was difficult, if not impossible, to discriminate between those physical characteristics that might be preexistent and possibly reflect predisposing causes, and those that were the consequences of long-continued chronic disease transmitted by contact infection from generation to generation and often persisting in the individual from earliest childhood to old age. It also appeared that the other lesions, particularly those of the skin, that had frequently been regarded as evidences of a scrofulous diathesis were not tuberculous but were due to casual infection with staphylococci, streptococci and probably other microorganisms.

This recognition of many of the appearances as "consequences" greatly weakened the whole conception. The further evidence that if there was a constitutional predisposition it was not strictly specific for tuberculosis but involved other inflammatory processes as well, put the question out of touch with the progressive thought of the time, which was primarily engaged in establishing specific relationships, either of etiology or immunity.

With the coincident and tremendous improvement in hygienic conditions and nutritional well-being in Europe

and especially in America, tuberculosis and the minor infections referred to have a greatly diminished prevalence. It is now to be accepted that practically all of the aforetime ability to segregate a type of people having the scrofulous diathesis (if such there are) was dependent on the continued manifestation of the infections to which they are susceptible.

It is of interest and significance that an experimental approach to the question with suitable material develops a picture which fits so well with the conception of a scrofulous diathesis as it stood at about the beginning of the present century. There is observed in the guinea-pig experiments already outlined an inherited group of reactive qualities that are related to susceptibility to tuberculosis, and also find expression in the character of the tissue changes in tuberculosis and in some simple inflammatory reactions. Respecting the limitations imposed by species differences this would seem to be as close as it could be hoped to come to an experimental definition of the scrofulous diathesis.

A generation ago the general conception of the fundamental nature of inheritance was that it was a blending or fusing of the parental characteristics, stronger characters being diluted by weaker. The cases which such a blend did not explain were regarded as unaccountable exceptions. Then the work of Mendel was revived and it was seen that when inherited qualities were sufficiently analyzed into their component parts the blended was rather the exceptional occurrence. But instances of blending inheritance could not be gotten over or disregarded and it seemed to some students that there must be two principal forms of inheritance. These views have been quite completely harmonized by further study. In the obvious Mendelian case a particular character, which to familiar scrutiny is simple and definite, is controlled by the presence or absence of a single inheritable unit known as the gene. Color in animals, eye color in man, tallness or dwarfness in the garden pea are such characters and their study clearly defined the Mendelian principle in inheritance. Skin color in man if albinism is contrasted with the presence of any pigment is similarly controlled.

But skin color among the pigmented of the human species, tallness or shortness in the human race (excepting particular types of dwarfism), the weight or ear length in rabbits and innumerable other conditions are at first sight not so controlled. The result of a cross between individuals of widely different character is usually a "blended" or intermediate state in the offspring. While it was difficult at first, as has been said, to fit these cases to the Mendelian hypothesis it is now apparent that blended inheritance means that the character as expressed in the individual is the resultant of the combined and overlapping functional expression of the action of two or more genes. It now is the consensus of opinion among students of heredity that this is the true significance of blended inheritance. Mendelian principles are as strictly applicable as in the more obvious instances but more than one, often many, unit characters are involved in the make-up of the observable quality. This is evidently the condition underlying the inherited factors in resistance to tuberculosis.

The guinea-pig material submitted to analysis with this principle in mind gives the following provisional result: For each of the five families there is a characteristic grade of resistance. This could be accounted for by the action of two separately inherited unit characters but not by one. The study of the crosses between the families indicates that there are operative not less than three and possibly four unit characters. The study of the physiological reactions shows suggestive relations in such widely separated functional activities as the immunological reactions, the tissue reactions, and responses to dietary changes, with an observable independence between them. This would also justify the assumption of at least three characters. The tissue reactions when further analyzed are found to be complex, involving at the least two characters. The other types of reaction are obviously blended and must involve at least two characters. The results at hand then must be assumed to involve at least six and possibly eight separately inherited unit characters. Probably the matter is much more complicated than this in the guinea pig, and even more so in the human.

Now for the color inheritance in these same families of guinea pig, Wright has made out the operation of at least seven separate characters and he calculates that the possible recombinations of these would lead in this stock alone to no less than 25,000 color varieties of guinea pig. There is, as suggested previously, no apparent reason for assuming that tuberculosis resistance is determined (in so far as it is dependent on inheritance) in any other or more simple way than this in either guinea pigs or humans, and we are led to believe that the possible varieties of humans from the point of view of their behavior with respect to tuberculosis must actually number in the thousands. In fact it appears rather remarkable on this basis that familial characters are ever recognizable even though the assumption of an inheritable influence were uncontested. One is inclined to think that there must be favored associations of characters which divert the results into fairly well-defined main channels in many cases. However this may be, and allowing all possible latitude for familial association of inheritable qualities, it is plain that under the systematic outcrossing which is the rule in human matings, the observed fact that, taken by and large, the individual variations in resistance to tuberculosis are more in evidence than the family likenesses is what one would expect.

In no other infectious disease of man has it been made so evident that inherited qualities are influential in either the prevalence or character of the disease in the individual. Instances are reported among animals, both in reference to spontaneous epidemics and inoculation diseases where the result is as definite or more so, and where the inheritance of the controlling factors is less complicated. The nature of these factors is undetermined in these cases and their consideration therefore would not at this time throw additional light on human problems.

It should of course be held constantly in mind that inheritance can be but one of the important influences determining the incidence of any infectious disease. In the case of tuberculosis as already outlined the factors we are dealing with do not determine the absolute level of the racial resistance. Such are at present intangible. What is determined is the degree and kind of individual variation

in the resistance. Calculation of the results with the guinea pigs has shown that such factors as age, ability to gain weight on a mixed diet, absolute weight, etc., factors in part determined by the inheritance and in part by environmental conditions, can account for something less than 10 per cent of the observed variation. Factors of direct influences and directly dependent on the inheritance account for somewhat over 30 per cent of the variation. There remain 50 or 60 per cent of the observed differences between individuals at present not accounted for. Such factors as differences in kind and amount of food consumed, "accidents" incident to the spread of the disease within the animal (implantation in particular organs, etc.) are doubtless to be included in this category. Essentially it is to be counted as an accomplishment that we may at present be quite certain that inheritance does play a recognizable part in the prevalence of an infectious disease.

CANCER AND OTHER MALIGNANT TUMORS

In general the state of our knowledge of the factors underlying the occurrence of malignant tumors is not dissimilar to that with regard to tuberculosis. The evidence from human sources is of about the same order but less significant on the whole. Tumors have been alleged to frequent occasionally certain families while others remain quite untouched. In the mass there is the sporadic, occasional appearance of a tumor case in most family histories. Cancer is not believed by most authorities to be an infectious disease although the fact that it can apparently be initiated in man and animals by chronic irritation with various substances, even by various parasites, creates many resemblances between tumors and infections. If the tumors classified as sarcomata are included there are cases in which the utmost consideration of detail fails to reveal any precise reason why they should not be accepted as infections; and yet because of that fact that these appearances suggesting infection are the exception rather than the rule, most scientists hold in reserve the thought that even in these cases it is more than possible that some other explanation will

be found, that eventually it will appear that all the true malignant tumors (including most forms now classed as such) will be found to originate in causes resident within the body.

Tumors bear a certain resemblance to infection in that those which originate in animals are often transferable to other animals of the same species by a succession of transplantations of the tumor tissue, or in some instances by extracts of this tissue containing no intact body cells. The conditions governing the transplantation are such as to make the influence of inheritance very apparent. These tumors are never transferable outside the species of animal in which they originate. For instance, mouse tumors can only be propagated in mice. Within the species they are transferable with great difficulty when at all, from one race to another. It is quite likely that this line is as rigid as the species line, but it is impossible to be sure because in the domesticated mice, rats, and fowls which are available for experimentation, racial lines have been hopelessly confused by repeated intercrossings. However this may be, it has been the common experience that when transplants of a spontaneous tumor are attempted they succeed in but a small percentage of the subjects unless by chance the subjects are the immediate relatives of the animal bearing the original tumor, when the percentage of success may be, and often is, greater. It is evident that a racial and familial variation in the *susceptibility-resistance* ratio is operative in the tumor transplantation experiments.

This variation in resistance has been the subject of thorough genetic experimentation and analysis in certain instances. When the Japanese waltzing mouse and the common tame mouse were compared it was found that their differences with respect to tumor transplantability across the race line must be under the influence of at least twelve separately inherited unit characters. The reasoning applied to the case of tuberculosis in the preceding paragraphs holds here. We should expect the familial evidence for inheritability in the human race to appear only very occasionally. Even less is known about the fundamental nature of the inherited characters in tumors than in tuberculosis.

There is also a great deal of evidence that the incidence of spontaneous malignant tumors in animals is quite dependent on the inheritance.

DISEASES BASED ON ABNORMAL SENSITIZATION

A number of disease conditions, all troublesome and some very serious, asthma, hay fever, and various "idiosyncrasies" against particular articles of food or particular drugs have been found to have certain features in common. They are alike in that they are all unusual reactions to particular substances found in the environment which do not affect most people in any harmful way. Of those suffering from the condition some react only to a single substance, others are affected by many substances. The diseases are so common as to be familiar to most people and place need not be given here to any detailed description of them. The simplest, and in many ways most characteristic, is uticaria, or hives. Most people suffer at one time or another from this trouble. Some people always have it as a consequence of eating a particular food, e.g. strawberries, eggs. The skin becomes blotched and irregular wheals are raised above the general level of the skin surface by reason of the fact that the skin in these areas is swollen. The swelling is due to fluid in these areas having left the blood vessels and stagnated in the tissue spaces. In asthma the same general process occurs but the area affected by the swelling is the smaller air tubes in the lungs and these are partly closed, making breathing difficult. In hay fever it is the mucous membranes of the eyes and nose which are affected.

Inquiry has disclosed a well-marked familial influence in these conditions. They are in some measure inherited. The inheritance seems to be based on recessive characters in the Mendelian sense. There is a certain difficulty in this interpretation, however, in that not all the offspring of matings with both parents diseased are afflicted. This is susceptible of alternative explanations. It may be that the inheritance is dependent on multiple factors in which case the line between dominant and recessive is not necessarily clean cut. Some characters may be dominant, others recessive and the actual behavior of the individual is the result of a kind of balance.

Another possible explanation is that the disease itself is not inherited but only the liability to contract it. That is to say, an individual potentially sensitive by reason of inheritance may escape the influence of the environmental factor and never reveal his latent tendencies.

It may well be remarked that in spite of a very great deal of experimental work many of the factors in the state of hypersensitiveness are not yet understood. For example, some of the most striking and disastrous instances are those of people sensitive to horse serum as determined by their reactions to the injection of diphtheria antitoxin. Those in whom the sensitiveness is most acute have usually also been subject to attacks of asthma when the dust from horses has been inhaled. But many people injected with antitoxin become very sensitive to further injections of horse serum without showing any tendency, so far recognized, to develop asthma on contact with horses. It is apparent that the inheritance is but one of the factors, even though an important one, which must be considered when we try to understand disease conditions.

DISORDERS AND DEFECTS OF THE CENTRAL NERVOUS SYSTEM

Popular interest in inheritance, alike of normal and abnormal qualities, naturally reaches its highest when the nervous system is considered. From the medical point of view we are here dealing with the diseases referable to a single organ. Gross defects of development occur and are likely to be lethal before their general effects on function can become manifest. Finer defects in structure may well be common but may escape recognition. The brain and spinal cord are affected in the course of infectious diseases which are to be considered as general infections, and also are the seat of infections primary in or affecting, chiefly themselves, e.g. poliomyelitis, encephalitis lethargica, and cerebrospinal meningitis. With reference to these what has been said with regard to the inheritance of immunity or susceptibility to infectious disease generally doubtless has some application in principle but we have no specific knowledge of inherited influences in the particular cases. The functional disorders of the nervous system are manifest in

almost infinite variety and the study of them has gradually become a very intricate specialty. From our present point of view only certain outstanding selections can be considered for purposes of illustration.

Feeblemindedness has a peculiar interest. The condition (one, it may be supposed, of limited development) rests in some instances on an inherited basis as made evident by careful and competent scientific investigation. Is feeblemindedness a disease? Obviously it may be so regarded in the social sense, since on a purely practical basis a highly developed society is forced to maintain large institutions for the care of such of its offspring as are unable to maintain the pace. From the pathological standpoint it is hardly to be looked upon as a disease except in the most extreme or particular instances. But when one begins to discriminate on a quantitative basis all the standards must be arbitrarily chosen. The question clearly becomes an academic one when purely practical standards are disregarded. The same may be said of many types of insanity. The discrimination between sane and insane in general is possible on a legalistic and practical basis, however difficult decision in particular cases may be. A perfectly sharp borderline in the scientific sense can hardly be drawn.

But insanity presents another aspect, in that there are certain disorders of the nervous system characterized by definite symptomatic behavior which clearly define them without reference to their severity or, in other words, whether the sufferer is incapacitated or not. The most widely illustrative perhaps is the disease known as essential epilepsy. Those most slightly affected may not only be not incapacitated but may be mentally quite normal or unusually brilliant people. Those most severely affected are or frequently become unquestionably insane. In its mildest forms or in its most severe, the symtomatology is characteristic. The difficulties of recognition in the mild cases are due to the fact that the slight symptoms long pass unnoticed. This disease is inherited in many cases, and apparently usually as a Mendelian recessive. There are indications of sex linkage in some instances and it sometimes appears as a dominant. Multiple factors are probably involved. Other

forms of insanity equally well characterized are recognized and some are probably inheritable.

A great mass of suspected and uncertain material is presented for consideration in this field which has usually, and doubtless some times properly, been explained by assuming that what is inherited is not any specific disease but a general instability of the nervous system on the basis of which variously classifiable disorders and diseases are developed. This is the kind of assumption which has in the past frequently been made for other conditions and has as often been replaced with advancing knowledge.

LONGEVITY

It has been increasingly recognized of late that the length of life of the individual is a measurable biological phenomenon, the analysis of which might uncover very interesting facts. It is, of course, a common impression that length of life is determined in considerable measure by inheritance. Some families are thought to be notably long lived. That the condition is counter-balanced by equally well-marked short lived families is possible but this is in the nature of the case less easy to be sure about. When an individual lives a long time we think naturally of his constitution as a responsible factor and when his ancestry and immediate relatives also survive, the constitutional factor becomes more and more apparent. But when an individual dies young, the disease of which he died or the accident of fate which carried him off is the impressive feature. Suffice to say that observations on selected families of animals, fruit flies and guinea pigs particularly, have shown that length of life whether short or long is a definite family characteristic and have given us some clues regarding its hereditary transmission.

It has not been sufficiently recognized that this matter is definitely related to the broad question of the inheritance of disease. To make it plain that there must be such an intimate relationship it is only necessary to point out that when the individual dies it is most usually from some definite and immediate disease. There are, it is true, some instances, and these in the long lived exclusively, where death comes in such a way that the rational description of it is comprised in

the statement that the bodily machine was worn out, that there was a general functional disintegration. Even here complete knowledge would be likely to show that some particular functional failure was really responsible, for the evidence from tissue culture work is to the effect that given a suitable environment, muscle cells, cartilage, aud many other tissue cells are capable of indefinitely reproducing themselves and presumably of thus perpetuating their proper function in a way indicative of potential immortality.

But on the whole, death is due to particular and recognizable causes. And those people who die young are carried away by infectious processes taking form as definite diseases, tuberculosis, acute lobar pneumonia, malaria, etc. Whereas those who live through this period succumb to cancer, degenerative disease of the organs (nephritis, arteriosclerosis, etc.) or less well characterized infections such as bronchopneumonia. These facts permit of interpretation in the sense that certain individuals and their relatives are more susceptible than the average to the diseases of early life, i.e. take them more severely than others and oftener succumb to them. At present for want of sufficiently precise information we are unable to assign values to the different factors in this very complex matter. Hypothetically if the human race were comprised exclusively of those we know as long lived such diseases as tuberculosis and typhoid fever would be unknown or would be recognized as disorders, disturbing but not especially dangerous to life. Whereas if the population were exclusively of the short lived, cancer, arteriosclerosis and many other diseases would be practically unknown.

ASSEMBLAGE OF CHARACTERS AND QUALITIES

Throughout this presentation it has been evident that the essential characters on the inheritance of disease depends are separately transmissible units of an almost endless variety. In some few instances one such unit may completely control a disease condition. But in most cases not only is the disease itself only partly influenced by the inheritance but even that part is controlled by a number of separately inheritable unit characters. Our present knowledge fails completely in so far

that in no single instance does it furnish a perfect insight into the fundamental nature of even one of these inheritable units. The task for the future is obviously enormous if we are to gain a usable understanding of the inheritance of disease on the basis of rational knowledge. We require to know for the different disease conditions the precise part played by the inheritance *in toto;* the number of unit characters involved for each case, and their structural or functional nature. It may well be, however, that the obstacles which intervene between our present understanding and a much more perfect and useful one are lessened by some favoring circumstances which may be sketched.

While it is considered fundamental that unit character is distinct in inheritance, certain definite instances are known where diverse characters are usually inherited together. This is termed linkage. Thus in hemophilia (which is manifest by failure of the blood to clot, so that those affected are "bleeders,") the disease condition is linked with the factors determining the sex. It is also true that a single unit character is sometimes known to be concerned with a variety of structures or functions although the author is unable to point out an example of this nature with reference to any disease condition.

From the point of view of pathology, also, there are rather clearly outlined associations between certain structural peculiarities and disease conditions, excluding cases previously outlined where the disease is directly dependent on a particular fault of structure. There are also recognizable tendencies for individuals and families to suffer from or be relatively immune to groups of diseases. Thus the tall, thin, flat-chested type of man is believed to be more liable to acquire tuberculosis. People who suffer from rheumatism and gout are believed to be less liable than the average to acquire tuberculosis. Most of these relationships are, as at present recognized, of the uncertain order resting on the impressions of successive generations of physicians. Yet recent approaches to the subject on the basis of careful measurements, accurately recorded case histories and adequate statistical analysis lend credence to the belief that there is a real and traceable set of associations here which it

will be worth while to develop by further studies. Up to now the interest has chiefly centered on recognizing certain anatomical types of people and trying to correlate with these the diseases from which they have suffered. The recent work of Draper who approached the question by taking typical cases of certain diseases and studying the physical conformation seems to promise more definite results. Of similar import and carrying even greater suggestion of future interest are observations indicating that the blood grouping, a functional inheritable manifestation developed under definite conditions between the blood cells and the blood serum, is associated in the inheritance with the natural immunity to diphtheria toxin or with the capacity to be immunized against this poison.

It is quite within the bounds of possibility that tracing such relationships as have here been outlined may make it possible to trace resistance factors, themselves intangible, through their frequent association with other characters more easily recognizable.

Sunburn as an Illustration. It is somewhat curious that much of what we know of the principles of the inheritance of disease can be quite well illustrated by a critical consideration of simple sunburn. The following paragraphs about this condition may well serve as a summary of the main features developed in the preceding discussion of more serious diseases and defects.

1. The effect commonly known as sunburn is pathologically closely related to, but not identical with, effects produced by heat rays, roentgen rays, acids and some other chemical agents. Burning is a property of the sun's rays, particularly those of a portion of the ultraviolet region of the spectrum. A rather common *type of disease* is thus induced by a highly specialized and particular agency.

2. A number of environmental conditions must be observed in order that the injury may be produced. These conditions need not be enumerated in detail here since they relate to the fact that ultraviolet rays are at a threshold level in sunlight as it reaches the earth and only reach burning intensity under clear skies, summer, high altitude, and other favoring circumstances.

3. Individuals of the human species vary widely in their susceptibility to this injury. These differences are largely dependent directly on the surface pigmentation although it is not unlikely that other qualities of the skin may be of definite influence.

4. All of the differences in pigmentation which are commonly recognized as characteristic of the various races and intraracial types of the human species are of significance for this disease. The most highly colored race (the negro) is supposed to be absolutely, and doubtless is practically, insusceptible to this injury or, in other words, possesses a complete natural immunity. The most completely blond types are most susceptible. Since there is entirely satisfying evidence that the pigmentary variations are controlled by the inheritance in accordance with Mendelian principles it may with propriety be said that susceptibility to sunburn (or *per contra*, natural immunity against it) is inherited.

5. Many of the less extreme blonds and all of the lighter grades of the positively pigmented types develop increased pigmentation (tan) under repeated exposure. The capacity for tanning varies enormously and many rather complete blonds seem to be entirely lacking in it. The tanning is in effect an acquired immunity to a specific injury. And it is proper to say that many individuals who under ordinary conditions are very susceptible to sunburn may by treatment be given a very perfect immunity against it, while others are not only naturally very susceptible but lack certain capacities and consequently cannot be rendered immune. From the point of view of the inheritance we are here concerned with the same mechanism that was considered in the preceding paragraph, i.e., the inherited pigmentary control, and we may accordingly consider that we have not only an inherited natural immunity but a variable inherited capacity to acquire an artificial immunity.

6. The natural pigmentation is transmitted as a blending type of inheritance, that is, it is controlled by multiple unit characters in the Mendelian sense. The same may naturally be said of the susceptibility to, and the capacity to acquire an immunity against, sunburn.

7. Finally, not to strain the illustration it may be pointed

out that the pigment when present is carried by a special type of cell with no other known function than that of producing and localizing the coloring matter. The pigment is produced by the oxidation (presumably by the associated activities of particular ferments) of a particular colorless substance. The final color depends on the amount of pigment and the distribution of the cells which carry it. There are evidently various points at which the controlling factors which genetic theory postulates as multiple unit characters could be operative. Complete absence or reduction in number of the chromophore cells, variations in their general functional activity, or differences in any of the particular chemical (fermentative) activities underlying the production and "ripening" of the characteristic pigment are obvious and distinct loci where controlling factors might well exert their force. One of the tasks for the future is to analyse and locate these factors in precise terms with reference to general and particular structures and functions.

Other chapters have given consideration to the more general aspects of inheritance and its social significance. This one may well be concluded by explicit reiteration of the rather obvious fact that any application of our knowledge of the inheritance of disease to the broad purposes of race betterment must be through the development of ability to control particular and individual cases. Our general culture, our freedom from certain infectious diseases may alike be immediately and largely a matter of social inheritance. Our liability to those diseases, defects, and discomforts which are controlled by the physical inheritance must always be based directly on the qualities of the germ plasm transmitted from father and mother to their children and so to their grandchildren.

We can perhaps sterilize certain obvious defectives and so minimize the economic burden imposed by the maintenance of institutions for their care. But we cannot so durably solve the problems imposed by the fact that disabling defects, diseases and tendencies to the development of disease are inherited. The faulty germ plasm considering the multitude of distorted conditions is too widespread for this. The ancients when they wished to completely subjugate a conquered enemy people "decimated" the population.

This seems to be the ultimate which cold-blooded immediate destructive human purpose can achieve. It is doubtful if we shall ever be persistent enough to interfere radically with the propagation of 10 per cent of the defectives even in cases where there is complete agreement as to the need for such measures.

Recognizing the wide distribution, the completely individualistic character of the faults in the germ plasm, it seems that most rapid progress can be made through the development of the individual understanding and conscience. The appeal to family pride has been a most potent force in the past, and one which it may be feared the present unduly loses sight of. From the present point of view this force has too often been misdirected, the pride has been in the concealment of existing defects so far as possible. This is equivalent to making contracts under false pretenses and in an informed society must come to be regarded as criminal.

Family pride is likewise regarded as undemocratic. But in terms of generations we can pass to our descendants as we choose a democracy of the unfit or one of the highest personal and social accomplishment. To the development of this end the study of the detailed manner in which diseases or the influences controlling disease incidence are transmitted in inheritance is likely to prove an increasingly useful and stimulating force. At present and doubtless in the end the practical guide to individual judgment would appear to lie in the item of longevity. A short lived strain *may* be fundamentally healthy, a long lived one must be at least superior. When this complex of physical attributes is balanced with the knowledge of the presence or absence of certain particular diseases in the strain and the whole weighed with a rating for success with the business of life, the basis for the intelligently prideful propagation of the family may be well laid.

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Chapter XXII

SOME ASPECTS OF THE BIOLOGY OF HUMAN POPULATIONS

Raymond Pearl

A POPULATION may be defined as an aggregation of individual organisms of the same species, living together in a limited and defined universe. In the case of human beings the limits of the "universe" of a particular population are commonly defined either geographically or politically. We thus speak intelligibly of the "population of the United States," meaning the aggregation of human beings living together within the geographical boundaries of the United States of America.

The problems presented by human populations are many and diverse. The economic conditions prevailing within any particular population, its social organization, its racial composition, and so on, all suggest many questions to which the answers are generally either not known at all, or only vaguely and imperfectly. But underlying all such questions are still more basic ones, which have to do with the *biology* of human populations. Man is an animal. However civilized he is or may become, what it is that after all keeps him present and voting, as the phrase goes, is the basic fact that he is an organism, which, in the aggregate, must be nourished, must reproduce, and must finally die. The fundamental characteristics of those groups of human beings that we call populations necessarily depend upon these basic biological attributes and actions of the individuals which compose them. But recent research has demonstrated that a complete account of the biology of a population will require something more than an examination of the biology of each separate individual composing it. The group behaves biologically in certain ways as a whole. For the adequate study of such phenomena there is rapidly developing a separate division of science, which is called "group biology," or the biology of populations. It is to the discussions of the biology of human populations that this chapter will be chiefly devoted.

Before embarking upon the consideration of the biological characteristics and problems of human populations it will be desirable to have before us some broad statistical facts about such populations.

So far as anyone knows, the curious animal which Linnaeus perhaps ironically designated *Homo sapiens* lives only upon one planet, the Earth (see chapter 1). Nobody knows exactly how many human beings are living on this planet at this moment, or how many have been alive upon it at any other moment. Theoretically it should be a simple matter to count them. Practically such a task is beset with difficulties. What then actually happens is that at intervals of five or ten years as accurate counts as possible are made of all those people whose aggregate state of civilization is such that any counts are feasible. Estimates are then made of the numbers of the others. Roughly speaking the numbers of persons living on the earth in 1927 were of the order shown in Table 1.

Table 1 furnishes a good deal of interesting information about the number and kinds of people who are spread over the earth's surface. It is seen that while Europe is only about a fifteenth part of the land area of the globe, slightly more than a quarter of all the people in the world live there. Oceania has about the same area as Europe, but less than a two-hundredth part of all the people live there. Asia covers less than a third of the globe but has more than half the people. Africa and North America have respectively about a fifth and a seventh of the area, but each has rather less than a twelfth of the people.

Plainly if Europe and Asia are to be regarded as normally populated, then the rest of the world is greatly underpopulated. Or, conversely, if North America is held to have something like an optimum population then Europe and Asia are enormously overpopulated. But there is scarcely a country in Europe which, at the present moment, is not at least talking about the desirability of larger populations. And, on the other hand, a great deal is heard in the United States about the wisdom which will inhere in sharply restricting the future growth of our population. In fact

TABLE I

AREA, POPULATION, AND RELIGIONS OF THE WORLD

	Europe	Asia	Africa	North America	South America	Oceania	Polar Regions	Totals	Per cent
Square miles	3,750,000	17,000,000	11,500,000	8,000,000	6,800,000	3,450,000	5,000,000	55,500,000	100
Per cent of total area	6.8	30.6	20.7	14.4	12.3	6.2	9.0	100	100
Population	475,000,000	1,013,000,000	143,000,000	146,000,000	64,000,000	8,500,000	Too small to matter	1,849,500,000	100
Per cent of all people	25.7	54.8	7.7	7.9	3.5	0.4	.....	100	100
Roman Catholics	220,000,000	7,000,000	2,000,000	40,000,000	61,000,000	1,500,000	.....	331,500,000	17.9
Orthodox Catholics	120,000,000	20,000,000	3,000,000	1,000,000	.....	.....	.....	144,000,000	7.8
Protestant Churches	115,000,000	7,000,000	3,000,000	75,000,000	900,000	6,000,000	.....	206,900,000	11.2
Per cent of all Christians	66.6	5.0	1.2	17.0	9.1	1.1	.....	100	
Per cent that Christians are of all people	95.8	3.4	5.6	79.5	96.7	88.2	.....	36.9	
Jews	10,000,000	1,000,000	500,000	4,000,000	100,000	30,000	.....	15,630,000	0.8
Mohammedans	5,000,000	160,000,000	44,000,000	20,000	.....	.....	.....	209,020,000	11.3
Buddhists	.....	150,000,000	.....	180,000	.....	.....	.....	150,180,000	8.1
Hindus	.....	230,000,000	.....	150,000	.....	.....	.....	230,150,000	12.4
Confucians and Taoists	.....	350,000,000	.....	600,000	.....	.....	.....	350,600,000	19.0
Shintoists	.....	25,000,000	.....	.....	.....	.....	.....	25,000,000	1.4
Animists	.....	45,000,000	90,500,000	50,000	.....	100,000	.....	135,650,000	7.3
Other	5,000,000	18,000,000	.....	25,000,000	2,000,000	870,000	.....	50,870,000	2.8
Total Non-Christians	20,000,000	979,000,000	135,000,000	30,000,000	2,100,000	1,000,000	.....	1,167,100,000	63.1
Per cent of all Non-Christians	1.7	83.9	11.6	2.5	0.2	0.1	.....	100	
Per cent that Non-Christians are of all people	4.2	96.6	94.4	20.5	3.3	11.8	.....	63.1	
Totals	475,000,000	1,013,000,000	143,000,000	146,000,000	64,000,000	8,500,000	.....	1,849,500,000	100

there is now in operation a law recently passed which greatly reduces the increase in our population from immigration.

These broad facts suggest that it would be difficult to draw up at this moment a definition of an optimum population for any given area, to which everybody would agree. Particularly those people already inhabiting the area in question are almost sure to have views about what is the best population size for them, which will be different from those reached by other groups, or by dispassionate students of population problems in general. For after all to speak of an "optimum" population implies a criterion of what is best. And tastes do differ so. In a brilliant paper read before the World Population Conference in Geneva in the summer of 1927 Prof. H. P. Fairchild took the position that the determining element in discussing optimum size of population should be "material well-being, or "standard of living." To this it is difficult to urge any specific theoretical objection. But there is a very considerable and real practical one, and it is again simply that tastes do differ so. The radio, the movie, the automobile, canned peaches, and Eskimo pie are clearly evidences of a high standard of living, in the sense of "material" well-being. But there are a great many people in the world who do not care for these things, not in the very least. On Professor Fairchild's definition, as on any other conceivable one, what will seem to one group of people an optimum population will not strike another group at all that way. The point is beautifully illustrated in the attitude of the city man and the country man towards each other's dwelling places and standards of living. Each really thinks the other a bit simple, not to say feebleminded, for living as he does, when after all he does not have to. But the truth merely is that each likes his own way of living better than another way. Europe had more than twice as many persons per square mile as Asia (roughly 127 as against 60). Perhaps both have long since passed their optimum populations. But this can hardly be true elsewhere because in all the rest of the world taken together, except Europe and Asia (and the Polar Regions), there are, on the average, only about 12 persons per square mile.

Has there been any tremendous dashing off of Europeans to populate the unused lands of the world? There has not. One example must suffice. Since the war Great Britain has been of all European countries perhaps the one from which one would be most likely to want to move, if motives of "material well-being" and "standard of living" were the only important ones to be considered. Taxes are enormously high, the national debt is large, amounting to something of the order of £180 per capita of population, there are many unemployed (1,180,290 on Sept. 22, 1924) and so on. But in 1924 only 371,306 persons left Great Britain for other than European destinations. In that same year 253,542 persons from other parts of the world than Europe decided that they wanted to come and live in Great Britain. So that the net *departure* was of only 117,766 people. This constituted only about one person in each 400 of the population. And the proportion of net emigrants to *unemployed* (who surely are enjoying a low standard of living) was only about 1 in 10. There seems no escape from the conclusion that the vast majority of people who live in Great Britain do so because they want to. They may be having a bad time of it, but even so they do not want to move. Why they do not is fundamentally because they are not merely units of economic and sociological discussion, but instead are *human* beings, full of prejudices, peculiar likes and dislikes all their own. Such things are fundamental biological attributes of human beings. Any science of mankind which neglects them will not be *human* biology, whatever else it may be.

There is finally a general point which needs emphasizing about the discussion of optimal population. Because the word "optimum" by its very definition, implies a matter of taste, feeling or emotion, it in so far removes the discussion outside the field of exact, objective science. Much sociology is filled with discussion of moral or other "values" overtly or otherwise. Many writers on population talk at length about what is "good," or "better," or "best," or "bad," "worse," or "worst" in respect to population. But surely the path to an exact science of population does not lie in these directions. What the subject needs is a Pareto rather than evangelists.

Going back again to Table 1, it is interesting to note that of all the people in the world just under 37 per cent are Christians, and just over 63 per cent are not. This should be encouraging to missionaries. So also, perhaps, should be the fact that no other single religious faith has anything like as large a proportion of the people on the earth as has Christianity. The nearest is Confucianism and Taoism, with 19 per cent.

Again, however it is clear that mere size is not all. There are more fundamental biological considerations. The Jews constitute less than 1 per cent of the people of the earth.* Is there anyone who would venture the assertion that their proportionate influence in human affairs is of the order of 1 per cent? Whether "chosen" or not they are as a people differentiated, in a statistical sense, from the rest of mankind by the most objective of tests, success in life and influence and power in the control of human affairs on a world-wide scale. And it is equally plain that the basis of their differentiation must be constitutional in the biological sense. Theirs has never been an easy environment, physical or biological. A differentiated tenth of any herd is never likely to have an easy time. The crowd is against them. And it is a big and rough crowd.

There is perhaps room for legitimate pride on the part of somebody that, on the record, the people of North America seem to be most tolerant of differences in religious faith of any in the world. For whereas 96 per cent of the people in Europe are Christians, and only 4 per cent Non-Christian, and whereas 97 per cent of the people of Asia are Non-Christian and only 3 per cent Christian, in North America approximately 1 person in every 5 is not even technically a Christian. In this 80 per cent Christian population there are included *also*, and mainly without prejudice, an appreciable number of devotees of every main brand of exotic faith except

* No one can discuss the Jews realistically without being accused, either by Jew or by Gentile, of having confused race and religion. The merits of this controversy seem to be few and slight. For the purpose of the present discussion it is sufficient to state the fact that, of the persons who are set down in Table 1 above as Jews, an overwhelmingly large proportion are biologically differentiated in a whole series of respects, anatomical, physiological and psychological from the rest of mankind. Whether they are called a race, or are not so called, is of no importance in the present connection.

Shintoism. The same thing is not true of any other continent except Asia, and there to a much smaller degree quantitatively.

In addition to such a birdseye picture of the number of different kinds of people who inhabit the earth as is given in Table I, it is also desirable that the reader have some idea of the age and sex distribution of human populations. To this end Table II has been prepared. In this table some 29 different human populations are arranged in descending order according to the proportion of males aged fifteen to forty-nine to the whole male population. Thus 55.4 per cent of the living male population of Belgium fall in age somewhere between fifteen and forty-nine years inclusive. This is a higher proportion than any other of the populations listed shows. Therefore Belgium stands at the head of the table. Russia has only 39.6 per cent of its living male population between the ages of fifteen and forty-nine inclusive, and stands at the bottom of the table.

Table II also shows the number of females living in each of three broad age groups, per 100 males living at the same ages.

This table has been computed from data given in a recent paper by Moine.

Let us consider first the proportion of the sexes. It is apparent from the table that the general rule is that in the first period of life, up to age fifteen, males are somewhat in excess in the living population. The only exceptions to this rule among the populations listed in Table II are France, Canada, Greenland and Russia (in Europe).

In the period of vigorous adolescent and adult life, between the ages of fifteen and forty-nine inclusive, the general rule is for females to be a little in excess of males in the living population, but there are fairly frequent exceptions. In Table II the countries having fewer females than males at these ages are: Samoa, United States, Union of South Africa (both natives and whites), Australian Confederation, Canada, British India, Japan and Brazil. These are all populations in which either there is a considerable immigration of young adult males for industrial reasons, or in which the female is under something of a handicap in the general social scheme of things.

TABLE II

SEX AND AGE DISTRIBUTIONS OF CERTAIN HUMAN POPULATIONS

Country	Sex ratio = Females per 100 males			Proportion in total population of indicated sex (Per cent)					
	Age 0–14	Age 15–49	Age 50 and over	Age 0–14		Age 15–49		Age 50 and over	
				Male	Female	Male	Female	Male	Female
Belgium[1]	98.9	102.1	102.2	25.5	24.5	55.4	54.7	19.1	20.8
Samoa	84.5	93.9	94.7	38.9	39.3	54.7	54.3	6.4	6.4
Switzerland	98.6	108.1	119.7	29.1	26.7	53.3	53.7	17.6	19.6
Germany[2]	98.4	114.7	115.3	30.1	27.0	52.7	55.0	17.2	18.0
United States (Continental)	98.0	96.6	91.0	31.6	32.1	52.6	53.0	15.8	14.9
England and Wales	98.7	113.3	116.5	29.3	26.3	52.3	54.1	18.4	19.6
Czeckoslovakia	98.6	109.9	116.0	30.6	28.1	52.0	53.1	17.4	18.8
Union of South Africa (Natives)	98.6	95.2	150.9	41.5	42.0	52.0	48.0	6.5	10.0
Finland	96.9	101.7	118.1	32.6	30.8	51.7	51.2	15.7	18.0
Australian Confederation[3]	97.1	99.1	89.0	31.6	31.8	51.5	52.7	16.9	15.5
France	107.1	112.8	116.4	24.0	21.6	51.5	52.6	24.5	25.8
Canada[4]	119.4	92.4	90.1	33.7	35.2	51.2	50.3	15.1	14.5
Hungary	99.0	111.7	103.3	31.8	29.6	50.5	53.2	17.7	17.2
Greenland[5]	102.3	109.3	147.3	42.2	39.5	50.5	50.7	7.3	9.8
Holland	97.1	102.1	107.5	33.3	31.9	50.2	50.7	16.5	17.4
Union of South Africa (Whites)	97.4	95.2	82.2	36.7	37.9	50.2	50.7	13.1	11.4
Denmark[6]	98.5	106.4	115.2	32.2	30.2	50.2	50.6	17.6	19.2
Sweden	96.0	102.1	120.0	30.5	28.3	50.1	49.3	19.4	22.4
Guam	96.2	108.1	142.3	45.0	41.3	49.8	51.6	5.2	7.1
British India	93.9	81.9	97.2	39.2	41.6	49.6	46.0	19.2	12.4
Lithuania[7]	98.6	116.3	111.4	32.6	29.2	49.3	52.5	18.1	18.3
Japan	97.7	96.2	104.2	35.1	35.0	49.0	48.1	15.9	16.9
Portugal	96.7	115.8	129.0	35.2	30.6	48.6	50.6	16.2	18.8
Spain	99.1	109.3	112.7	35.6	33.3	48.5	49.8	15.9	16.9
Ireland	95.2	103.2	131.0	34.8	31.6	48.5	47.5	16.7	20.9
Brazil	97.2	99.9	97.0	43.0	42.5	48.2	48.8	8.8	8.7
Colombia	99.5	113.7	119.9	41.8	39.4	47.6	49.9	10.6	10.7
Bulgaria	95.4	105.5	95.8	37.2	35.4	47.1	49.6	15.7	15.0
Russia (in Europe)	101.3	147.0	121.2	45.2	37.4	39.6	47.6	15.2	15.0

[1] Excluding Eupen and Malmedy.
[2] Excluding the Saar region and Eupen and Malmedy, but including Schleswig Holstein.
[3] Excluding the native population.
[4] Including Eskimos and Indians.
[5] Native population only.
[6] Excluding the Faroe Islands.
[7] Excluding Melme.

In the last period of life, from age fifty on, females are rather considerably in excess of males in most living populations. The exceptions to this rule, among the populations listed in Table II are Samoa, United States, Australia, Canada, Union of South Africa (whites), British India, Brazil Bulgaria. The fact that, in general, females have a greater longevity than males accounts for their usually greater frequency in the living population at ages from fifty years on.

Turning now to the age distribution of living populations it appears that, on the average, approximately a half of the population of living males falls between the ages fifteen and forty-nine inclusive. Thirty five per cent are under fifteen years of age and 15 per cent are fifty years of age or over. For females the corresponding average percentages are 51, 33, and 16.

Among the different populations the greatest variation is found in the percentage of the total population under fifteen years of age. In this age group the effects of differences in both natality and mortality are directly felt.

The age distribution of living populations has much more than merely statistical interest. Figure I shows in graphic form the average situation documented in Table II.

Practically no children below the age of fourteen are completely self-supporting by their own effort. A large proportion of persons above fifty also are not, by their own efforts at those ages. The half of the population between the ages of fifteen and forty-nine has to support a large part of the rest of the population as well as themselves. This burden includes both direct expenditure at the time, that is while they are under fifty, and also savings for their own old age, when they can no longer work. This extraordinary overlapping of generations characterizes human populations to an extent perhaps not equalled in any other living form. It is a factor of profound importance in their biology. The tremendous burden depicted in Figure I is borne by mankind for reasons in part emotional. We (in a statistical sense) care for our offspring and our parents beyond the time limits of biological necessity in good part because we want to. But for this satisfaction we pay a high price.

In these facts is to be found unquestionably one of the basic reasons for the practice of contraception or birth control in countries having what we are pleased to regard as

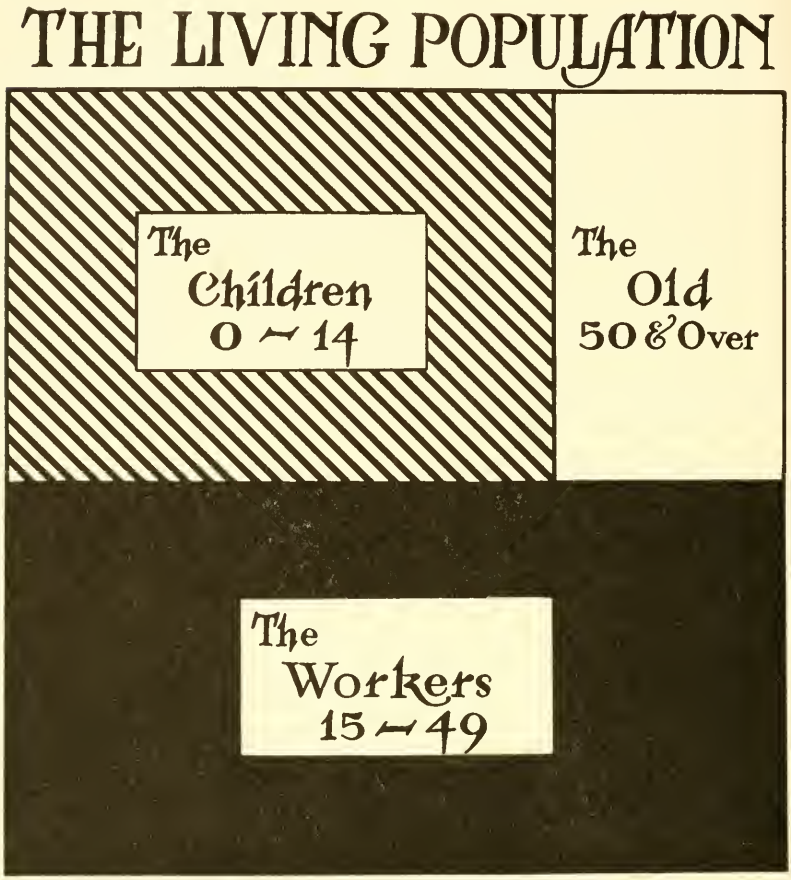

FIG 1. Approximate average distribution of living human population Frequencies are depicted as areas.

a "high" state of civilization (see chapter XXII). As the burden becomes more and more clearly recognized the natural tendency is to attempt to reduce it by limiting the number of children. But this hope is in some degree illusory, because what frequently happens is merely that the distribu-

tion of the burden is altered, not its total drag. Consider, for example, the population of France, which is not far from the condition technically called "stationary" by statisticians. France has slightly less than a quarter of its living population under fifteen, in place of the average 35 per cent. But on the other hand she has almost exactly 25 per cent of her population aged fifty or over. So once more each of the potentially actively working fifty per cent has one extra mouth to feed besides his or her own, in whole or in part.

Consider another case. The native population of Greenland is not particularly solicitous about keeping its old people alive after they are unable to fend for themselves and earn their own keep. Eskimos of advanced age are hard to find, on the testimony of all Arctic travellers. But does this materially reduce the burden in total on the workers? It does not. For while, according to the figures of Table II, only about 8.5 per cent of the living population of Greenland is fifty years or over in age, something over 40 per cent are children under fifteen.

The figures of Table II give us a glimpse of one of the most important elements of the biology of human groups or populations. This is the principle of *self-regulation*. Self-regulation of the individual organism, in its regeneration and in its physiological and morphological processes generally, has long been familiar to the student of biology. It is also one of the most striking and important phenomena in group biology, or the biology of populations.

In the next section we shall consider this matter more particularly.

THE SELF-REGULATION OF HUMAN POPULATIONS IN SIZE

The primary biological variables involved in the growth of population are two in number; *natality*, measured by the birth rate, on the one hand; and *mortality*, measured by the death rate, on the other hand. These primary elements are fundamental to the discussion of the growth of populations of any and all organisms whatever, from ameba to man. In most of the lower organisms living in a state of nature, whether plant or animal, these are the only first-order

variables which have to be taken into account in discussing the problem.

In most human populations, especially those inhabiting large geographical areas, a third factor may influence directly the size of the population at any given moment, in greater or less degree. This third factor is *migration*, and it is theoretically to be regarded as a primary variable in determining the growth of such human populations. While theoretically a first-order variable, migration is, in large population aggregates, practically always much less important in its purely quantitative effects upon population size than are the basic variables, natality and mortality. The growth of the population of the United States is a case in point. If one plots the census counts of this population (as in Fig. 5 *infra*) from 1790 to 1920 inclusive it is impossible to detect in the curve of growth any separate or disturbing effect of immigration. Unfortunately it is impossible to analyze the effect of immigration upon the population of the United States in detail, for the reason that *net* immigration figures, which take account of departures as well as arrivals, are available only since 1908. But some general facts are available and illuminating. In the years between 1830, when records began on the point, and 1870, the total number of immigrants into the country was 7.3 millions. The total population of the country, as given by the census in 1870 was 38.6 millions. So that if all the immigrants who came into the country had stayed here, and none had died in the meantime (both assumptions being, of course, far from the real facts) the total immigration in the period would have constituted only 19 per cent of the total population. For the census years beginning with 1870 and coming down to 1920, numbers of immigrants, *in gross* (i.e., without deduction of emigrants) in the year, per thousand of population existing in the same year are as follows:

TABLE III

Year	Annual Immigration into the United States Per 1000 Population
1870	10.0
1880	9.1
1890	7.2
1900	5.9
1910	11.3
1920	4.1
1926	2.6

Richmond Mayo-Smith and Thomas Allan Ingram give the following corresponding figures for emigration from Great Britain and Ireland, with the comment that: "Even taking Great Britain and Ireland together, the loss by emigration per annum has not been very large."

TABLE IV

Period	Annual emigration per 1000 of the average population of Great Britain and Ireland
1853–1855	8.4
1856–1860	4.3
1861–1870	5.2
1871–1880	5.1
1881–1890	7.1
1891–1895	5.1
1896–1900	3.7
1901–1905	5.5

Besides the three primary biological factors of natality, mortality and migration which influence the observed growth of human populations there are various secondary environmental factors which may play a part in determining the final result. These are such things as food supply, the economic situation in general and particular, social forces of various sorts, and perhaps others. But it should always be kept in mind that these are all *secondary* factors from a biological point of view. They produce whatever

effect they may have upon the final result, namely the size of the population at any given moment, by acting, more or less powerfully as the case may be, upon one or more of the three primary biological variables, natality, mortality and migration. Thus an economic depression in a particular country may affect adversely the birth rate of that country, or even the death rate if the degree of the depression is sufficiently great or its duration sufficiently prolonged. These effects will, in greater or smaller degree, reflect themselves finally in the size of the population. This final effect upon the growth of the population may, however, be extremely slight, and difficult or even impossible of separate statistical recognition or measurement, because of compensating influences at work at the same time. Logically, however, the operation of these secondary factors must always be recognized. But from the point of view of the theory of population growth their influence is always a second order one. They can produce any effects upon population only by operating upon the primary biological forces of natality, mortality and migration.

The net effect of the two important variables, natality and mortality, upon population may be studied in various ways. One of the most illuminating is by the use of a constant which has been called the "vital index" of a population. It has this form:

$$\text{Vital index} = \frac{\text{Births} \times 100}{\text{Deaths}}$$

The vital index gives an accurate picture of the net biological status of a population as a whole at the moment of its calculation. If the ratio 100 births: deaths is greater than 100 the population if growing naturally, and is in so far biologically healthy. If the ratio is less than 100 the population is not exhibiting natural growth, however sound it may be in other respects. There may be a sufficient amount of immigration to compensate the deficiency in births, so that there is no actual depopulation. But the condition is fundamentally unsound biologically.

The vital indices of the population of the United States have been extensively studied by the writer (1924, Chaps.

III and IX). Sweeney has made an interesting and comprehensive examination of the vital indices of all the populations of the world for which records of births and deaths exist.

Using the vital index as a measure of the phenomena we may now discuss two examples of autonomic regulation in a human population. The first concerns the population of England and Wales. For each quarter of each year from 1838 to 1920 inclusive the vital index of the population was computed. Grouping the data in five-year periods gives the results shown in Table V.

TABLE V

GROUPED DATA FOR VITAL INDEX AND CRUDE BIRTH RATE OF ENGLAND AND WALES

Period	$\frac{100 \text{ births}}{\text{deaths}}$	General birth rate per 10,000
1838–1839	140.28	310
1840–1844	148.04	322
1845–1849	139.61	326
1850–1854	151.69	339
1855–1859	155.23	343
1860–1864	157.30	349
1865–1869	157.11	353
1870–1874	161.35	355
1875–1879	167.69	356
1880–1884	171.81	338
1885–1889	169.85	320
1890–1894	161.48	305
1895–1899	166.40	296
1900–1904	171.25	285
1905–1909	177.40	267
1910–1914	175.09	242
1915–1919	134.95	208
1920–	205.48	255

The immediately striking feature of this table is the general smoothness of the trend of the values of the vital index as one runs down the column. In order to appreciate

this fact fully, however, it is necessary to resort to graphical presentation. The vital index and birth rate data from Table v are shown graphically in Figure 2.

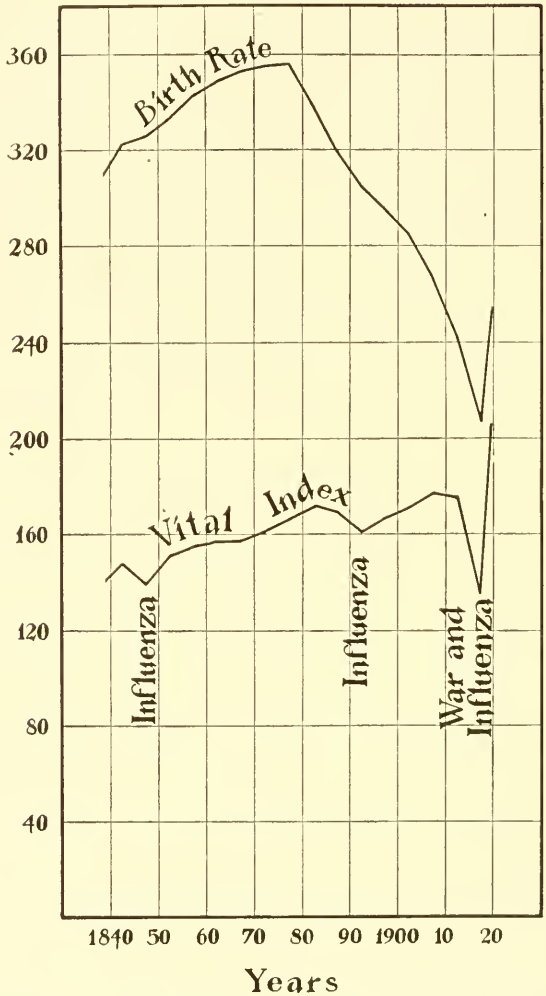

Fig. 2. Trend of vital index (100 births: deaths) and crude birth rate in England and Wales, 1838–1920, inclusive.

It is at once apparent that the ratio of births to deaths in England and Wales had but a slow but on the whole even and steady tendency to *increase* from 1838 to 1914. This

steady progress was interrupted to a degree sufficient to be apparent upon only two occasions during the three quarters of a century. These were in 1847–1849 and 1890–1892. These fluctuations, which only slightly affected the even upward trend of the curve, were apparently due to the influenza pandemics of 1847–1848 and 1890–1891.

The broad result is perfectly clear and outstanding. The population of England and Wales is today exhibiting a greater purely biological survival value as a whole population than it was three-quarters of a century ago. Whether it is a mentally, morally or anthropometrically fitter population does not now concern us. We are dealing here solely with the fact that, taking the people of England and Wales as a whole, slightly over two babies were born for every death per year in 1920, as against 1.4 babies per death per year in 1838–1839.

Now this result will strike any one informed as to the sociological and eugenical literature of the last two decades as curiously at variance with the pessimistic tenor of that literature, taken as a whole. It has been pronounced from high places that the general trend of British people was biologically downwards, that they were in fact becoming a decadent race. Abundant quotations in support of this contention could be cited, were space available and were it necessary. This gloomy view has had its foundation mainly upon the fact that, since the quinquennium 1875–1880, the birth rate in England and Wales has been falling rather rapidly, as is clearly shown in Figure 2. This fact has been studied by Miss Elderton in great detail.

But from a purely numerical viewpoint, what matters a falling birth rate if the death rate falls even more rapidly, so that the net survivorship at any instant of time is constantly getting higher? To this it will, of course, be answered at once by those who view with alarm the declining birth rate that the real crux of the matter is in the differential change in fertility. Nowadays the "best" people are said not to produce their due share of progeny, while the "worse" people are alleged to overproduce. In the American population, however, the writer (1924 Chap. VIII) has shown that the element perhaps least effectively integrated socially with the rest of

the population, the negro, has the lowest survival value as a group (vital index generally less than 100). Measured by this same test the population, as a whole, of England and

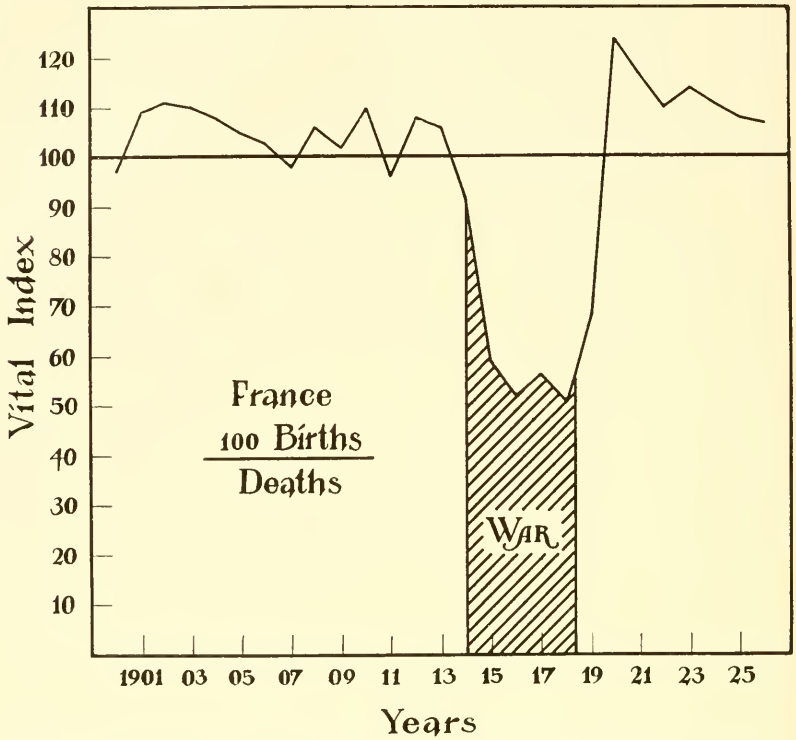

Fig. 3. Vital index (100 births: deaths) of population of France during 20th century.

Wales is today more vigorous than it was in 1838. This is a plain fact. Whether this fact is, sociologically or eugenically considered, a bad thing or a good thing, is the kind of question which, as has already been pointed out, has no place in an objective, quantitative science of human group biology.

For this, our present point of view, the interesting and important feature of the case is the extraordinary self-regulation of the population growth during this long period, by intercorrelated changes in birth rates and death rates. During the period under review the birth rate steadily rose

for more than thirty years, and then even more decisively fell. But the concurrent changes in the death rates were such that no sensible alteration in the general trend upward of the vital index was produced by this change in the course of the birth rate.

The second example of the self-regulation of human population size is afforded by the vital index of the population of France. Figure 3 shows a plot of this index for the years 1900 to 1926 inclusive. The abscissal points of plotting are taken as mid-year points.

What the diagram shows is that during the period from 1900 to the outbreak of the World War in 1914 the birth-death ratio in France had maintained a level somewhere between 100 and 110, with fluctuations which occasionally, brought it a little below the dead line of survival at 100 per cent. With the onset of the war the vital index fell to unprecedentedly low values. But immediately upon the cessation of hostilities the vital index rose at an even more rapid rate than that of its previous fall, reaching in 1920 a higher value than it had attained at any time during the century.

Again the magnitude and speed of action of the size-regulating powers of a human population are strikingly demonstrated.

THE GROWTH OF HUMAN POPULATIONS

It is observed that the growth of populations of the most diverse organisms follows a regular and characteristic course. The population at first grows slowly, but gains impetus as it grows, passing gradually into a stage of rapid growth, which finally reaches a maximum of rapidity. After this stage of most rapid growth the population increases ever more and more slowly, until finally there is no perceptible growth at all. In short, the populations of various forms of life first wax in this speed of growing and then wane.

The equation to the curve which has been found by experiment and observation to be descriptive of population growth in a wide variety of organisms as first discovered by the Belgian mathematician Verhulst in 1838. His pioneer work was forgotten, and consequently overlooked by most subsequent students of the population problem. In 1920 th

present writer and his colleague, Lowell J. Reed, without any knowledge of Verhulst's prior work, independently hit upon the same equation.

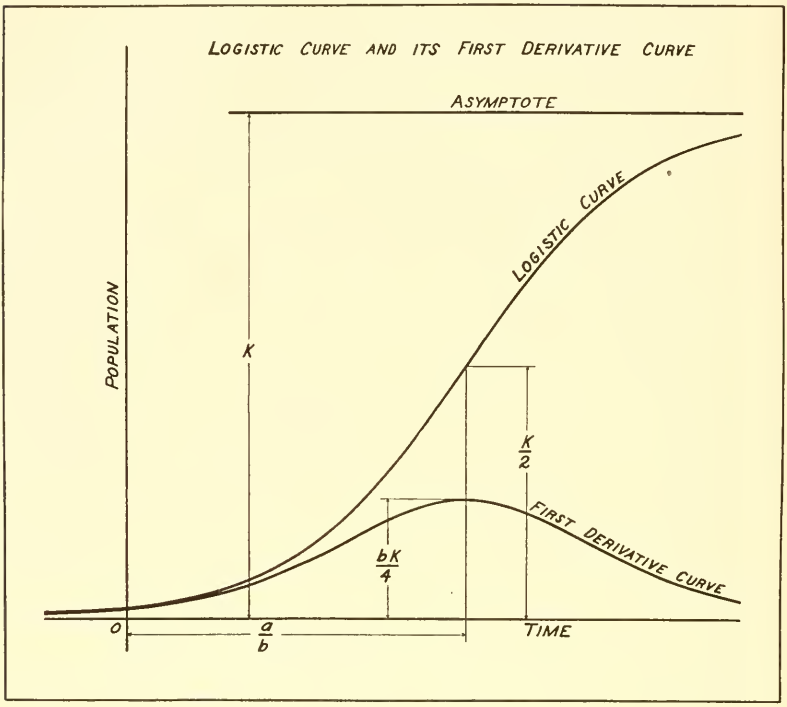

FIG. 4. Logistic curve and its first derivative.

Verhulst called his curve "logistic." This usage we shall follow. The characteristic appearance, and some of the mathematical properties of the logistic curve are shown in Figure 4. The equation to the simple logistic used by Verhulst is:

$$y = \frac{k}{1 + e^{a+bx}}$$

The generalized logistic, developed by the writer and Reed, has the form

$$y = \frac{k}{1 + e^{a_0 + a_1x + a_2x^2 + \ldots a_nx^n}}$$

In these equations y denotes population size and x denotes time.

It has been demonstrated statistically that populations

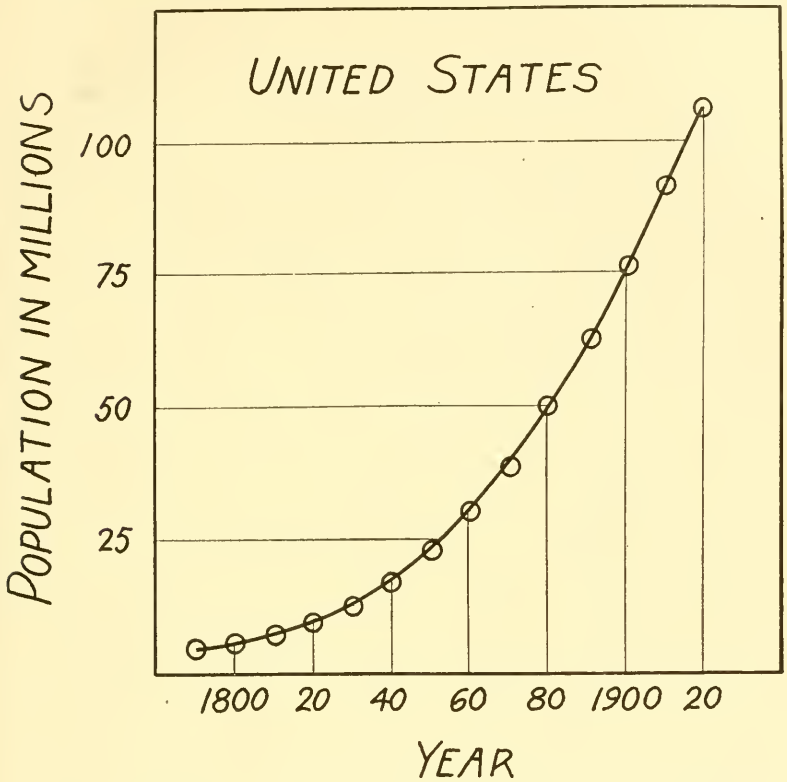

FIG. 5. Observed and calculated growth of population of United States.

of human beings have grown according to the logistic curve, so far as may be judged from the available census records, in at least the following countries: Sweden, United States of America, France, Austria, Belgium, Denmark, England and Wales, Hungary, Italy, Norway, Scotland, Servia, Japan, Java, Philippine Islands, Baltimore City, New York City, and the world as a whole.

In illustration of this statement three cases are presented graphically here. These are the United States (Fig. 5),

France (Fig. 6), and the world as a whole (Fig. 7). In these diagrams the circles give the census counts (or, in the case of the world as a whole, estimates) of the populations

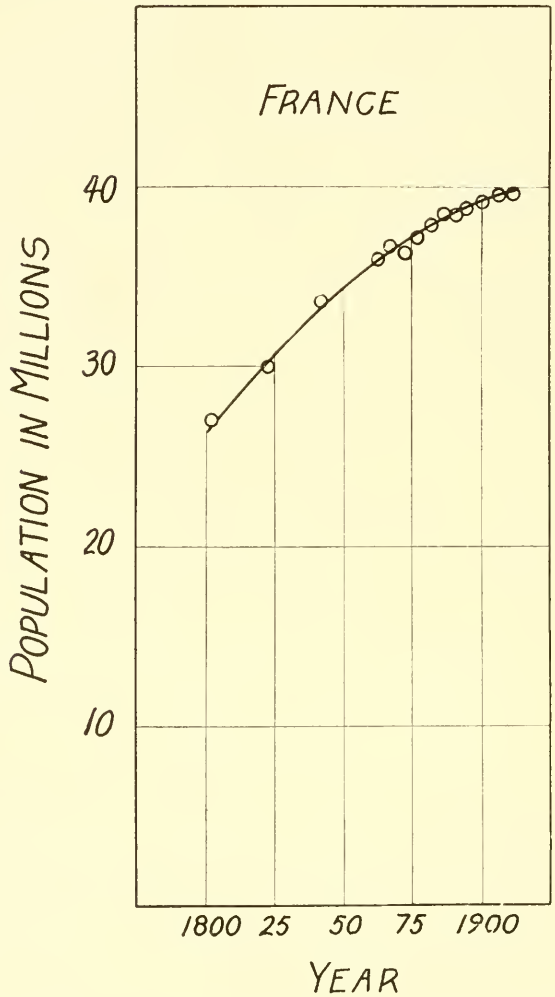

Fig. 6. Observed and calculated growth of population of France.

existing at the given dates, while the smooth curves are the fitted theoretical curves of population growth.

In the case of the demographic units listed above the census records do not extend over a sufficiently long time

to make the case conclusive that population growth, if undisturbed, would follow in human groups the complete course of one cycle of a logistic curve. The available data

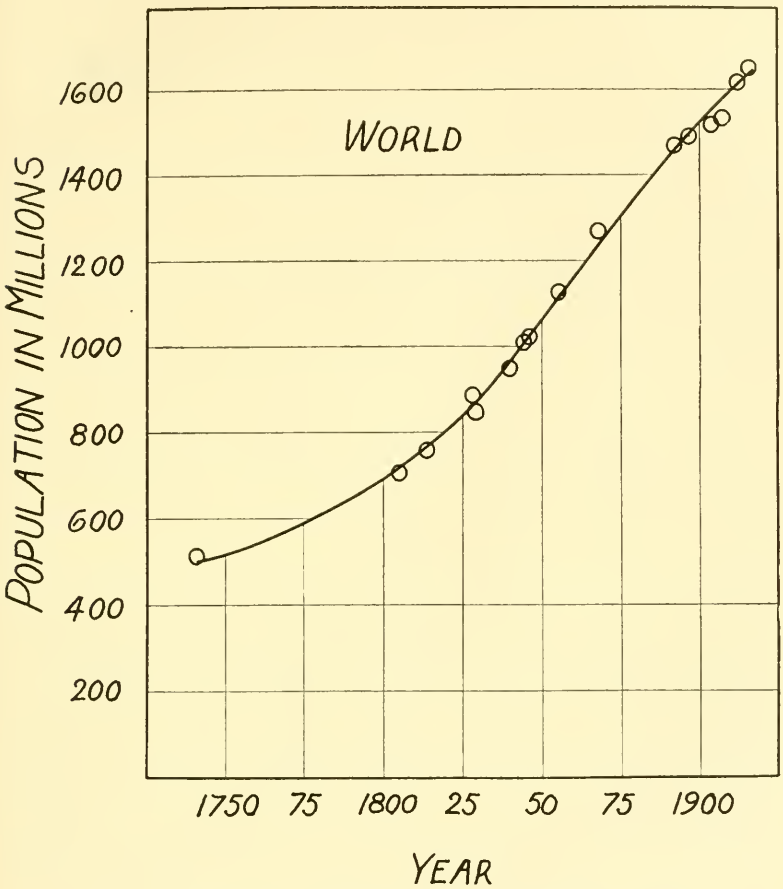

FIG. 7. Observed and calculated growth of population of world.

only make such a conclusion in some degree probable. And one cannot conduct experiments with human beings on this point, as can be done with lower organisms. But fortunately it has been possible to find one group of human beings, the indigenous population of Algeria, in which a cycle of population growth has been practically completed during the period for which census records are available,

these having been carefully made by the French. In this case the human population followed in its whole cycle of growth a simple logistic curve. This case has been fully

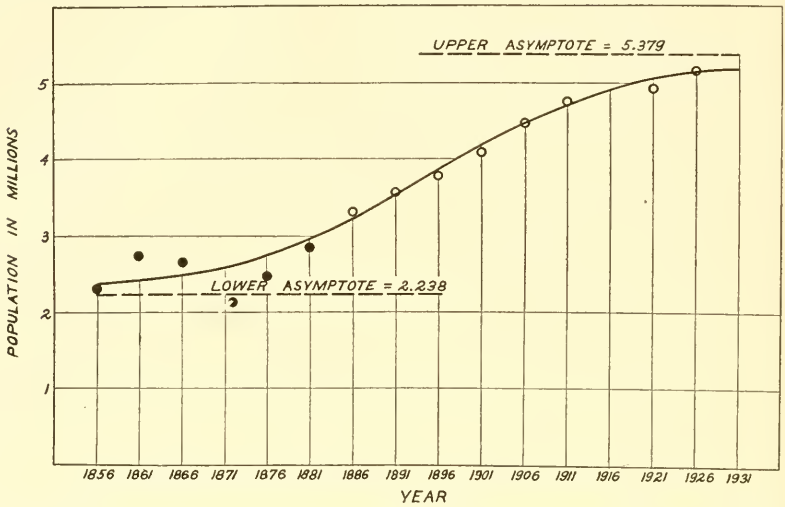

FIG. 8. Observed and calculated growth of indigenous native population of Algeria.

described and analyzed in the writer's book "The Biology of Population Growth" and is illustrated here in Figure 8.

The logistic curve, which is found by actual experience to describe accurately the course of population growth in a wide variety of organisms, constitutes a valuable first step, but only a first step, towards reaching an understanding of the biology of the process. What we want to know is how the biological forces of natality and mortality are so integrated and correlated in their action as to lead to a final result in size of population which follows this particular curve rather than some other one.

In the laboratory a series of investigations, experimental mathematical, and statistical, has been carried out for the purpose of throwing light on the problem. Limitations of space make it impossible to do more here than give a brief résumé of the results to date. A full account of these investigations is given, however, in certain of the references listed

at the end of this chapter Pearl, 1925, 1927*b* and other papers cited in the sources referred to.

In brief what is found is that both of the fundamental first-order population variables, natality and mortality, are directly and markedly influenced by density of population above a certain magnitude. The sense of this influence is that fecundity rates are markedly lowered by small increases in density at relatively low densities, while after a certain density is passed further increases produce only slight decreases in birth rates down to an asymptotic limit; and, second, that death rates are insignificantly affected by increasing density at relatively low densities, while after a certain density is passed death rates markedly increase with increasing density up to an asympototic limit.

In short it is possible to account for all the main features of the growth of experimental populations of the fruit-fly, by a simple hypothesis as to the correlated behavior of three variables, natality mortality, and density. There is some evidence that the situation is similar in human populations, in its fundamental biology, although there the influence of other second-order variables complicates the situation.

THE COMPOSITION OF POPULATIONS AND DIFFERENTIAL FERTILITY

The total size of a population is of course only one of its attributes. There are others of great biological interest, notably the composition of a population in respect of different kinds of individuals. All societies, whether of ants or men, tend to differentiate into castes, each performing a different function in the whole integrated group. Wheeler has particularly discussed this phenomenon.

The writer has recently studied one aspect of this matter in the population of the United States (1927*a*). In a recent report on natality from the United States Census Bureau (Birth Statistics, 1924) there is a table (numbered 10, pp. 171–181) which makes available some new and welcome data regarding differential fertility in this country.

The data apply to the United States birth registration area *exclusive* of Delaware, Maine, Massachusetts, New Hampshire, Rhode Island and Indiana.

The original table provides the following information: The births, number of children born, and living, and average number born and living to mothers of 1923, by occupation and age of father The occupations of the fathers are grouped into the following main classes, with a number of smaller subdivisions in each main class:

1. Agriculture, forestry, and animal husbandry.
2. Extraction of minerals.
3. Manufacturing and mechanical industries.
4. Transportation.
5. Trade.
6. Public service (not elsewhere classified).
7. Professional service.
8. Domestic and personal service.
9. Clerical positions.

When one considers carefully the subdivisions under these nine main heads the usual difficulty with official vital statistics is at once encountered. Economically and socially differentiated groups are included in some particular general class from the remainder of which they are, in these respects, sharply set apart, in reality. But it is reasonably obvious that economic and social factors and forces are among the most important elements in determining the biologically significant environment of human beings, as they exist here and now. Relative wealth virtually determines the character of the immediate physical environment in which men live. Furthermore, economic and social position are significantly correlated with the amount of physical labor which individuals perform, and this has been shown (Pearl, 1924, Chap. XI) to be biologically important.

In view of these considerations it was deemed necessary to reconstitute the main occupational classes, as given in the original document cited, so that they might conform at least somewhat more closely to significant reality. The general plan followed in this reconstitution of the classes has been described in detail (Pearl, 1927*a*) and need not be repeated here. The net upshot of the manipulation is to leave all the main occupational classes except 7 (professional service) composed chiefly of laborers, more or less skilled, but still persons whose living depends upon the daily

performance of more or less routine tasks, *in contrast to* the persons composing the reconstituted class 7, who, in the large, get their living rather more by the exercise of their wits than of their muscles.

In order that there may be no misunderstanding the names of the main occupational classes which have been altered by the described procedure will be printed in *italic* type throughout. This typographical usage will serve to indicate that the statistics so printed are for the reconstituted classes, and not for the classes originally so named in the official report.

The next and final point of method to be considered before coming to the results is that of age. The ideal in all studies of fertility is, of course, the completed family. In the present case this ideal cannot be precisely attained from the available data. General consideration of the problem, and careful examination of all the figures themselves as given in the original report, led finally to the decision to deal analytically with the data for fathers aged forty-five and over. This procedure will probably give as close an approximation as it is possible to get, from these or similar records extracted from the official standard birth certificate of the United States, to the unknown average size of completed family for the different occupational classes.

Table VI represents the first set of basic data which we shall need in the discussion.

Before discussing at all the results of this table, it is necessary to consider some of the important peculiarities of the data. In the first place, if the figures of column d could be regarded as representing exclusively completed families, which they almost but not quite can, they would still give an erroneous impression of the gross fertility of the several occupational classes, for the following simple reason. All the data in the table are derived from the experience of women who were mothers in 1923. That is to say, they were women who were fertile in that particular year. No other women are included. No sterile matings appear, and no matings of generally low fertility throughout the mated life, except the few in which the female chanced to

TABLE VI

CHILDREN BORN TO MOTHERS OF 1923, BY FATHERS AGED FORTY-FIVE YEARS OR OVER, BY OCCUPATION OF FATHER, IN RECONSTITUTED GENERAL CLASSES OF OCCUPATIONS

Occupation of Father	Total births (a)	Total number of children ever born (b)	Total number of children living (c)	Mean number of children ever born (d)	Mean number of children living (e)	Mean number of children dead (f)	Per cent of children dead (g)
Agriculture, forestry and animal husbandry	41,825	289,140	251,833	6.91	6.02	0.89	12.9
Extraction of minerals	*4,117*	*32,677*	*26,609*	*7.94*	*6.46*	*1.48*	*18.6*
Manufacturing and mechanical industries	*32,875*	*216,996*	*179,601*	*6.60*	*5.46*	*1.14*	*17.3*
Transportation	*4,480*	*27,002*	*22,997*	*6.03*	*5.13*	*0.90*	*14.9*
Trade	*6,771*	*34,885*	*30,389*	*5.15*	*4.49*	*0.66*	*12.8*
Public service	*949*	*5,189*	*4,374*	*5.47*	*4.61*	*0.86*	*15.7*
Professional service	*5,828*	*24,386*	*21,672*	*4.18*	*3.72*	*0.46*	*11.0*
Domestic and personal service	2,424	12,820	10,799	5.29	4.46	0.83	15.7
Clerical occupations	1,677	7,149	6,296	4.26	3.75	0.51	12.0
Totals	100,946	650,244	554,570	6.44	5.49	0.91	54.8

have a baby in 1923. That there are very few of such low fertility matings included is evident if it is recalled that we here are dealing only with families in which the father was forty-five years of age or over in 1923. In general the vast bulk of men who engender a baby when they are forty-five years old, or over that age, are probably persons whose whole marital history has been characterized by relatively high fertility, as compared with the rest of their same social class.

The net result is that the values in columns d and e of Table IV somewhat exaggerate the true average fertility of the whole population of the same age in the various occupational classes. The figures represent the average size of family of a selected sample only of the total population in each class, *the basis of the selection being high and probably historically continued fertility*. This means that, in the best case, we can only discuss from these data relative and not absolute fertility values. But there seems no reason

to suppose that the relative fertilities of the most fertile portions of the populations in the several main occupational classes, as given by these data, are not safely comparable.

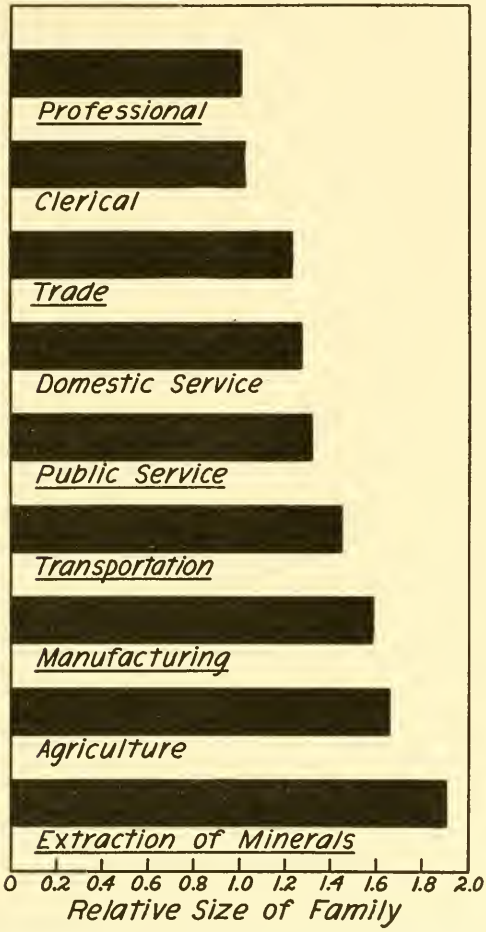

FIG. 9. Bar diagram showing relative average size of family experienced by mothers of 1923 in their reproductive lives up to that date, according to occupation of fathers who were, in 1923, forty-five years of age or over.

The only essential difficulty with the figures is that the universe of discourse which they encompass is a definitely limited one, and we cannot safely generalize beyond these bounds.

In the portion of the population here under discussion, the figures show that when the average size of family produced by a mother of 1923 in her total reproductive life up to

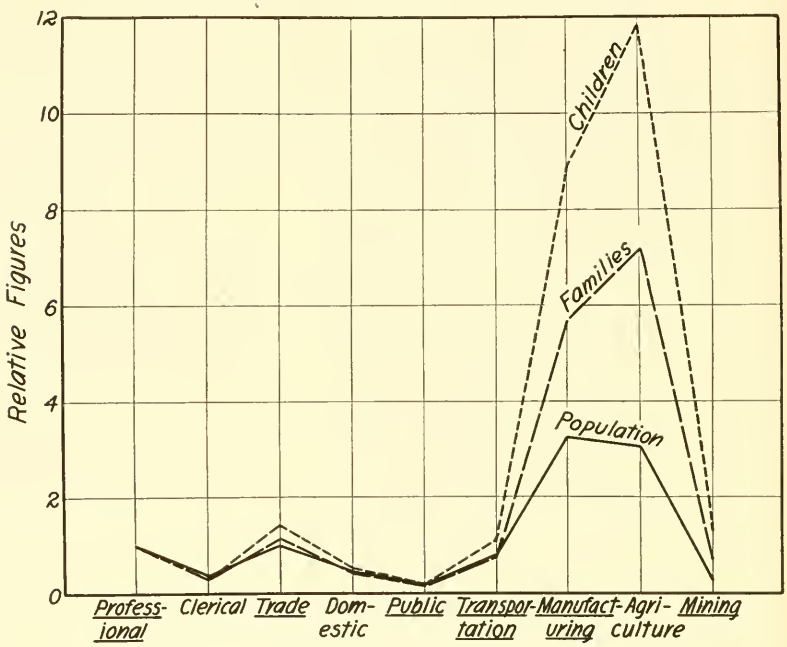

FIG. 10. Relative population and fertility by occupational classes.

that time, by a father who fell in the *Professional* class and was forty-five years of age or over in 1923, is taken as 1.0, the average size of family reproduced from mothers of 1923 by fathers who fell in the occupational class *Extraction of minerals*, and similarly aged forty-five years or over in 1923, was 1.9.

The professional, capitalistic group exhibits the lowest average size of family, and the labor groups, whether in factories, farms or mines, the highest. The facts are shown graphically in Figure 9.

Let us now examine the relation between fertility, the number of more fertile families, and the total population of occupied males, in the several reconstituted occupational classes. This is done graphically in Figure 10, on the basis

that for each of these variables the condition in the *Professional* class is taken as 1.0.

Broadly what Figure 10 shows is that:

1. For each male forty-five years or over in the class *Professional service* in 1920, there was 0.34 of a male of corresponding age in Clerical occupations; 1.60 in *Trade;* 0.47 in Domestic and personal service; 0.23 in *Public service;* and 0.79 in *Transportation.* In these six occupational classes more fertile families, as defined above, occurred in about the same proportions relative to the *Professional service* class taken as 1.00 in both instances, as the dash line of Figure 10 shows. This means that in these six occupational groups more fertile families are represented in about the same relative proportions to each other, as occupied males of corresponding age in the classes as a whole. This is only approximately true, because the population figures are for 1920, and those for more fertile families are for 1923. But the general consonance of the relative figures for the six classes named will probably not be significantly disturbed by this consideration.

2. For every male forty-five or over engaged in *Professional service* in 1920, there were 3.22 workers of corresponding age in *Manufacturing and mechanical industries;* 3.04 in Agriculture; and 0.27 in *Extraction of minerals.* But for every more fertile family, as here defined, in the *Professional service* class, there were 5.64 such families in the *Manufacturing* class; 7.18 in the Agriculture class; and 0.71 in the *Extraction of minerals* class. What these results mean is that families of more than average total fertility occurred in these three classes, in proportion to the male population of corresponding age, taking the *Professional* class as 1.00, from two to three times as often as they did in any of the six occupational classes discussed above.

3. The relative total number of children ever born, up to and including 1923, in the more fertile families is not widely different from the proportion, always relative to the *Professional* group as 1.00, in which the several occupations are represented in the general male population, so far as concerns the first six occupations. This means that in these six occupations the total fertility up to 1923, in the more

fertile group with which we are dealing, was nearly in simple proportion to the size of the groups themselves, having regard to age, and when the *Professional service* group is

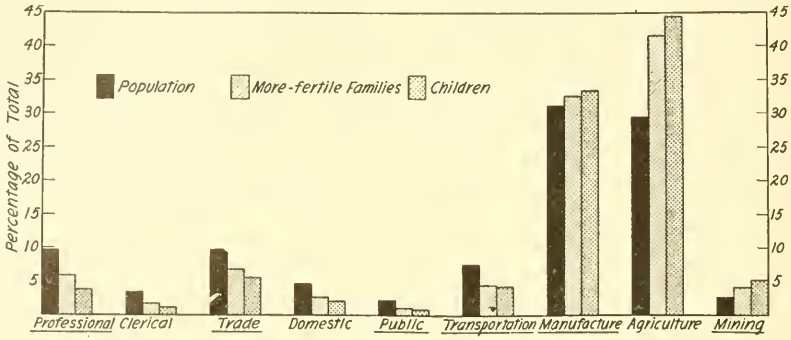

FIG. 11. Graph of the three percentage columns of Table VII.

taken as 1.00 in each instance. But in the three occupational classes *Manufacturing*, Agriculture, and *Mining* the case is quite different. Whereas there were 3.22 times as many males aged forty-five and over in the *Manufacturing* class in 1920 as in the *Professional* class, the females mated to males in the *Manufacturing* class had produced, up to and including 1923, 8.9 times as many children as had the females mating to the corresponding portion of the males in the *Professional* class, in the same period. In 1920 there were 3.04 times as many males forty-five years of age and over in the Agriculture class as they were in the *Professional.* But the total production of children up to and including 1923, by the more fertile moieties in the classes, had been 11.86 times as great in the Agriculture class as it had been in the *Professional.* In the *Extraction of minerals* class there were only 0.27 as many males forty-five years of age and over as there were in the *Professional* class. But the production of children up to 1923 had been 1.34 times as great in the former class as in the latter.

So far we have considered the populations, more fertile families, and total children ever born, of the several occupational classes, only in relation to the *Professional* group taken as 1.00. This procedure gives a correct picture of the situation so far as strictly interclass comparisons of

the unit elements are concerned. But it does not permit entirely correct conclusions to be drawn in respect of the important question as to the proportionate contribution of each occupational group to the total population of the next generation.

The figures necessary to permit the discussion of this point are given in Table VII, and are shown graphically in Figure 11.

TABLE VII

FERTILITY OF THE OCCUPATIONAL GROUPS RELATIVE TO THE TOTAL POPULATION

Occupational class (Reconstituted)	Per cent in each class in 1920 of males 45 and over (a)	Per cent of more-fertile families in 1923 (b)	Per cent of total children ever born to families in column (b) (c)
Professional service	9.66	5.77	3.75
Clerical occupations	3.33	1.66	1.10
Trade	9.69	6.71	5.36
Domestic and personal service	4.59	2.40	1.97
Public service	2.19	0.94	0.80
Transportation	7.43	4.44	4.15
Manufacturing and mechanical industries	31.13	32.57	33.37
Agriculture, forestry, and animal husbandry	29.39	41.43	44.47
Extraction of minerals	2.59	4.08	5.03
Totals	100.00	100.00	100.00

While the general trend of Figure 11 is similar to that of Figure 10, as it is in fact bound to be, Figure 11 brings out an additional bit of information that is not shown by Figure 10. What Figure 11 shows is that in the first six occupational groups (*Professional*, Clerical, *Trade*, Domestic, *Public*, and *Transportation*) the more fertile families in each group form a smaller percentage of the total number of more fertile families than the males forty-five years of age and over, in that same group do, of the total number of

occupied males of the same ages. The single cross-hatched column is shorter, in every one of these first occupational groups, than is the solid column. Similarly in these same six occupational groups the number of children ever born in each group forms a still smaller percentage of the total number of children, than do either the males forty-five years and over or the more fertile families in each group of their respective columns. The double cross-hatched columns in these six occupational classes are shorter than either the solid or the single-hatched columns. These results mean that the men aged forty-five and over in these occupational classes have not contributed to the next generation in as high a proportion as their own representation in this generation.

The case is quite different for the last three occupational groups (*Manufacturing*, Agriculture, and *Extraction of minerals*). In these three groups the percentage of children ever born, and the percentage of more fertile families is *higher* than the percentage of males forty-five years of age and over in the total population of occupied males. In each of these three occupational groups the double cross-hatched column is taller than the single cross-hatched columns, which in turn is taller than the solid column. The men aged forty-five and over in these three occupational classes have contributed to the next generation more than their own proportionate representation in this generation. The excess contribution is particularly marked in the case of the farmers.

Summing the whole case up it appears that the great laboring groups, *Manufacturing*, Agriculture and *Mining*, not only have a higher proportion of more fertile families per unit of population so occupied, than do the other occupational groups, but also they have a much larger average number of children per family. Put in another way it comes to this: In our population it appears that the *Professional*, Clerical, *Trade*, Domestic and personal service, *Public service*, and *Transportation* occupational classes are reproducing themselves in such a manner as not to maintain in quite its present status their relative representation in the population. But the heavy laboring classes, *Manufacturing*, Agriculture, and *Mining*, are reproducing themselves in

excess of their representation in the population. From this excess must necessarily be supplied the deficiencies in the first six classes in the next generation, if these classes are to maintain about the same representation in the total population that they exhibit in the present generation.

In a theoretically ideal social organization there would presumably be a constant relative number of persons engaged in each of the numerous differentiated occupations, which when integrated together are essential to the well-being and survival of the society as a whole. There is theoretically a fixed proportion of teachers, lawyers, store-keepers, laborers, soldiers and so on, necessary to the most economic functioning of the whole social organism. But in actual human societies there is no extraneous autocratic determination of these occupational classes. Instead the actual existing number is determined by a process of natural selection, in which processes economic factors are probably the most important element.

But another factor comes also into the case. The human units wear out faster in some occupations than in others, and therefore need to be replaced faster. Also this is not only an industrial country, but a country in which the increase of prosperity and well-being is apparently almost solely dependent now, has been for some time in the past, and presumably will be for some time in the future, upon the continued growth of industry.

In order to permit the population to increase roughly two and a half times, and enjoy the standards of living which prevail at the present time, it has been necessary to increase coal and pig iron production from 50 to 70 times, the cotton production 20 times, the railway mileage 3000 fold, and so on. It is only because the organization of industrial processes, inventions, and scientific discoveries have made possible the growth of industry of all sorts at the rates indicated that human beings have been able to enjoy the standard of living that they have and do, and at the same time permit the population to grow as it has.

These facts suggest further that all along there has had to be an increasing production of laborers, skilled and unskilled, in the manufacturing and mechanical

industries. Machinery alone does not make a profitable factory. There must be workmen to run the machines.

It is possible that the findings regarding fertility in this country are not widely divergent from what theoretically ought to be if our society is to continue in general prosperity and well-being, and continue to grow in these respects. In short do we not *need* to have laborers reproduce faster than the first six occupations on our list, in order first to take up the greater human wastage in the laboring classes, and second to permit of continued industrial growth and prosperity? Possibly a sound economic structure of the country as a whole is in a very real and considerable sense dependent upon just this relationship.

The facts set forth in Table VII plainly mean that some part of the next generation's supply of professors, doctors, lawyers, bankers, railroad presidents, and the like, will have to be recruited among the sons of the farmers and factory laborers of this generation. But what of it? Just precisely this relationship has always been true so far in the history of the world and probably will be for a long time to come. And furthermore from just the same sources will have to be recruited some of the clerks, typists, small tradesmen, job-holders, brakemen, motormen and various other citizens.

In the United States the agricultural group has for a long time produced far more than enough children to maintain its own industry. These farm boys have contributed in no small measure to the highest intellectual, social, and economic classes of our population. In fact the agricultural class has demonstrated an especial fitness to contribute sound stock to other occupational classes. It is possible that time will show that the industrial class in our large cities is, in already measurable and probably increasing degree, doing the same thing.

The falling birth rate and death rate and the type of occupational differential fertility discussed here may perhaps be regarded as adaptive regulatory responses, that is biological responses, to alterations in the environment in which human society lives. In this environment the economic element is perhaps the most significant biologically.

Additional evidence relevant to this discussion is afforded by an examination of the immigration statistics. In the year ending June 30, 1926, the net immigration (immigrants minus emigrants) of persons who had some occupation amounted to 133,752 persons. This figure is arrived at after deducting from the total net immigration 93,744 net immigrant persons of "no occupation," who were chiefly women and children.

Among the 133,725 immigrants having an occupation the percentage distribution was as follows:

Occupational class		*Percentage of total net immigrants having an occupation*
Professional		6.8
Clerical		11.9
Agriculture	19.1	50.2
Skilled laborers (chiefly manufacturing)	23.3	
Laborers	7.8	
Servants		19.5

Fifty per cent of the net immigration falls in the three occupational classes at the extreme right-hand end of Figures 10 and 11. These classes not only have the greatest fertility but they are the classes into which immigration is most heavily attracted. All this is a part of the picture of a predominantly industrial type of social organization. It needs all the time more and more workers if it is to continue to maintain or increase the average standard of living of its inevitably growing population.

CONCLUSION

In this chapter I have attempted to discuss a few of the many biological problems presented by human population from the viewpoint of objective, quantitative science. Some of the points discussed are the subject of major controversy from the sociological and humanitarian viewpoints. But with such controversies human biology, if it expects to be regarded as a science, can have no concern. Its primary objective must be to *describe* the phenomena accurately and in quantitative terms, and not to attempt to justify them, or deplore them, or get alarmed about them, or have any emotional reactions about them whatever. Perhaps when a clear, comprehensive and precise understanding of the

phenomena of human group biology has been achieved man can do something effective about purposefully altering some of its elements, if he then still desires to do so.

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Chapter XXIII

THE MINGLING OF RACES

Charles B. Davenport

RACES are groups of individuals within a species which differ by one or more well-marked characters. Thus, in the human species, we have the white, negro and Asiatic races; and, in the European group, we distinguish the blue-eyed, blond race of the Northwest; the brunette, long-headed race of the Mediterranean and the short-headed race that extends from the Alpine region eastward.

Wherever two races come to inhabit the same country they tend to hybridize. The question that arises is what about the children? Do they take after one race or the other or do they show a mixture of the unlike traits of the two races or will the traits blend in them? Will any mental differences in the two races be inherited? Will the hybrids be socially equal, or superior, to the pure races from which they are derived?

In the last quarter of a century more research has been made on race crossing in animals and plants than ever before. Certain principles have come about through this genetical research and we may well inquire in how far they apply to man. The first genetical principle, which we may test in man, is the principle of dominance. When two crossed races differ in that one possesses a trait that the other lacks, then one of three things may happen. Either the trait may appear in the offspring, in which case it is said to be *dominant*, or it may disappear in the first hybrid generation, in which case it is said to be *recessive*, or it may show a blend between the parental conditions, in which case it is believed to be of a genetically *complex nature*. Where the inherited trait depends upon a single dominant gene in the second hybrid generation, resulting from a mating of the F_1 hybrids, the dominant trait will ordinarily appear in three-quarters of the offspring, the other quarter being of the recessive type. In the case where the trait is not simple but compound, the

proportion of pure dominants, or recessives, in the second hybrid generation will be changed. Thus, instead of one-quarter showing the recessive condition, only one in 16 may show it fully developed, or even one in 64. In these cases all sorts of intermediate grades between presence and absence will appear.

The phenomenon of segregation appears in the second hybrid generation, as stated in the last paragraph, for some of the individuals show a trait and some do not show the trait. Actually, in any hybrid population, we do not have the experimental conditions set down in the foregoing paragraph for first hybrid generation individuals do not exclusively, or regularly, mate with each other. In most of the hybrid populations that we know there are, besides the crossing of first generation hybrids, back crossing with the parental types, second hybrid generations mated with second hybrid individuals, also with first hybrid generations, or the parental types. After three or four generations, the hybrid generation is a great mixture of all conceivable combinations of hybrid generations of various degrees with each other and with the parental stocks. In such a population, mingling by chance, we expect no definite proportions of individuals possessing any particular trait, or any particular blend, but rather a great variability in respect to the trait in question, some individuals being characterized by its presence, some by its absence and others by various grades between these extremes. The standard deviation of the trait in question is thus high in a hybrid population.

HETEROSIS

When two races are crossed it sometimes happens that the first generation hybrids show a character that is not favorable in either of the parental races. This result is ordinarily found in the case where a trait is dependent upon two factors for its expression. One of these factors, A, may be carried by the one race in which the trait does not appear phenotypically, the other factor, B, may occur in the other race which is also phenotypically without the factors. The combination, A B, will bring together the two essential factors and the trait is expressed phenotypically. To cite

an example from poultry, two races of white birds may be crossed and produce a bird with the full pigmentation of the jungle fowl. This is because one of the races is white, through the absence of factor B, the other through the absence of factor A, and the hybrid brings together the two factors essential to full coloration.

One of the commonest expressions of this law is seen in the union of races both of which are unable phenotypically to express their full developmental potentialities, due to the absence from each of some developmental factor. When this factor is different in the two races their union may result in the hybrid possessing more development-stimulating factors than either of the parental races possessed. Accordingly, the hybrid may show an exceptional capacity for growth. This result is known as hybrid vigor, or heterosis. We naturally look for evidence of heterosis in the first generation hybrid between two races.

In later generations some of the individuals possess both of the developmental factors in question. Others possess neither and others will possess one or the other so that we should expect in a later hybrid population to find a great variability in capacity for growth.

The case of hybrid vigor is well illustrated in maize. When any variety of maize is inbred it tends to produce dwarfed offspring. Indeed, the ears developed on such self-fertilized plants produce a small proportion of viable seeds. If, on the other hand, any female flower is pollinated with any other plant the large ears are produced and these, when planted, develop into vigorous offspring. If two depauperate products of inbreeding are mated in corn the offspring show this hybrid vigor.

Coming now to the traits of human races the first question that we have to consider is whether any of them are inheritable. It would seem to be foolish to raise this question, but we do so because such inheritance has been denied.

On the physical side we know of not a few traits that are inherited in accordance with simple Mendelian laws. Thus brown eye color is dominant over the absence of brown pigmentation in the iris, as exhibited by blue eyes. The first generation shows a dominance of the brown eye color and in

later generations browns and blues appear, with the browns in greater number, as we would expect in a dominant trait. In a hybrid population, derived originally from Nordic and South European stock, we get in the same family brown and blue-eyed children in varying proportions. This is because the germ cells of the parents are dissimilar, due to the hybrid origin of their parents.

In some other cases, inheritance is more complicated, as in skin color. It has been shown that in the first generation hybrid between white and a black-skinned negro the children are of an intermediate color, as we see in the mulatto. When two mulattoes are mated their offspring are partly mulatto; sometimes they have a darker color to which the term "Sambo" is applied; sometimes the lighter color of the quadroon. If, indeed, a large number of the children of such first generation hybrids are examined it will be found that in every sixteen there is, on the average, one white child and one full black. This is the basis for the conclusion that the brown or black skin color depends upon two pairs of factors A and B. In the negro these two pairs are both active in the mulatto; the A and B factors are both present but unpaired. Of the germ cells of the hybrids some carry the factor A only, some the factor B only, some neither factor and some both factors A and B. When two germ cells, both carrying A and B, unite, the full black color is restored; but when two others unite, neither of which possesses A and B, the offspring will be white. Other combinations will give brown to black skin color.

Still other traits are even more complicated in their inheritance, partly because there seem to be more than two pairs of factors involved and partly because the development of the trait is to a considerable extent influenced by environmental conditions. Thus it is known that a tendency to be over-fat is inherited so that we may speak of an inherited factor in the building of the body. We have reason for believing that slender parents are such by virture of the absence of factors that promote the laying on of fat. In two such slender parents, especially if of slender stock, all of their offspring remain slender. Through excessive feeding or inactivity these offspring may lay on fat but

they do not lay it on readily, or are easily disturbed in their alimentary functions by overfeeding, and return readily to their normal weight after the super-feeding, which they generally find distasteful, has ceased. On the other hand, persons derived from a union of two families in which fleshiness is common often find (1) that they have fairly large appetites and (2) that they tend to lay on flesh, even with moderate feeding, (3) that they are tolerant of large amounts of food and, (4) that dieting and exercise are able to reduce their build only slowly and with great difficulty. Nevertheless, the fact that variations in food ingestion play some part in body build complicates the study of inheritance of this trait.

Not only physical traits, like eye color, skin color, body build and such characters as stature, color and form of the hair, proportions of facial features and many others are inherited in race-crosses but also mental traits. This is a matter which is often denied, but the application of methods of mental measuring seem to have produced indubitable proof that the general intelligence and specific mental capacities have a basis and vary in the different races of mankind. Thus it has been shown, by standard mental tests, that the negro adolescent gained lower scores than white adolescents and this when the test is made quite independent of special training or language differences and also when the children tested have a similar amount of schooling. Not only the psychological examination in the army but also the special studies made by Mayo and others, working in the Department of Psychology at Columbia, and many other investigations are agreed in this result. On the other hand, it seems probable that, in the matter of sense perception and discrimination, the negro race is, in general, superior to the whites. Tests made on whites and negroes in Jamaica indicate that the negroes are superior in their ability to discriminate slight differences in musical pitch, intensity and time. There is no doubt, in view of the studies of Dr. Hazel M. Stanton, that differences in capacity for such discriminations are inherited and we can, therefore, understand the more readily how they may become racial traits.

Not only in respect to physical traits and mental traits do races of mankind differ, but also in regard to temperament. Common observation shows that the emotional output of different peoples is very different. We note that the North American Indian is little given to emotional expression. On the other hand, the African negro expresses his emotions copiously. In Europe the Scotch Highlanders are characterized by a prevailingly somber tendency, while the South Italians are characterized by lightness of spirit. Now there can be no question that temperament is inherited, though in a rather complicated fashion. This was worked out some years ago by the author, who found a factor for excitability which is possibly a simple Mendelian dominant and a factor for cheerfulness which may, or may not, be combined with excitability. The combination of these two factors results in persons who are, on the one hand, both cheerful and excitable and, on the other hand, in those who are cheerful and somewhat stolid; those who are of a depressed temperament and easily aroused and, finally, those who are both depressed and unresponsive to stimuli. These conditions are inherited and show definitely that when one parent exhibits excitability, at least half of the children will show a similar trait. Where both parents are depressed, all of the offspring will show a general depression. The differences in temperament of different peoples are not to be ascribed to their environment but to differences in bodily, physiological functions which determine unrestricted output of the emotions on the one hand, or inhibitions of output on the other.

Not only in temperament but also in instincts do the races of mankind differ. For example, it is well known that most of the races of Europe are fairly stable and domestic, engaged in agriculture or industry. However, from eastern Europe and western Asia have come forth races of mankind with a strong tendency to wander over the face of the earth. Such are the Gypsies which have run through Europe and America and such are some nomadic peoples who are scattered across the face of Asia and Northern Africa and who even before the time of Livingstone had penetrated into the heart of Equatorial Africa. Now the instinct to wander, or nom-

adism, is one that has an hereditary basis. This has been worked out in some detail by the author and the results of his investigation have, so far, not been disproved. We have evidence also that other instinctive qualities are characteristic of the different races of mankind and have likewise an hereditary basis.

A race is more than a haphazard collection of individual traits. Each well-established race which has persisted for many generations in the same locality has gained in the course of these generations an adjustment to the particular environmental conditions in which it lives. This adjustment to environment has been brought about in man by a different method from that employed with domestic animals. A breeder of dogs, let us say, finds a mutation which offers certain advantages to the possessor for particular purposes. He seizes upon this advantageous trait; succeeds in reproducing it by breeding and then seeks to place the dog, or the new breed of dogs, in a position where it can make use of this trait. It will be observed that the new mutation is not, from the beginning, better or worse, but it is better or worse for a particular environment in which the animal is to be placed. It remains, in order that the mutation should be advantageous, that the dog should come to find an environment for which this new trait peculiarly fits it. Thus, in the course of time, there have come into existence many races of dogs which differ from each other in form or in temperament or in instincts, and for each of these differences some niche has been found which has made it possible to preserve the particular strain of dogs as a useful race.

So, also, in mankind the races that have survived have been those which have become possessed of one or more traits that have peculiarly fitted them for the environments in which they arose or which have enabled the possessor to find an environment in which the new traits would give him a special advantage. The adjustment of races to their environments depends first upon the possibility of mutation. The experience of geneticists in the last twenty-eight years has demonstrated that such mutations are constantly present in all species of animals and plants. The problem is no longer how mutations arise but rather how it comes about

that a species can maintain for a long time its specific characteristics in the midst of such widespread mutation. One answer to the last question is that so many mutations are lethal, or disadvantageous, that their possessors are eliminated. If all the traits that arise through mutation are not disadvantageous they do not handicap the possessor and may persist. If they give the possessor an advantage in his environment or in some other environment to which he may migrate then he will have a peculiar opportunity to survive and perpetuate these advantageous qualities. An important principle then is, to recapitulate, that each race that has inhabited an environment for a long time has become adjusted to that environment by the acquisition of certain favorable mutations.

The question at once arises, what happens in the case of hybrids who are representatives of two such adjusted races? Will the new combination of characters that arises in the progeny be more or less fitting for the hybrids in the situation in which they find themselves?

With these general principles in view we proceed now to a more or less systematic survey of the principal groups of human hybrids that have been produced.

1. *Indian-European Crosses.* A crossing between the American Indian and the white man has frequently taken place in the Americas. In South America the early Spanish conquerors were young, single men, some of whom established themselves in America and produced large families of hybrids with the Indians. Some of the descendants of these unions are among the leaders in South America. They have more ambition than the average Indian and they are better acclimated to the tropical conditions met with in certain parts of the west coast of South America, than are the Europeans. In the early days of North America also, French adventurers penetrated in large numbers into Canada and left a numerous hybrid progeny. These were often characterized by great vigor and activity and ability to withstand the hardships of frontier life. Precise measurements of intelligence of Indians, Mexicans and mixtures between them by Garth (1922) leads to the conclusion that the mixed bloods are the most intelligent of the groups.

2. *Negro-white Crosses in America.* Many crosses were made in Brazil between Portugese and negroes, producing a race known as the Metis which is not, in general, characterized by hybrid vigor. Tuberculosis is said to be common among them. They show dissatisfaction with agricultural life and have often proved to be unreliable in matters of trust. Many of them are keenly intelligent but generally are fond of display, rather than of solid achievement. There has been no social barrier to their progress and they frequently achieve high political office.

The negro-white hybrid of North America and of the United States results from a cross between two races that resemble each other in stature, though they differ in their proportions, for the negro has longer legs than the white. In the mulatto hybrid the skin color is intermediate; the form of the nose, the prognathism and other facial features are blends of the two races. In body build the mulattoes are, on the average, slightly superior to the whites, at least this was true of the white and negro soldiers returning from France in 1919. The negro has, on the average, many advantages in physical qualities over the white. He is much less apt to suffer defects of the spine; and goiter, obesity, deaf-mutism, deafness and most important diseases of the eyes and nasal fossae and throat are less common in his case than among whites. The mulattoes exhibit many of the excellent physical qualities of the negro, but on the other hand, they have an extraordinarily high incidence of tuberculosis and the venereal disease rate is several times higher than among the whites. The mulatto, however, is more restless, on the whole, than the negro and less easily satisfied with his lot. This is possibly due to a disharmony introduced by the cross. In the United States the colored population has a crime rate of between two and three times that of the white.

3. *Hottentot and Dutch.* Hybrids between the Hottentots and Dutch of South Africa have been extensively studied by Professor E. Fischer. He finds that the bastard males show some evidence of hybrid vigor but they are said not to be more variable than the Dutch in respect to stature and some other qualities. However, the bastard stock contained few

pedigreed individuals. Perhaps the general low variability found by Fischer in various traits may be due to a mate selection of an intermediate type, the extremes being eliminated. Fischer finds these hybrids between phlegmatic, industrious, thrifty, Dutch stock and the Hottentot stock, on the average, honest and faithful. They are serious, without being melancholy. They show a good deal of curiosity. They lack energy, pertinacity, foresight and prudence. They do not properly control their strong taste for alcohol. We have, here, evidence of a composite of the behavior of the parental stocks. Seriousness is a Dutch trait. Curiosity is a trait of primitive peoples to whom a strange sound or unexplained object may mean a lurking cause of death. Curiosity is an intense desire to know; knowledge is a necessary preliminary to defense. Extreme energy in pushing through undertakings against difficulties is a European and not an African trait and this the bastards do not get. The need of alcohol is associated with a serious, mildly depressed temperament which finds relief in the effect of spirits. This need may result, also, from a feeling of insufficiency, a reflection of an internal conflict of instincts.

4. *Polynesian Hybrids.* The Polynesians of Hawaii have been extensively hybridized. The native Hawaiians have been crossed with Nordic Europeans, Portuguese, Chinese and Philippinos. The results of these crosses have been described by Porteus (1926) and by Dunn (1928). The Chinese coolies are thrifty and frugal and have a strong sense of family duty and responsibility. They are individualistic and secretive and show a marked tendency to murder. The Chinese-Hawaiian hybrids stand first among all of the hybrids in industry and self support and are sought for in positions of responsibility. The docile temperament of the Hawaiian and the intellectual elements of the Chinese are combined. The excellent home training afforded by the Chinese fathers is largely responsible for the high ideals of their offspring. In the Hawaiian-white union, the restless, ambitious, individualistic temperament of the white appears to be dominant. A study of physical features of the hybrids between Hawaiians and Europeans has been made by Dunn. The shorter head of the Hawaiians is inherited as a dominant

in the hybrids. The broader noses of the Hawaiians also reappear in the hybrids. The darker hair color, the wave of the hair, the dark eye and skin of the Hawaiians are, at least, partially dominant in the offspring. Much variability is found among the hybrids of the second and later generations.

5. *The Philippinos of Luzon.* The Philippino has come in contact with the Chinese, Japanese, Negrito and Caucasian and has in himself their united and commingled bloods. The result is an over-emotional, weakly inhibited hybrid. Transported to the Hawaiian Islands the Philippinos, though constituting only about 10 per cent of the population, are responsible for over 42 per cent of the murders and 43 per cent of the sex offenses. Porteus explains their impulsiveness, noisy self-expression, alternating obstinacy and suggestibleness, as due to a conflict of dissimilar temperaments. Ordinary education is not suitable for them. "An education," he states, "that stimulates an unattainable ambition is cruelty."

6. *The Dutch East Indies.* In the neighborhood of the Straits extensive race crossing has taken place from early times. The Chinese have penetrated into the East Indian islands in great numbers. Their children are comely of form and possess excellent manners. This, again, may be in part due to the discipline of the Chinese fathers. However, hybrids with the Dutch are likewise possessed of much beauty and grace so that the traits of the native Malays have contributed much to the high quality of their offspring. In Sumatra the hybrids between the Dutch and the native women enjoyed the status of the Europeans and many of these hybrids, after European training, have come to fill offices of distinction in the islands. Thus, in the Dutch East Indies, we find little adverse effect on the progeny resulting from hybridization.

7. *Eurasians.* In India hybrids between native women and European men have been produced in considerable numbers. These are called Eurasians. While able to endure the climate of India better than the Europeans they are said to lack in industry and perseverance. They are less useful as clerks than the natives because they often decline to learn the

native language and are, thus, cut off from transacting business with the natives. Serious temperamental conflicts seem to occur in their emotional life.

8. *Scandinavian-Lapp.* Among the European races, one crossing that has been most thoroughly studied is that between the Lapps and the Scandinavians. Mjöen finds that the hybrids are non-resistant to tuberculosis, feebly inhibited to alcohol and show an unusual amount of psychic disturbance and criminalistic behavior. Dr. Halfdan Bryn, the anthropologist, likewise states that he has a firm impression that crossing between Lapps and Norwegians is especially bad for both parties. He cites the large number of cases of congenital dislocation of the hip and suggests that this is due to disharmony between the pelvis and the head of the femur. Lundborg also finds the Lapp-Swedish crosses to be especially susceptible to tuberculosis.

This survey of the results of race crossing leads to the conclusion that there is no single rule that applies to all racial hybrids. Some of them, like the French Canadian-Indian hybrids and the Chinese-Hawaiian seem to show hybrid vigor; others, like the Eurasians, show an enfeeblement. Some are devoid of beauty of form and figure while others, like the Javanese-European crosses, are characterized by comeliness and grace. The most widespread physical defect seems to be a liability to tuberculosis, although it is possible that this is due to a persisting lack of resistance, inherited from the more primitive race, and contact with European carriers of the disease. The most serious defect found in hybrids is perhaps the bad behavior of Philippino hybrids and the negro-white crosses, apparently due to conflicting instincts.

In regard to variability of hybrids, there has come to be a difference of opinion. Herskovits has found a low variability of the negro-white hybrids in respect to stature, height of nose and cephalic index. These are, however, characteristics in which the negroes and the whites are not strikingly dissimilar and, therefore, a high degree of variability is not necessarily to be expected. On the other hand, it is clear that in features which are most unlike in the parental races, hybrids are most variable; as, for instance, in the skin color

and nose breadth that show such great variability in the mulattoes. Fischer also refers to the low variability in the bastards of South Africa and Rodenwaldt is surprised by the same phenomenon in the hybrids of Kisar. Here, again, the disappointment is perhaps due to expecting a generally greater variability of hybrids. The greater variability of the hybrid is to be found only in those traits, if any, which are strikingly dissimilar in the parental stocks.

As a result of this rapid survey of race crossing we are led to the conclusion that there is no universal rule as to the physical or social consequences of race crossing. Sometimes the progeny are superior to, sometimes equal to, sometimes inferior to the parental stocks. In the absence of any uniform rule as to the consequences of race crossing and in view of the disharmony shown by many hybrids it is well to discourage hybridization between extreme types, except in those cases where, as in the Chinese-Hawaiian cross, it clearly produces superior progeny. The negro-white and the Philippino-European crosses seem, on the other hand, of a type that should be avoided.

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Chapter XXIV

THE PURPOSIVE IMPROVEMENT OF THE HUMAN RACE

Edwin Grant Conklin

THAT the human race is physically, mentally and socially far from perfect and that there is great need for improvement in each of these regards is universally admitted. The armies of defective and delinquent persons in every nation and race, the crowded hospitals, asylums, jails and penitentiaries in almost every country, the enormous cost of caring for this human wreckage and wastage, all testify to the fact that there is urgent need for improvement. Indeed it is merely a question of how long civilization can continue to carry this ever-increasing burden of the bungled and botched, of paupers, feebleminded and insane, of bums, thugs and criminals. In the United States it is said that the cost of maintaining public custodial institutions for these social parasites is from one-third to one-seventh of all the public revenues of the several states, while the direct and indirect cost of crime in this country has been estimated from three and one-half billion dollars each year at the lowest figure to twenty billions at the highest (Prentiss, 1927). There is no doubt that the human race, in America as well as in other countries, stands in the utmost need of improvement, if civilization is to endure and progress.

But is there any possibility of checking this tide of degeneracy and of turning it in the direction of racial improvement? Is it one of the inevitable results of civilization that progress for the few means degeneration for the many, and that in the end the weeds must necessarily choke out the wheat? The histories of many great civilizations of the past would seem to confirm the opinion, sometimes expressed, that civilization itself is a disease which ends in suicide. But on the other hand our greater knowledge of nature and of man places in our hands the power to combat the evils which have overthrown former civilizations and to

turn the current of human evolution from degeneracy to progress. Already we know how to improve the breeds of domestic animals and cultivated plants; we know that man also is a living creature and that all the principles of heredity and development, of progress or degeneration, of life or death apply to man as well as to the humblest animal or plant. Mankind could, if it would, breed a healthier, more intelligent, more ethical type than the general average of the existing race. Exactly the same principles which are used so successfully in the improvement of horses or cattle or crops would produce corresponding results if applied to human reproduction and development.

PRINCIPLES OF GOOD BREEDING

What are these principles of good breeding which have doubled the best speed of horses, the best weight of cattle, the best yield of wheat during the past century? They may be summed up under two general heads: (1) improved heredity through selective breeding: (2) improved environment through better food, nurture, training. No successful breeder neglects either of these factors.

The only living bond between one generation and the next is found in the germ cells, and whatever is inherited must be carried in these cells. Of course no adult characters are present in germ cells, but certain *genes* or inheritance factors are contained in those cells and by the interaction of these factors on one another and by their reactions to environmental stimuli the adult characters gradually develop. Every developed character is the result of many factors or causes, some of which are inherited (that is they are present in the germ cells) and others are environmental. For example, there are multitudes of factors both hereditary and environmental involved in the development of the eye; most of these are common to all eyes and hence are non-differential, but as between a blue eye and a brown one there must be at least one differential factor and if this factor is located in the germ plasm, as it is, the eye color is said to be inherited in spite of the fact that many of the factors in the production of this character are environmental. However, if the differential

cause of any character is found in conditions outside of the germ plasm, as for example in the production of blindness by drinking wood alcohol, the character is plainly environmental. When such environmental factors act at an early stage of development, and especially before birth, it is often difficult to distinguish them from hereditary ones. But whenever a particular trait appears in several individuals of the same family or confraternity, it is generally safe to say that its differential cause is inherited. On the other hand, if it occurs but once or rarely its cause may be either hereditary or environmental and in such a case only the study of the progeny of such individuals, preferably under experimental conditions, will reveal which is the differential factor.

Even the development of inherited characters may be modified by environment, especially if it acts at an early stage in development, and consequently the breeder must select not only good seed or stock but he must also provide good soil, food and care if he is to produce superior plants or animals. Heredity and environment are not contestants but cooperators in making or destroying breeds or races or civilizations. Heredity furnishes the materials, environment shapes and uses them; heredity is the mechanism, environment is the stimulus which sets it in action; heredity fixes the possibilities of development, environment determines which of these possibilities shall become realities.

As applied to man these principles of good breeding are known as eugenics and euthenics. They are never in conflict, though this cannot be said of all eugenicists and euthenicists. Both principles are indispensable in all development whether it be that of the body or of the mind, of the individual or of society, and where two factors are indispensable it is useless to debate which is the more important.

But while we cannot match these factors against each other we can point out some of their contrasts. In general heredity is more constant, environment more variable; heredity more specific, environment more general; heredity less easily controlled, environment more easily controlled. Therefore in efforts for human betterment more attention has

been paid to euthenics than to eugenics. Indeed almost all the agencies that have been employed for the betterment of mankind have been aimed at the improvement of the environment. Among these are government, education, religion, art, literature, science, medicine, sanitation, engineering; and practically everything which we include in that social complex which we call civilization.

Only eugenics, which is the attempt, or rather the proposal, by man to breed from the fit rather than the unfit, and natural selection, which is this same objective attained by the slow and wasteful processes of overproduction and the elimination of the unfit in the struggle for existence, are directed to the improvement of heredity. And yet for continuous and lasting human progress there must be improvement of heredity as well as of environment. As the motto of good photography is "Get it in the negative," so the motto of good breeding is "Get it in the blood."

The only known method of improving heredity purposively is by selective breeding, that is by mating individuals that come of good stock and that show good qualities, and by the prevention of the breeding of poor stock and of defective individuals. No method is known by which inheritance factors can be improved directly. Very rarely such factors may undergo change, or what is called mutation, but such changes are generally for the worse rather than for the better and their causes are almost wholly unknown. Neither the experience of breeders nor the principles of genetics holds forth any hope that bad inheritance factors can ever be purposively changed into good ones. The only practicable method of improving heredity is by selection of the best and elimination of the worst.

And yet there can be no progress apart from favorable environment, and human progress is peculiarly dependent upon it. Man's environment is more extensive and more varied than that of any other living creature and its effects on his development and activity are correspondingly greater. In addition to the same sort of environment which he shares with other organisms, he is peculiarly affected by intellectual and social stimuli. By means of language, institutions and education, the experiences of men in all countries and

ages may be a part of his environment. Furthermore, by intelligence and social cooperation, men are able to control their environment as no other creatures can. Indeed it may be granted at once that the only possibility of the purposive improvement of the race lies in the control of environment, using this term in its broadest sense, and thus including the selective agency in propagating good stock and eliminating bad. For even the improvement of heredity must rest upon science, education and social cooperation and all of these are parts of human environment.

The great importance of environment in human life and progress has led some environmentalists to minimize the importance of heredity. They sometimes assert that it determines only unimportant physical traits such as the color of the eyes or hair, and that environment determines all the rest. But of course there is a basis in the germ cells for everything that will ever develop out of those cells and in many instances this germinal basis is the differential cause of many important characters. It is needless to say this to biologists, but there are some psychologists, sociologists and apostles of human equality who still maintain, in the realm of theory but not in actual practice, that "all men are born equal" and that the differences between races and classes and individuals are caused only by differences in environment, and not by differences in heredity.

Of course the major differences that distinguish one species from another are inherited; each "produces seed after his kind." Men differ from horses or dogs primarily because they come from different kinds of germ cells. In the same incubator and under practically identical conditions, a hen's egg develops into a chick, a duck's egg into a duckling. Similarly racial traits, such as those that characterize different breeds of dogs or horses or men, are inherited. This is true not only of physical but also of psychical characteristics; the bull dog, or pointer, or hound inherits not only his physical but also his mental and temperamental traits; the European, the Asian, or the African inherits not only his skin color, hair form, shape of eyes, nose, lips, jaws and skull, but also many of his mental, emotional and social peculiarities.

Likewise traits that occur repeatedly in the same family and under various environmental conditions are certainly inherited, and this is true not only of physical traits but also of psychical ones. In the case of dogs the type of behavior characteristic of different breeds is as certainly inherited as is their physical form. There is good evidence that the same is true of different breeds of men. Some families are predominantly highly emotional, others stolid; some intellectually brilliant, others stupid; some contain many feeble-minded individuals, others many that are insane. Where such traits are repeated in several members of a family and under various environmental conditions there can be no doubt that they are inherited. By the very definition of racial or family traits they are inherited; otherwise they are not racial or family traits.

It is only when we come to the individual differences that appear in members of the same race or family that questions arise as to whether they are hereditary or environmental. Children of the same family may be male or female, tall or short, light or dark, cheerful or morose, wise or foolish, and therefore it was formerly held that such individual differences must be the results of differences in early environment, since all children of the same parents were once supposed to have the same heredity. But since the rediscovery of Mendel's law in 1900 we know that each parent transmits only half of his or her inheritance factors to children and almost never the same combination of factors. Of course parents can never transmit factors which they do not possess and consequently "the inherited nature of the offspring is determined by that of the parents until men gather grapes of thorns or figs of thistles." (Bateson, 1921).

Individual differences, therefore, may be caused by new combinations of inheritance factors and very rarely by new mutations of those factors, or by modifications of the environment; sometimes only a study of large numbers of individuals of the same stock and under varying environmental conditions will reveal whether these differences are hereditary or environmental.

DOES GOOD ENVIRONMENT OR TRAINING IMPROVE HEREDITY?

It has long been an article of faith with extreme environmentalists that improvement of environment will improve not only development, but also heredity itself. Doubtless inheritance factors can be modified in rare instances by changes in environment. It has been shown that such modifications can be produced by *x*-rays, though these are almost always of a degenerative sort. But there is no satisfactory evidence that good environment will produce improvements in heredity or bad environment, bad heredity: no evidence of the inherited effects of use or disuse or training. A given kind of wood, such as pine, oak or mahogany, may be shaped into chairs, tables or doors by the tools and forces that act upon it, but the wood itself does not change its nature. Similarly a given kind of egg, such as that of a fish or frog or bird may have its development shaped and modified to a certain extent by the environment that acts upon it, without changing its fundamental nature or heredity.

In the mental and social fields, as well as in the physical, there is no satisfactory evidence that the effects of use or disuse are inherited in the biological sense. Numerous claims of such modification of heredity have been made. One of the most important of these was announced in 1923 by the distinguished Russian physiologist Pavlov who found that it took about 300 trials to teach the first generation of white mice with which he experimented to come to food on the ringing of a bell, the second generation came in about 100 trials, the third in 30, the fourth in 10, and the fifth generation in 5 trials. Here was apparently an amazingly rapid inheritance of the effects of training, indeed it was so at variance with all other experience in animal training and in human education that it was generally discredited in spite of the scientific standing of the author. Recently Pavlov has admitted that his results were based on errors and he withdraws his claims as to the inheritance of the effects of training (McDougall, 1927). The psychologist Wm. McDougall, has recently (1927) published the results of a very careful and extensive study of the inherited effects of the training of

white rats through twelve to seventeen generations. He is convinced that there is some evidence that such training does slightly affect heredity, but such modification is so slight and slow that he honestly admits the improbability of greatly improving the human race by the inherited effects of good environment, good training or good education. Other investigators, notably Bagg (1920) and MacDowell (1924) have found no evidence that the training of ancestors facilitates the learning of the descendants in the case of mice and rats.

Of course good environment, training and education greatly improve individual development but in spite of the fact that no one has ever proved conclusively that they improve heredity or that the effects of use or disuse are inherited, this doctrine of "the inheritance of acquired characters" is still maintained by many persons who feel that it ought to be true even if it is not, and who sometimes, by hook or crook, attempt to make nature agree with their theories. So many persons have gone wrong morally in maintaining that acquirements are inherited, from the patriarch Jacob in his dealings with his father-in-law Laban down to a few real scientists and many pseudo-scientists of the present day, that an interesting article might be written on "The influence on moral character of the doctrine of the inheritance of acquired characters." If the inheritance of acquired characters were as important a factor in human progress as some persons suppose, it would not be necessary to make a minute search for it in every hole and corner, it would occur frequently and indubitably, but even its defenders must admit that it occurs rarely and doubtfully if at all. All human experience teaches that children still have to learn their mother tongue, that they still have to be "house-broken," that they still have to be taught good habits, that they still must be taught what is right and what is wrong, although such training has been going on for countless generations. In these and in a thousand other instances the universal experience of mankind confirms the conclusions of the biologists that the effects of training are not inherited.

But while the acquirements and experiences of former generations are not passed on to descendants through the

germ cells, they are passed on through many forms of social communication, through imitation, signs, language, writing, education, customs and institutions. This has been called "social inheritance," but it is not inheritance at all in the biological sense but rather a part of the social environment. By means of social continuity each generation is bound to every other one, each later generation builds on the work of earlier ones. Thus science, art, government and culture in general advance from age to age: whereas in germinal inheritance later generations begin almost where earlier ones began and not where they ended. It is this immensely important difference between germinal and social inheritance that makes biological progress so slow as compared with social progress. It is this which causes knowledge to outrun performance, and ideals to point the way to realizations. It is this continuity and development of society from generation to generation which makes possible such a topic as "the purposive improvement of the human race." And it is this contrast between the rapid improvement of environment and the slow improvement of heredity that causes many persons to seek some short cut to the desired haven of a more perfect human inheritance. Unfortunately no such short cut has ever yet been found and so far as we know at present the only possible method of improving heredity is by the method of selective breeding.

APPLICATION OF BIOLOGICAL PRINCIPLES TO HUMAN BETTERMENT

These are the fundamental principles that govern individual and racial development and any program for the improvement of the human race must rest upon these principles. In what practicable manner can these principles be utilized and controlled for race betterment?

The tremendous improvements that have been effected in almost all breeds of domestic animals and cultivated plants by the method of selective breeding have led certain enthusiastic eugenicists to predict that corresponding improvements in the human race could be made in a relatively short time by the same method, and many persons have looked forward to a eugenic paradise in which all

physical deformity, mental defect and moral delinquency would be abolished and "men like gods" would people the earth. But a more careful and cautious appraisal of the difficulties involved has led many biologists to the conclusion that while the principles of good breeding apply to man as much as to any other organism, the practical difficulties in the way of utilizing these principles are so great that it is hopeless to expect any rapid improvement of the heredity of the race under existing social conditions or under any others that are likely to be realized within the next few centuries. Under popular forms of government, the great mass of mankind cannot be expected to observe the laws of good breeding and to eliminate from reproduction all but the very best hereditary lines, and the most that can be expected from the prevention of the breeding of defectives is that the race may be saved from further deterioration. If some wise and benevolent despot, or if some superhuman intelligence and power, were to control the breeding of men as man controls his flocks and crops, the same sort of improvement could be brought about in the human race as has been accomplished in the case of domestic animals and cultivated plants. In a certain sense, society has such power and it can impose all sorts of restrictions and inhibitions on individuals, but it is more than doubtful whether it has superhuman intelligence or benevolence. Under these conditions, the whole program of human eugenics is reduced to an attempt to prevent or reduce the breeding of the worst lines, to promote the breeding of the best types and to leave the great mediocre mass of mankind to people the earth as it has always done in the past. How inefficient such a program is can be appreciated if one compares it with the rigid elimination from reproduction of all but the best lines in modern stock breeding. And how long it would take markedly to improve the entire human race by such a feeble measure can be left to those who deal with geological ages and light-years.

The difficulty, or rather the impossibility, of any more radical program of eugenics than that indicated above, namely the gradual reduction of the fecundity of the worst human types and the encouragement of greater fecundity

in the best types, makes it extremely improbable that any great or rapid improvement in the inherited nature of the human race can be produced by this method. It is relatively easy for the breeder of animals or plants to choose the types which he wishes to propagate and to make new combinations of desirable traits, but the case is far different in man where in the main restrictions on reproduction must be self-imposed, where there is little uniformity of opinion among different people and in different ages as to what is the best human type, and where social and moral customs are at variance with the best genetical procedure. Alexander Graham Bell (1914), who was greatly interested in human eugenics and who was also a skillful breeder of sheep, once contrasted the differences in the technique of sheep-breeding with the social conditions governing human reproduction, by supposing that the sheep breeder were compelled to observe human customs, namely (1) all must be allowed to breed and none must be sterilized, (2) weaklings and deformed individuals must receive special care and must be permitted to propagate, (3) polygamous and consanguineous unions must not be permitted, (4) every individual must be allowed to choose its own mate and for life. Under such conditions, he says, no improvement in a flock would be possible, and as long as these social conditions prevail among men no hereditary improvement in the human stock will be possible. But already the first and second of the social customs named are being changed, and we may confidently look forward to the time in the near future when all civilized societies will prevent the propagation of the worst forms of bodily defect, mental disease and moral degeneracy that are known to be inherited. But even for the purpose of breeding a race of supermen mankind will probably never consent to abolish marriage and monogamy and adopt the morals of the farmyard and the breeding pen, for by such methods more of social value would be lost than could be gained biologically.

IS THE PROGRAM OF EUGENICS BIOLOGICALLY SOUND?

These and other practical difficulties in the way of eugenical progress have been pointed out by many biologists

as well as by popular writers. Long ago (1872–1873), Darwin expressed to Galton his doubt as to the feasibility of any satisfactory method of selecting the best human stocks and Huxley (1894) indicated the difficulties and dangers of permitting any individual or class of individuals to decide which human families were most fit. Recently several leading students of genetics have criticised many phases of current eugencial propaganda. Bateson (1921), in his Galton Lecture before the Eugenics Education Society, while endorsing the fundamental principles of eugenics, said that we know altogether too little of the ways in which heredity and environment cooperate to produce genius to justify at present any extensive interference with human reproduction. He pointed out that eugenic caution might have lost to the world Beethoven, Keats, perhaps even Francis Bacon, and to these names he might have added many others, such as Schubert, Faraday, Lincoln and a host of others in whom democracy glories. Still more recently, Jennings (1925) and Pearl (1927) have stressed the difficulty, if not the impossibility, of deciding who are the fittest and the real danger that any attempted decision of this kind might be made on the basis of family, class or race pride and arrogance. Both of these authorities also emphasize the fact that good and bad heredity are so mixed in all men, in short that man is such a mongrel or heterozygote, that no one can predict with any degree of accuracy what the individual characteristics of the children of any particular mating will be, and both insist that social distinction may depend more upon environment than upon heredity.

All modern geneticists approve the segregation or sterilization of persons who are known to have serious hereditary defects, such as hereditary feeblemindedness, insanity, etc., but they very properly object to the extravagant proposals to sterilize all persons who are socially delinquent. Bateson says that the sterilization of habitual criminals, which has been mooted in America, might eliminate many with good inheritance as well as those with hereditary defects. Morgan (1925) says that the segregation of defectives is now attempted on a somewhat extensive scale in asylums of the insane and feebleminded, but that he "would hesitate to recommend the

incarceration of all their relatives if the character is suspected of being recessive." In view of the fact that East (1917) has estimated that feeblemindedness is carried as a recessive in one person out of fourteen in the entire population of the United States, this hesitancy on Morgan's part is more than justified.

As contrasted with some of the extravagant proposals of propagandists, against which these scientists have protested, should be cited the actual proposals of legislation regarding sterilization which have been made by the American Eugenics Society: "State authorization by approved physicans to sterilize a person who is insane, feebleminded, epileptic, one with inherited blindness or deafness or other very serious inherited defect, when desired by such persons or guardians. The approval of such proposed operation and operator by a deputy appointed by the State Board of Health for such purpose is required." Can any serious objection be urged against such a law?

Many students of heredity have criticised the condemnation of a whole race or class as being genetically inferior and have insisted upon the democratic principle that persons should be measured by their own worth. Morgan (1925) very truly says: "If it is unjust to condemn a whole *people*, meaning thereby a political group, how much more hazardous is it, as some sensational writers have not hesitated to do, to pass judgment as to the relative genetic inferiority or superiority of different *races* . . . A little good-will might seem more fitting in treating these complicated questions than the attitude adopted by some of the modern race-propagandists."

While these criticisms of the more extreme advocates of race superiority or of the "human thoroughbred" are fully justified, they do not properly apply to the more sober and scientific advocates of eugenics. Admittedly it is difficult to decide which human traits and stocks are *best*, especially when one considers the needs of a distant and unknown future, but it is much easier to decide which are *better* and which *worse*. To anyone who has first-hand knowledge of the many forms of inherited human defects, of the great differences between the feebleminded and the highly intelligent, between the insane and the sane, between

bums or thugs and useful members of society, this alleged difficulty of deciding between the better and the worse appears to be a purely academic matter. Of course eugenicists should avoid indiscriminate condemnation of whole races or classes; real eugenics is as democratic as the Mendelian law and recognizes good qualities wherever they occur. Of course eugenicists should manifest the good-will which Morgan commends, but they would be recreant to duty and false to truth if they should affirm that "all men are born equal" in respect of bodily efficiency, intellectual capacity, or social value and that either west or "east of Suez the best is like the worst."

Most of these criticisms have been aimed at extravagant statements of propagandists and not at the fundamental principles of eugenics proposed by Galton and his followers, but Pearl (1927, 1928) has recently attacked the fundamental principle "that superior people will have, in the main, superior children, inferior or defective ones, inferior or defective children, and therefore that the former should be encouraged to have large families, the latter small ones or none at all." By an examination of all biographies that occupy at least one full page in the Encyclopedia Britannica, he finds that of the 214 greatest philosophers, poets and scientists who have ever lived, only ten had superior or distinguished parents and that 95 per cent came of mediocre or inferior stock. "Ordinary people," he says, "have produced nineteen times as many of the greatest human beings . . . as have people in some degree distinguished." These results, he admits, are objectively much the same as Galton's in that in his investigation of the English judges, the latter (1892) found that about nine times as many distinguished men were produced by mediocre people as were produced by eminent people. But while Galton concluded that the incidence of distinction was *proportionally* far greater in distinguished families than in the whole population, and indeed that the chances that a distinguished man would have a distinguished son were at least five hundred times greater than that an unknown man would have such a son, Pearl maintains this conclusion is not true biologically since it was based upon Galton's so-called "law of ancestral inheritance," which

has now been replaced by the "law of Mendel." Furthermore, he says that early environment rather than heredity may determine this greater incidence of distinction in distinguished families. Finally, Pearl concludes that even if the argument of Galton and Pearson were completely true biologically, its social application would be questionable, for even if the average of the race were raised, and modern genetics offers no guarantee of this, 95 per cent of the greatest men who have ever lived "*would never have been born* because the people who were in fact their parents would not have been allowed to breed under such a regime."

This is the most destructive criticism of the fundamental principles of eugenics that has ever come from a distinguished geneticist. Other criticisms have dealt largely with the extravagances of certain popular writers on eugenics, but these criticisms strike at the very foundations of eugenics and if they are true indictments, eugenics must go to the scrap-heap along with astrology and other pseudosciences. But the eugenicist may well examine critically these criticisms before proclaiming with Othello his occupation gone. It is true that Galton's "law of ancestral inheritance" has been replaced by Mendelism when dealing with the mechanism of the hereditary transmission of inheritance factors, but when dealing with average results of inheritance in a general population, Galton's law is still true. It is true that in individual instances "like does not produce like, but only somewhat like" as Brooks (1899) expressed it, but on the whole and as an average of mass results it is true that "like produces like" to such an extent that this principle has for ages past furnished a valuable basis for selective breeding; how much can be accomplished by such a method is shown by the improvements in the breeds of domestic animals and cultivated plants in all the period before the discovery of the Mendelian principle.

With regard to Pearl's conclusion that "ordinary people have produced nineteen times as many of the greatest human beings . . . as have people in some degree distinguished," it is only necessary to say in reply that ordinary people are at least several million times as numerous as distinguished people when measured by Pearl's standard of distinction,

namely mention in the Encyclopedia Britannica. Of the two hundred fourteen philosophers, poets and scientists whose biographies occupy at least one full page of that Encyclopedia, ten had parents of such distinction as to merit independent mention. These names are drawn from all countries and periods during the past twenty-five hundred to three thousand years and during that time it would seem to be a safe guess that there must have been in all civilized countries at least one billion parents. If all of these had produced great personages in the ratio of 1:21, as in the cases cited by Pearl, there would have been nearly fifty million persons instead of two hundred fourteen whose biographies would have occupied a full page each in the Encyclopedia.

Finally when Pearl says that 95 per cent of the world's greatest men would never have been born if reproduction had been limited to distinguished persons, it must be granted that this is true but only in the sense that not a person in the world would ever have been born the same person if he had had different parents. Beethoven would not have been Beethoven if his father had been Haydn, but who can say that he might not have been replaced by an even greater musical genius?

Modern genetics does not support the idea that genius comes more frequently from mediocrity than from superiority, except in the sense of the old conundrum: "Why do white sheep eat more than black ones?" Answer: "Because there are more of them." Genius has natural causes and one of the most important of these is heredity. There is no reason for regarding it as miraculous in origin nor as belonging to the "Order of Melchizedek, who had neither father nor mother, pedigree nor posterity." Owing to extraordinarily fortunate combinations of good genes and of stimulating environment, good things may sometimes come out of Nazareth and world leaders from poor stock, but the fundamental principles of eugenics are absolutely sound and Galton's conclusion that genius is hereditary has been abundantly proved by Pearson and his school, by Gowen (1925), Terman (1916, 1915) and practically by all who have seriously studied this subject. No doubt environment is very important in the development of human personality, but the study of identical twins by

Galton and of school children and college students by Terman and by Gowen have shown that Galton's conclusion is well founded that "nature prevails enormously over nurture when the differences of nuture do not exceed what is commonly to be found among persons of the same rank of society and in the same country."

WHAT ARE THE PROBABILITIES OF RACE IMPROVEMENT?

The limitations of eugenics as a means of race improvement lie in the field of practical application rather than of genetical principles. Some of these practical difficulties in the path of eugenic progress can be overcome with an aroused social conscience, and with increased knowledge of human inheritance and development the time may soon come when all highly civilized nations will prevent by segregation or sterilization the propagation of the worst elements in society. This is already being done in many states and nations by the segregation of the feebleminded, insane and criminals in asylums and prisons. It is doubtful whether it will ever be possible to segregate or sterilize normal persons who are known to come of tainted stock and hence may carry inherited defects as recessive factors. By means of simpler and more effective means of sterilization and especially by methods of preventing conception such persons may choose to be childless, and in a stationary population, which we may except within a few centuries, public sentiment may be a great aid in restricting the reproduction of the unfit. Indeed sentiment and custom are much more potent in such matters than are legal enactments. Already the practice of voluntary birth control is widespread and is rapidly solving the population problem, and it is not improbable that it will also help to solve the problem of the propagation of hereditary defects, for people with even a modicum of intelligence would prefer to have no children rather than to have defective ones.

More important and still more difficult of accomplishment than such measures of negative eugenics are the perpetuation and increase of the best elements in human society, or the promotion of positive eugenics. As civilized society is at present organized the most intelleuctal, progres-

sive and ambitious members of society are most heavily handicapped in reproduction. The long period of education, intensive application to preparation for a career, luxurious ideals of family life and unwillingness to be burdened with children have greatly reduced the fertility or have completely sterilized some of the best human stocks. Some silly aspects of modern feminism which put individual freedom and personal pleasure before family and racial duties, which teach that social success is a more worthy aim than motherhood, and that the devoted mother of a large family is to be pitied or even ostracised are contributing mightily to race deterioration. If the heredity of the race is to be improved such dysgenic social customs must be changed and a premium put upon the reproduction of the most fit. Many suggestions have been made looking to this end but apparently the only ones that hold much promise of success are better education regarding eugenics and an awakening of religious fervor in behalf of race betterment.

While many peoples of the western world are cultivating a spirit of race suicide among the most intelligent and progressive elements of society, the peoples of the Orient still regard reproduction as a supreme duty to the family and the race. The ancient cry of Rachel, "Give me children or I die" is still the cry of the great mass of women of the East, where the most honorable salutation to a woman is, "May you be the mother of many sons!" Many eastern and some western countries are already overpopulated and the need of the whole world is not for more people of the mediocre or inferior sorts but rather more of the better and fewer of the worse varieties. To what extent this spirit of the East can be limited to the better portion of the population, and whether any similar spirit may be aroused in the western world is doubtful, but upon such a differential between the better and the poorer lines the whole program of eugenics depends.

In the meantime environment can be and will be greatly improved. There is now much greater opportunity for every person to develop his innate potentialities than ever before in the world's history. Education and social cooperation are more widespread than ever before. Science is discovering means of preventing disease, prolonging life and increasing

efficiency. While these improvements of environment and of development do not directly improve heredity they do open the way to an indirect attack upon that problem. Whatever is accomplished in the way of eugenics or euthenics must be through intelligence, education and social cooperation and of these three factors education is the one that can be most readily controlled. Education in the broadest sense is the chief hope of human progress.

THE DISTANT FUTURE

When one looks back upon a billion years of life upon this planet and forward to another possible billion years, he cannot fail to inquire whether there is likely to be any such evolutionary progress in the future as there has been in the past. Will the human race persist and become more perfect in body, mind and society, or will it also go the way of every species of former geological ages? Of course one can only speculate about such questions, but there are certain scientific data that may serve as a basis for such speculations.

In the past, progressive evolution has led to increasing specialization and integration of increasing numbers of living units; to increasing complexity and perfection of structures, functions and adaptations; to increasing responsiveness, capacity of profiting by experience, intelligence, control over environment, freedom. The pressure of overproduction of individuals and variations has forced living things, like plastic clay, into every possible crack and cranny and way of escape. Whenever in the past evolution has gone as far as possible in any single line, some other path of outflow has been found. Organisms have probably already explored every path that was possible to them. But in the course of past ages new paths have been made possible not only by changes in environment but also by changes in the organisms themselves.

One of the most important lines of evolution in the past was the path of multicellularity, by which multitudes of cells are integrated into tissues, organs, systems, persons, thus affording means of progress in size and in differentiation and perfection of structures, functions and adaptations,

But progress in most if not all of these lines long ago reached its possible limits within a single individual.

Another line of evolution was found by a few animals in the combination of persons into societies which are the highest and most complex type of organization that has yet appeared on earth. It is very probable that this path has not yet been fully explored, certainly there seem to be many opportunities for further advance along this line both for animals and man.

Finally the path of increasing responsiveness, capacity of profiting by experience, intelligence, control over environment and consequent freedom, represents the most important outlet that is now open to the highest organisms.

In all of these paths man has made great progress. But there does not seem to be much if any improvement to be expected from further increase in the size or complexity of his body; in this direction his progress has practically come to an end.

In social specialization and cooperation, mankind is at present making its most important advance and the end in this direction is not yet in sight. The same is true of the advance in intelligence and control of environment. The most rapid and significant advance in human evolution has passed on from individual cells to persons, then to social organizations, and it now takes in the environment, for man is now adding to his own individual powers the illimitable forces of the universe. In such a brief sketch one may catch a glimpse of the general course of past and present evolution and of its probable future.

Certain human families and stocks are now becoming extinct and in the distant future this may extend to some of the primary races of mankind, but it seems probable that some of these disappearing races will be incorporated in the surviving ones. By extensive intercommunication and hybridization, it is probable that the distinction between existing races will gradually disappear. In this process it is possible that new types may arise which may ultimately replace the older types, and thus human evolution may go on. But so far as one can now foresee there is no likelihood that the entire human race will become extinct before other

higher animals do, and therefore there is little probability that man will disappear and leave the lead to some other type of animal. Already man controls his environment to such an extent that it is almost inconceivable that his race should be wiped out and leave other forms of life persisting which are so much more the slaves of environment than he is.

There is no probability that the human race will ever become perfect in body, mind or society; no doubt there will always be room for improvement. There may be a reduction in the relative amount of degeneracy, a decrease in the numbers of the bungled and botched, the feebleminded and insane, the antisocial and the brutal, but probably without any prospect of eliminating all degeneracy. There may be an increase in the relative number of really superior persons until the general level may be more nearly that of the best specimens of the present race, but there is no likelihood that the entire race can be made illustrious or perfect.

Possibly new mutations may occur that may lead to the production of individuals superior to any that have appeared hitherto, superior in physical vigor and length of life, in mental capacity and performance, in social and moral qualities. But if such mutants should appear, they would have to be preserved and perpetuated by intelligent social selection rather than by natural selection, for man is no longer the slave of his environment or the helpless victim of circumstance. To a large extent he shapes his own environment and to that extent he controls his own destiny.

Consequently great secular changes, such as changes of climate, the coming of another ice age, the formation of deserts, or the rising or falling of continents would never again affect the human race as greatly as they did in the past. Changes in climate might cause extensive migrations, another ice age might make tropical resorts popular, formation of deserts might necessitate extensive irrigation projects, changes in the land and water areas of the globe might necessitate extensive migrations but they would probably not greatly change the human type, for man now is able to control his environment rather than permit it to control him. And the more he is able to control the condi-

tions of his life, the less chance will there be for natural evolution.

In large part the future evolution of man will be self-directed and his progress will be an approach to his own ideals. One of the chief joys of life is growth, one of the deepest desire of the entire human race is for progress. But in spite of these emotions and desires, human beings would not willingly abandon their humanity in order to become superhuman. Their ideals are not of some other more perfect species but rather of a more perfect humanity. Even his gods have always been created in man's own image. Even the most ecstatic visions of a new heaven, a new earth and a new humanity are still in specific type the old heaven and earth and humanity slightly remodelled. Our highest ideals are merely new combinations of the most perfect conditions, traits and beings that we have known. In his vision of the future triumphs of the race, Whittier describes:

> A dream of man and woman
> Diviner but *still human*,
> Solving the riddle old,
> Shaping the Age of Gold.

And all the visions and aspirations of poets, prophets and seers cannot picture any more ideal being than man released from his imperfections and limitations. If the future evolution of man will be largely self-directed and if the goal toward which he would go is merely a more perfect humanity, it follows that there is no probability that the human race will ever in the future give rise to other orders or genera or species of superior beings, no prospect that the future evolution of man will duplicate the tremendous advances of his past evolution. By his knowledge and power man has in a measure risen above nature, he has eaten of the fruit of the tree of knowledge and has become as the gods, knowing good and evil, and now it remains to be seen whether in future ages his race may secure the fruit of the tree of life and become immortal.

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Chapter XXV

THE INTENTIONAL SHAPING OF HUMAN OPINION

H. A. Overstreet

WHAT seems most significant about our human order of life is that we can intentionally reshape our fundamental behavior patterns. In the lower orders these patterns: food-getting, shelter, sex, group-living, etc., appear to be almost entirely fixed. Generation follows generation with no changes save those slowly wrought by the impersonal forces of Nature. We, on the contrary, seem able to take thought; and while we cannot thereby add a cubit to our stature, we can so alter our ways of doing things as to create for ourselves successively more adequate worlds. On the level of humankind, in short, we seem to discover a type of causal agency, thought, which, for the first time, with a degree of obvious power, makes itself felt in the evolutionary process.

What thought is, still remains so much a matter of controversy that it need not detain us here. But that thought actually exists and that it is productive of far-reaching changes in our behaviors ought to be so obvious as to need no defense. And yet there are those who take but small stock in the power of thought to change our fundamental behaviors. They are the believers in the inborn and unchangeable character of human nature. They point to the basic instincts, of pugnacity, food-getting, sex, etc., and assert that these are what govern and will always govern man's life. But they fail to make a distinction. Sex may be a fundamental biological pattern, but the ways in which the sex life can operate will be as different as that between the savage who drags his wife home with a club and the modern urbanite who goes a-wooing in his motor car. Food-getting may be fundamental, but the ways will differ from the crude hunting of the primitive to the organized husbandry of the modern. No doubt the raw material of human life remains steadfast, but

the ways in which that raw material is shaped and reshaped are as multitudinous as the generations of man.

The really significant processes of human life, in fact, would seem to be marked by the passage from one powerful thought system to another. At the present time, two such thought-transitions are apparent. The first has to do with the so-called instinct of pugnacity. For a number of centuries the thought governed mankind that war was both a natural and an honorable mode of settling differences between political units. That thought is beginning to lose its undisputed power. It seems not extravagant to predict a time when the thought of settling political conflicts by killing people will appear so monstrously absurd as to be relegated to barbarism.

During the centuries in which the war point of view prevailed, a thousand and one behaviors resulted. War departments were organized, war leaders trained, armies were enlisted, navies built, guns were manufactured, schools of strategy were maintained, defensive patriotism was taught, war heroes were lauded. The war-idea, in short, was the powerful cause which generated a vast, mutually supporting system of behaviors. On the other hand, let the thought once begin to prevail that war is a monstrous absurdity, and the ground is cut away from all these modes of behavior. Other behavior-patterns will begin to be shaped. Departments for mutual cooperation will succeed departments for mutual annihilation; armies will be devoted to the conquest of Nature instead of the conquest of men. In short, the typical institutions and the typical heroisms will come to be those which contribute to the upbuilding rather than to the destruction of life.

In another respect also the western world is passing from one powerful thought system into another. In this case it is in connection with the basic pattern of food-getting. In the early nineteenth century the invention of steam-driven machinery opened up unexpected opportunities for accumulating wealth. Up to that time the feudal thought-system had built up characteristic behavior-patterns. Chief among these was the obligation for life-long service on the part of retainers and responsibility for defense and livelihood on

the part of the overlords. The invention of steam-driven machinery swept away this feudal point of view, bringing in its place the new generating idea of free competitive enterprise. With the new idea-system came the independence of the worker, but also the release of the overlord from responsibility for the support of his retainers. We all know the fairly tragic story of what happened as the feudal idea began to fade out and the free-enterprise idea began to prevail. There came the "masterless" man, the wage-earner; there came the ruthless misuse of the lives of the workers; there came a new kind of poverty, city slums and regimented factory slaves. Then slowly, as we know, two new ideas began to emerge. On the one hand, there was the thought that the political order must now take some of the responsibility hitherto assumed by the feudal chiefs. Factory legislation was born. On the other hand, the idea developed among the workers that they must now stand together in their own defense. The trade union was born, with the alleviating and reconstructive results that we know.

At the present time, the alert mind easily senses the fact that the economic world, being still far less than perfect in its organization, is in transition. Poverty has been diminished, but fear remains. Factory slavery is less degrading but drabness rules. The State has assumed obligation, but riches flaunt their opportunities in the face of labor. At the present time, western civilization is apparently fumbling forward to a new underlying idea that will enable it to produce, exchange and consume without the fairly tragic waste of life entailed by the present system.

From the foregoing we may, I think, properly conclude that the really significant history of mankind is the history of the change of its governing thoughts about things. What we call progress, in brief, would seem to be the substitution (however caused) of a thought-system which generates more adequate for one which generates less adequate satisfactions.

CAN GOVERNING IDEAS BE INTENTIONALLY CHANGED?

If this is true, then the most important question which human life could seem to ask itself would be: How can we

intentionally change our less adequate governing ideas? Back of that, of course, is the previous question: *Can* we intentionally change our present governing ideas? Are not the ideas that rule our behavior themselves the creatures of circumstances, generated in us by impersonal forces that are beyond our conscious control? To return to our examples, was it not steam-driven machinery which brought the new idea of free-enterprise, and was it not the exigencies of poverty and the misuse of life which forced the ideas of factory legislation and collective bargaining? Again, was it not the unspeakable horror of the late international slaughter which made the war-idea so monstrous that it had to be cast away? Do men ever intentionally shape new ruling ideas? Are we not in this, as in all matters, in the grip of forces greater than ourselves?

The answer to such questions is difficult to obtain and even when we have ventured one answer, there will still be doubt. It may help to clear the issue, however, if we examine a case of idea-change which we seem, in a measure, to be able to trace to conscious beginnings.

Perhaps the most profound of the idea-changes which have been effected among us is the development of the scientific habit of thought. In many regions of life, to be sure, and about a multitude of matters, that habit of thought is still not developed, but in most of our western world, in all that concerns physical matters, the scientific habit of thought now rules with a fair degree of universality.

To illustrate by contrast, let me recall a pathetically amusing case which happened recently in a small town near New York. An Italian boy had been taken ill. The sister, who was a university student, suggested calling a doctor. But the peasant mother would have none of it. She sent for an old woman who was reputed to cure by magic. When the old woman came, she directed that all the dishes in the house be brought into the boy's room and spread about him. Then she poured a drop of oil into each plate, pronouncing as she did so an incantation. Then the plates were gathered up, more incantations were pronounced, and she left. In the course of time, the boy, being a fairly healthy youngster and suffering only from an over-dose of food

recovered. For the mother there was not the slightest doubt that the magic of the old woman had turned the trick.

Here was a fundamental idea governing the behavior of this Italian woman, an idea which, one suspects, it would be difficult to find among the average folk of our modern western world. Formerly, of course, the Italian mother's attitude was universal. How came it that the change was made from the magic-idea to the now prevailing physical-cause-and-effect idea?

The story goes back, of course, into ancient history when men like Thales, Democritus, Leucippus, Archimedes, Hippocrates, and others refused to follow the prevailing ignorances and superstitions and made their independent observations of the world. But the most dramatic episode in the story, I venture to believe, occurred about three hundred years ago when the young Italian Galileo made his startlingly simple experiment from the top of the Tower of Pisa. That experiment was a direct challenge to the older truth-technique, which had relied upon tradition and authority and had made no effort, by observation, experimentation and calculation, to discover the actual relationships existing in the physical world. Out of Galileo as we know, and largely because of his actual experimentation, there grew the brilliant activity of the succeeding three hundred years, which included such men as Newton, Huyghens, Helmholtz, Faraday, Clerk Maxwell, Einstein, and the rest, and which generated a way of thinking about the world and of doing things in it and with it wholly new in human history.

The examination of what actually happened in this case may perhaps give us a helpful clue to the question: How can we intentionally reshape our governing thought-systems?

HOW OUR GOVERNING THOUGHTS MAY BE RESHAPED

Starting with Galileo, let us look for the widening influence of his challenging idea. In the first place, there was the individual, himself, product, no doubt, of his environment, but bringing into his environment something that was not already there. What was this so-called environment? In one

sense it was the same as that of the traditionalists who opposed him. In another sense it was different. His selective mind saw things that they did not see. Also, he read what they did not read and pondered the things he read in ways to which they were not accustomed. In short, Galileo was not simply a product of his environment. He was a selective mind which in large measure shaped its own environment.

This, it seems to me, is the first fundamental factor. Back of all these three centuries of brilliant transformation stands a mind looking out independently at its world.

But there was a second important factor. Galileo's mind was associated with other minds. First there was his association with minds that had gone before, the minds kept alive on the printed page. In the second place there was the association with contemporary minds of like interest and similar intelligence. Out of this association there arose that mutual give and take of ideas, that checking up, that recognition of unity in diversity which seems to be essential to all effective thinking.

Then there came a third stage. Those who were fired by the same interests came to the laboratories of Galileo and the other masters to watch them work and to work with them. Also there grew up the need for new modes of scientific communication. Where formerly the few masters could write personal letters to one another, accounts of experiments now began to be printed and exchanged among the investigators. The scientific journal was born. Books were printed for those who were expert in the field.

Generations passed while these things were taking place. Galileo and the first masters died, and others followed. Then came the fourth stage. Research began to be widespread, workshops of investigation were accepted as essential for truth-seeking, journals and books were widely issued. Discoveries followed discoveries. Above all, practical use was made of the discoveries. Whereat we enter the fourth stage—of teaching the results to the non-expert. The school master conveyed the scientific information to his pupils. Books and journals were written now not for expert alone, but for the non-expert, e.g. the children in the schools, the youth in the colleges, and for the older folk. What, in short,

began in the brain of one man finally reached the masses of the population.

The story, of course, thus briefly sketched, was far from brief in its unrolling. Nor was its unrolling quite as smooth as we have seemed to indicate. But in the end Galileo's challenge won. Hated in his time by the priests and the academic traditionalists, forced even to recant, his fundamental idea now rules so securely that any thought of going back to the attitudes and procedures of his tormentors is completely out of the question.

CAN SCIENTIFIC-MINDEDNESS BECOME THE GOVERNING THOUGHT IN OUR WORLD OF SOCIAL VALUES?

I have chosen this example for the reason that if one were asked what idea-habit most needs to be developed in the modern world the answer, it seems to me, would run something as follows: In the physical world, Galileo and his successors have won; in the world of individual and social values, they still remain largely defeated. And the question forces itself, can the type of thinking which has so powerfully transformed our physical world become the ruling type of thinking in our world of human values? We need not elaborate upon the comparative rarity of scientific-mindedness in matters political, economic and social. The question which needs answering is, what can be done to generate scientific-mindedness in these deplorably unscientized regions? Can the modern world deliberately set itself to building a Galilean habit of thought in the social as well as the physical areas of its life?

The answers usually given to this question are fairly discouraging. How, it is said, can we ever expect a newspaper-fed, movie-debauched, prejudice-ridden mass of people to regard all human questions with the detachment and the generous all-roundness of the scientific mind? The thing seems inconceivable. And yet is it so? May it not be that in this matter, as in the case of Galileo, the mills of the gods grind slowly, but they do somehow grind?

It seems worthwhile to go back to our first fundamental. There was Galileo, the individual thinker. But more than that there was Galileo *the experimenter*. This, it seems to me,

is crucial. Galileo did not simply talk about what he believed to be true. He climbed to the tower's top and did something that could be accurately verified. That, doubtless, in the end, was why he won. The experiment he performed carried its own persuasion.

In the field of social values, it is at once apparent, there are many thinkers but few experimenters. These thinkers would like to eliminate poverty, would like to have a warless world, would like to develop a citizenry of tolerant and growing minds, would like to put color and adventure into the human scene. For the most part they write books about these matters. In other words, they use the fairly easy technique of verbal persuasion instead of the much more difficult but far more powerful technique of persuasion by experiment.

Can experimentation be introduced into the field of human values? There are, I think, at least two outstanding examples which are worth examining. The first has to do with a profound change of ideas about what education means. In this case the Tower of Pisa was at the University of Chicago, and the Galileo in question was a professor of philosophy, John Dewey. Dewey believed that the basic ideas then prevailing in education were in error. He seemed to find in the schools no effort to tie up the material of instruction with the actual life of the children in such manner as to make it both significant and vitally effective. He might have expounded the matter to his students and gone no further. On the contrary, convinced of the idea that education must in every respect be vital to each age-period and must actually function in the life of the child, he established a school in which to try out his ideas. As the school began to show results, interested educators came to observe. Some of these went away and established other schools. A wider circle of teachers observed and carried the methods into their classrooms. Articles began to be written. That was in 1896. Today, only a little more than thirty years later, the Dewey-idea of education has become so powerful among the progressives in education that it not only begins to circle the globe but it bids fair to penetrate and transform the traditional system of instruction.

Let me cite a second example. In the middle of the nineteenth century the peasantry of Denmark were in a fairly deplorable condition. They were ignorant, and economically they were almost bankrupt. An idea was born in the mind of a thinking individual, N. F. S. Grundtvig. It was the idea that what the Danish peasantry needed was responsible intelligence and that through responsible intelligence they could raise the status of their own and their country's life. But he, too, did not simply preach his belief. He tried the experiment of gathering a group of young men about him and of starting with them the process of self-education. That was the beginning of the Danish Folk High School. Today, in a small country less than half the size of Indiana, there are over sixty of these schools for adults. But what is more noteworthy is that, directly as a result of this ideal developed in the brain of one man and growing stronger through widening circles of followers, the Danish farmer as a class is today probably the most enlightened, cooperative and prosperous in the world.

VALUE OF CONSTRUCTIVE IDEAS CAPABLE OF EXPERIMENTAL TEST

These two examples will be sufficient to serve our present purpose, although a number of others might be cited. From these examples it seems possible to assert that intentional reshaping of the basic thought-systems of man can be accomplished. And it also seems clear what factors are essential. Fundamental to the process, apparently, is the presence of an individual with a constructive idea capable of being put to experimental test.

No doubt the calling forth of such a constructive idea will often be brought about by the exigencies of situations. It is, however, probably untrue to hold that the exigencies of situations will themselves generate new ideas. We seem forced to believe that the thinking and experimenting individual is the prime essential.

Granted this, and granted also the slow widening of influence, I think we have the clue to the process of intentionally reshaping our human behavior-patterns. At the present time, one such reshaping seems to be in its early

stages. We have already spoken of the change taking place in the war-idea. Let us note how it fits into the foregoing description. Before the Great War there was a tolerably widespread feeling against the mutual slaughter of men. Conferences on peace had been held with a fair degree of frequency. Nevertheless, despite the growing sentiment of humaneness, the Great War swept us into its horrors. What is significant about practically all post-war peace talk is that it insists upon one or another experiment being made in the art of living together internationally. The outstanding experiment is the League of Nations, conceived in the mind of a constructively thinking individual. The average person is as yet hardly aware of what is happening in Geneva. But so, in like manner, the average person in Italy or Germany or England was quite unaware of the profoundly reconstructive event that was happening in Pisa. It is probably true, however, that as, in the international atmosphere of Geneva, case after case of political conflict is resolved, a new habit of mind will develop among the citizens of the world, the habit of expecting reasonable discussion before a resort to arms. War will doubtless disappear when the new idea-system becomes so firmly formed in us that the older idea-system will vanish by reason of its utter absurdity.

Another reshaping seems also to be in its early stages. Who the individual was who first caught the idea we do not know. But at the present time, a large number of individuals are possessed of the idea that the habit of straight and responsible thinking in matters that still lie outside the range of exact science can best be developed by the process of discussion among adults. At the present time, discussion-groups are being formed all over the world. In these groups—experiments in thinking together—the essential intent is to overcome the one-sidedness and the intolerant finality of the kind of thinking that considers no point of view save its own.

One may safely predict, I think, that a new behavior pattern is here in process of being formed. As it takes shape, many things will change, for example, the habit of reading only one partian newspaper, of being content to make

judgments on hearsay or on tradition, of judging issues solely from a single national or racial point of view. In their stead will be increasingly developed the habit of viewing debatable matters from all sides and with all possible consideration.

SWEEPING CHANGES ARE TAKING PLACE IN THOUGHT-HABITS

We have referred to two examples or experiments which would seem to promise changes in our thought-habits. A brief reference to a number of institutions may emphasize the fact that a far more widespread modification of thought-habits is in process than we are ordinarily accustomed to believe. Within the last thirty years the public library has become an established part of our life. Where formerly all of us, with the exception of a favored few, were cut off from the accumulated heritage and the growing intelligence of the world, today access to the wisdom of humankind has been intentionally provided. No doubt the effect of this in another generation will be profound.

Again, within little more than a decade, one entire sex has emerged to a condition of life in which it has the right to be effectively intelligent. Almost overnight a type of women's organization of a new kind, the kind where serious study and discussion are carried on, has developed, with the result that a fairly vast population of new readers and thinkers has been added to our country and is being added to the world at large.

Another sign of the times is the formation of what have come to be called child study groups. Where formerly parenthood was taken for granted, and little or no effort was made to become intelligent in the highly significant function of child-rearing, the effort among parents to incorporate for their use the best that modern science has to offer is becoming widespread. Again, parents are no longer, as in previous generations, supposed to hold aloof from the educational processes. In the formation of associations of parents and teachers, the thought begins to prevail that the basis of the education of the child lies in an intelligent cooperation between the home and the school.

Another development is the public forum, where the effort is made to develop the many-sided outlook which is the beginning of all true thinking. Still another development is the adult school. Sometimes it is an evening high school where adults make up for educational opportunities lost in youth; sometimes it is a school which offers the adult the privilege of continuing his education on a level of mature insight impossible in the days of school and college.

These things are all still in their beginnings. But back of them, apparently, is a single idea, namely, that freedom among human beings and elevation of life can be gained only by searching out and applying such truths as humans are progressively able to discover. It is that single idea which seems increasingly to be on the way to becoming the governing thought-habit of our life.

THE GRAFTING OF IDEAS GOOD AND BAD

But there is one further significant point to notice. The modern age differs from the ages preceding by the swiftness with which it can universalize an idea. Had Galileo lived today, his Pisa experiment would doubtless have been front page news, and, overnight, it would have reached scientists at the ends of the earth. Ideas have always been powerful, but much of their energy has had to be wasted in the sheer effort to cross barriers. Now an idea can go with the swiftness of the lightning, girdling the earth in an instant of time.

This means that, once an idea is conceived and put to the test, it has a power to launch itself never before possessed. Ghandi's passive resistance in India affects the attitudes of hundreds of thousands of persons throughout the world. Russia's effort to free herself from ignorance and oppression, however faulty the methods may be, helps to inspire new hopes for mankind in regions thousands of miles away. The western world's emancipation of an entire sex from bondage helps to remove the veil from the Turkish woman. The eight-hour day in England and America begins to raise the industrial status of the labor-slaves of India and China.

But unfortunately the thing works both ways. The shot fired at Sarajevo inflamed a world to slaughter. Lying propaganda swung whole peoples into fanatic hatred. The

communiques of a state department can still be counted upon to turn a freedom-loving people into oppressors of the weak. Both parties, in short, the liberal and the reactionary, have equal access to swiftness and universality of communication. What bearing is this likely to have upon the progress of ideas?

As a matter of fact, in the past centuries, the chief agencies for the communication of ideas have invariably been in the control of those who, to say the least, have not been eager for a departure from the established ways. The priesthood and the political state have been guardians of the *status quo*, not explorers of the new. Doubtless it will always be so. Certainly, in the present day, the chief agencies, newspaper, school, church, and state, are, as often as not, opponents of new ideas. Or, to express it in positive terms, they are deliberate propagandists for the established thought-systems. With the swift and wide-reaching devices of communication at their command, they have a power which was never before possessed by governing groups.

This must halt us in our first thought that with swift communication the rate of progress in human opinion will be more rapid. As a matter of fact, the greater the power that progressive ideas now have to move over the face of the earth, the greater is the power of reactionary ideas to outstrip them and neutralize their effects.

Is there any hope of breaking the preponderant power of the neutralizing influences? There would seem to be one, perhaps only one: namely, the development among the citizenry of the world of an increasing ability to be critical-minded, to think for themselves instead of taking their ideas predigested. Is that development possible? There are three ways in which it is already taking place. The first has to do with advertising. A generation ago, advertising was unblushingly the art of more or less clever deception. It had unhindered scope to deceive a people too naively uncritical to know that they were being deceived. Today, however, a widespread critical scepticism has developed with the result that advertising, in the main, has been compelled to be honest, in accordance with the old adage, "honesty is the best policy."

The second instance applies to newspapers. As a matter of fact, while we still read our newspapers for the news and accept such coloring of the news as is skillfully foisted upon us, there is a conspicuous absence of confidence in newspapers as purveyors of social and political judgments. Outstanding cases are on record in which the citizenry of municipalities have deliberately voted against the candidates and the policies supported by the newspapers.

A third case of critical scepticism applies to politicians. About a generation ago it began to be bruited about that politicians served "special interests." Politicians are now known for what, in large measure, they are, a special kind of business men making profits for their own group. With such widespread skepticism, the politician is finding it increasingly difficult to orate his way into easy power.

Critical skepticism can, indeed, be developed. Is there anything that can be done to accelerate the development of critical-mindedness among us? The schools, hitherto, have applied themselves to this need in far smaller measure than it would seem they ought. They have developed adults apt with the tools of life, arithmetic, spelling, geography, and the rest. They have actually done far too little to inculcate that power of critical questioning which is the essence of good judgment. An outstanding instance is the teaching of history. Practically nowhere is history taught in the critical spirit of seeking out all the possible points of view. It should be obvious, however, that the history of America, to take a single example, studied solely out of American textbooks can hardly give the student that access to divergent points of view which is the prime essential for critical judgment and of a truly liberal education.

Is there any way of setting for the schools this more adequate goal of critical-mindedness? Since it is the adults who must set the standards for the schools, one suspects that no way will be found save through the eventual development of critical-minded grown-up people. Are we here in a vicious circle? How are uncritical-minded grown-ups to demand an education in critical-mindedness for their children?

It is at this point that the new and growing interest in the continuing education of the adult becomes of essential

significance. To many persons it has seemed an astounding fact that while fairly rich provision has been made for the training of juvenile minds, no systematic provision has ever made for the training of the adult mind. And yet it is obvious that in the juvenile years most of the matters that are of importance in the social, political and economic conduct of life are still beyond the level of immature intelligence since they require experience of things as they are. To an increasing number of persons throughout the world, then, it seems of primary importance that a new idea of education be conceived and put into effect, the idea, namely, that adulthood is the period, not when education ends, but when the deeper and far more essential education in intelligent judgment really begins. No doubt this is an idea which will be of most constructive value for the future. It may take another three hundred years to get it thoroughly domesticated. Nevertheless, since it is most fundamental of all to the progress of human thinking, it would seem to be a major idea worth pushing into effective realization.

INFLUENCE OF INVENTION ON GOVERNING HABITS

In the foregoing, we have considered only the intentional shaping of human opinion. There is, of course, one powerful factor which is constantly, but unintentionally shaping ideas and attitudes. This factor is invention. The invention of electric lights has unquestionably developed reading habits and amusement habits never before possible. The invention of the automobile has developed travel habits, not to speak of financial habits, which were not found in the older days of slow-moving vehicles. The invention of the moving picture helped to break the saloon-habit of mind. It has likewise broken into the ignorances and provincialisms and has served to bring the most distant and colorful experiences within the compass of the average life. Also, it has developed a new and perhaps questionable habit of erotic interest.

But the inventor, as we know, does not deliberately set himself to bring about these things. They happen along with the new device. Nevertheless, it is significant to note that inventions do change the ideas and attitudes of individuals and groups. It is even possible to believe that, knowing this,

one might with deliberate intent set about to make the type of invention which would serve in an intended way to reshape the mind-habits of men.

Summing up the whole matter, then, it would seem wholly within reason to assert that there are ways of shaping human opinion, ways that are intentional and ways that are unintentional. Back of both ways, we seem always to find the thinking individual, the individual able to challenge things-as-they-are, able to ask pointedly whether things-as-they-are must forever be as they are, able above all through the power of imaginative insight to transform untried possibilities. The most important event in the world would seem to be the planting of a new idea. The next important would seem to be its nurture and propagation.

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