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EARTH SCIENCES AS THE BACKGROUND OF HISTORY[1]

By JOHN C. MERRIAM

CARNEGIE INSTITUTION OF WASHINGTON

The Larger View of History

THE concept of history as generally accepted has undergone extraordinary changes in recent years. History as read and taught has frequently expressed only in part the broader relations of events with a view to indicating their true bearing on the present. In its origin as a constructive science much of history was concerned with the emotional side of national propaganda, and in varying measure it has been an instrument used to promote a nationalistic spirit. Fortunately, we find many interpretations which have clearly stated the continuity of events, their real relations and significance in the world sense, and their proper trend.

Not less insufficient than the use to which history has often been put is in many instances the structure of the account presented. Continuity has not always been the fundamental factor. Descriptions of events in series, but unrelated, have at times formed the basis for discussion, and fundamental laws or scientific principles have not always played an important part.

Reaction against the incomplete view of historical study is in some measure due to application in human affairs of the hypothesis of evolution or development growing out of the fundamental historical sequence of geology as presented by Lyell and applied in the broad biological concept of Darwin. Assuming that man remains on a constant level, representing the type as created, human history might show indefinite fluctuations of movement; or it might be cyclic, each cycle representing approximately the same plane of development. According to the evolution hypothesis, the trend of the living world would be toward the more specialized, or more complicated, or more advanced. Although it might be cyclic, each cycle would rise to a

[1]Delivered as the Presidential Address before the Geological Society of America, December 29, 1919.

higher stage, and the path would be helicoid. According to the developmental or evolution interpretation, every part of a historic sequence is related to every other part, and each feature of past series contributes somewhat to the interpretation of the present. This concept gives us for every portion of historic succession a formula, through which, with a certain degree of accuracy, the line may be projected forward. Viewed in this light, history becomes not merely a teacher by comparison or by analogy, but interprets the development of present conditions, and also furnishes a key to the future.

Rarely has the range of historical account included all major influences actually involved. Largely by reason of the fact that the world is so complicated, there is no connected statement which shows the happenings as a whole with their interlocking connections. The records are mainly pieces, or pieces of pieces, limited to one phase of the subject, restricted to one portion of the world, and covering only a small section of time. True world history scarcely exists.

Analysis of the elements composing the fabric of history, considered in its enormous complication and as a world problem, shows that we cannot doubt the need for every item of knowledge which may be brought to bear for interpretation of our present situation and requirements. We must have these materials also for guidance of mankind in decisions on those greater problems demanding for their proper settlement a vision reaching over long periods and extending beyond the present generation. We should have light with increasing brilliance thrown into many dark corners.

Present world questions will be solved in part by men who trade and those who study commerce, in part by men who rule and those who study ruler and politician. But the only view that can show us where we are and whither we go is one that, with other items, includes at least the outlines of the path over which we have come.

The point of my story in this paper is that the farther back we see the path clearly, and the better we know our progress over it, the more certain we are to eliminate the minor curves and determine the true direction and the rate of speed to expect.

I am suggesting that the deepest view of history is desirable for the purposes of fundamental decisions; that, no matter how far back this vision leads us, if it continues to add to knowledge of what we are by showing us how we came to be, it is needed and should be secured.

Contribution of the Sciences to History

The sciences especially concerned with historic sequence are astronomy, geology, geography, paleontology, biology and anthropology. Astronomy, with its broad conceptions of stellar evolution, concerns us because it discusses the origin and early history of our planet. Geology and geography deal directly with the earth. Paleontology, representing biological history, must go to geology for its record. Anthropology has, as one of its most important phases, the history and origin of man.

The field of the astronomer, with its myriad bodies of the heavens, presumably represents wide range in development of the stellar systems within our view. Yet, with all our information as to the stages through which these bodies may proceed in their history, there is but little positive evidence on which we may depend. We may note modifications in the surface of the sun or in the clouds of Jupiter, or we may observe the varying brightness of the stars; but there is little in these variations which we have proved to be more than incidental fluctuation. Our knowledge of evolution of the stellar universe must depend largely upon comparisons of stars of various types, or of groups of stars and nebulae which we assume to represent incipient stellar systems. The nebular hypothesis, which has served to present a type of evolution of the solar system and a basis for interpretation of the origin of the earth, is called in question to such an extent as to be no longer acceptable to a large group of astronomers. The planetesimal hypothesis, developing similar world systems out of spiral nebulae, seems also to suffer under recent criticism. For practical comparisons in study of world evolution, we appear to have one of the most important sources of information in the history of our own planet. For the universe in the large we can prove little more than that there is shown a process of development for which almost infinite time seems required and in which cycles seem determined.

Our greatest scientific contributions to the study of history and of origins have come through geological and biological investigations. Geology is the greatest of historical sciences. From comparative and experimental studies alone biology makes large contribution, but its distinctly historical phase lies in the field of paleontology, in which the life record is read from the geological book. To geology and biology, furnishing together the life records, anthropological history must be added, reaching back, as it does, into geological history and expressing the beginnings of our account of human life and activity in terms of geology and paleontology.

For the purposes of this paper, geological history may be divided roughly into two portions. One, the later division, is represented in the known section of stratified rocks formed through the piling up of sediments and by the out-welling of molten material spread on the surface or squeezed into the strata. An earlier period expresses in a more doubtful manner the partly astronomic history of the earth antecedent to the record presented by the lowest or earliest known strata.

The astronomic period of our earth's history is a subject for investigation by astronomer, physicist, chemist, and geologist. As yet the results of studies in this region are in large part of a speculative nature. The field furnishes one of the most attractive opportunities in science for further investigation. Although this phase of the problem has in it very much of fascination, the results are still of such a nature as to contribute little toward the objects of the present discussion. I shall therefore refer to geologic history only in terms of the distinct record extending to the lowest known strata in the second chapter of the account.

The length of the period which remains after elimination of the earlier or astronomic stage may be very short measured against the total age of the earth. We know that the lowest strata, wherever we find them, rest upon rocks which have been molten and in their molten state have destroyed the basement upon which the oldest known stratified rocks once rested. We admit, therefore, that not only have we lost the record before the earliest strata were formed, but that the earliest strata themselves have disappeared. The record remaining is, however, by no means brief in terms of human understanding. Few recent estimates have suggested that the section comprises less than two hundred thousand feet of strata, or that the time involved measures less than one hundred million years. This time may not be long compared with the entire age of the earth, and may not be more than a moment compared with the age of our solar system, but it furnishes all that we require for purposes of interpretation of human history.

Reduced to their simplest terms, the geological data of the stratified rocks give us a history relating to the accumulation of sediments, movements of the earth's crust, the making of continents and ocean basins, erosive agencies tending to wear down the land, volcanic activities, climatic changes, and life succession. This history presents, as its first significant lesson, the fact of instability of the earth's crust and the evidence that throughout geologic time, as we know it, the surface has shown diversity of form dependent upon movements of large magnitude. By offering opportunity for erosive forces to act, the movements which have produced continents and mountain ranges have also been responsible for accumulation of the sediments washed down to form the strata from which our record is read. Also intimately related to the succession of crustal movements is the history of igneous activity evidenced from time to time in the great extrusions of molten material forming successions of lava flows intercalated in the sedimentary series. The history of climate, furnished us through a great variety of data, gives evidence of almost continuously fluctuating conditions in the physics of the atmosphere, ranging between high and low humidity, and between temperatures comparable with those of the glacial periods and the climate of tropical or subtropical regions of the present day. The salient features of climatic history are the continuous change and the evidence of comparatively slight range of temperature for the earth as a whole within the span of geologic time as known.

Earth history, as we see it in this record, shows from the most remote periods to the present constantly varying surface conditions dependent upon an unstable crust; continents and mountains arise only to be subject to the steady grind of erosion, wearing them away and spreading the débris over the seas. Always do we find land areas and seas, but with much variation as to size and form; always was the temperature near that of the present, though fluctuating from warmer and more humid to climates like that of the Glacial Period.

Within the whole span of geological history and its continuous changes recorded, the phases of purely physical history presented do not show us in any of their various aspects definite progression or trend which may be described as an evolutionary process. It was once our practice to place emphasis on the geological history of the earth as the continuation of a graded or evolution series based on the succession of stages described in the nebular hypothesis. According to this view, we seemed to see in climatic evolution a gradual movement away from the conditions of the primitive heated earth and toward the present temperature of a cooling sphere. We once thought we saw the early atmosphere fit only for lower organisms and later cleared and purified for the higher types of life. With better understanding of climatic history, it comes out more and more distinctly that while the earth's climate fluctuated continuously, there is no clear evidence of definite progression through a series of stages dependent on gradual cooling of a once highly heated globe.

So in other phases of purely physical history we have worked out what seemed at first to be evolution series, which have all proved finally to be nothing more than cycles that may be represented by variable formulae. As nearly as we can determine, the physical history of the earth within the span of time represented by our legible record has been so nearly stabilized as to show little or no variation which may not be considered merely as fluctuation rather than as evolution.

As evidence of a continuously changing evolution series, the most extraordinary record of all history is that included in the paleontologic succession of life, running down through the story of geology, practically to the beginning.

Not only do we find the character of the earlier stratified rocks indicating atmospheric and climatic conditions similar to those now obtaining on the earth, but we find the rocks containing traces of living forms such as now are fitted to these climatic conditions. Throughout the whole stretch of the strictly geologic record, conditions in temperature and humidity evidently kept within the range permitting development of living forms. The period in which life came to be on this earth is represented by a chapter now obliterated.

The life record is, to be sure, fragmentary, but in many groups it is extraordinarily full. Although there is much to be desired, out of the long series of events certain features in the evolutionary sequence are so clear as to be unavoidable. We find this record showing: (1) that life has been in almost continuous state of change. From top to bottom of the geologic section, in no two great groups of strata do we find that the assemblages of living forms represented are the same. (2) We know the life of each stage to exhibit closer resemblance to that found in strata immediately above and immediately below than to the life representation of the more remote divisions. And (3) we note that the series of forms with certain common characters, but differing in grade of specialization, generally trend toward greater specialization from earlier toward later time. The way in which the changes in living forms took place from age to age may not always be evident, and the paleontologist may admit his ignorance of the causes, but the fact of more or less rapidly changing, definitely specializing series of presumably connected or related types seems reasonably clear. The evidence, taken in its entirety, furnishes strong support for the view that the life of each stage is derived or modified from that of a preceding stage, and that the whole series indicates the continuity of life from earliest to latest time.

Unlike the sequence in purely geologic history, we have in the paleontologic succession continuity with progress in a definite direction. We have, however, noted that there is probably close relation between the continuous change of the progressing living world and the fluctuations in condition of earth climate and earth crust. Movements of the crust producing change of topography and variation in distribution of land and water, taken with changes of climate, must have had important influence in keeping the currents of life moving. A dead earth, without crustal movement and with uniform climate, might have limited greatly the possibility of biological evolution. The fluctuations in physical conditions on the earth in geologic time have, therefore, great significance in consideration of the larger problems of earth history.

It is not my purpose to bring into review, or to discuss, the tremendous field for evolutionary studies in the history of groups of animals and plants whose records we find preserved in the rocks. One after another these series have been considered by specialists in various fields. In all cases, the laws of which I have just spoken find expression, whether this be in the evolution of nautilus, dinosaur, or elephant. Given lapse of time and change of environment, and the old goes out, the new comes in, the unspecialized gives way to the specialized. As the ages go by, in each successive step, almost without exception, we find a higher level of life, representing greater intelligence, greater efficiency, and greater progress.

The most interesting of all the series of fossil forms represented in the geological record, and particularly interesting in the first instance because it begins well back in past time, is that succession giving us the beginnings of the race of man. The earliest known traces of human beings represent a normal part of the life of the earth in a period so remote from the present that our calculations must be in terms of eons rather than of millenniums. We find that since these first man-like forms appeared great crustal movements have changed the face of the earth, and that the climate has shifted back and forth many times through relatively wide ranges of temperature. We know also in this period a long procession of living generations of animals other than man passing through the ages and disappearing.

We find the first remains of humans more beast-like than any living race, approaching the ape-monkey group in many characters, and meeting the requirements of the missing link. We find this first stage followed by others still different from man of the present day, but approaching more nearly to the modern type. The laws applicable to the evolution of other groups apply to man. We note the same relation of physical change in man to lapse of geologic time, to climatic and crustal change, and to other factors in the history of the earth. So far as the evidence goes, it meets the requirements of those who assume the emergence of man from the animal in the manner in which innumerable other organic types have arisen in the long life record as we know it.

Through still later stages of the geologic and paleontologic record man advanced in intelligence and culture, his environment gradually approximated present conditions in both physical and biological factors, and we record the history of these stages partly in terms of archeology, which in turn merges into history based on written records.

Through the evidence of archeology, paleontology and geology we see human history extended back stage by stage until we go from history to prehistory, where in ages remote and in environments strange we find man already widely distributed over the earth, varying as to kind and culture and advancing as to ideas. With this view there seems no escape from recognizing that not merely the foundations of history, but the greater part of the human span, falls within a realm the approach to which has been largely by investigators concerned with the problems of earth science and using the methods developed for this field of study.

The present paper is addressed to the relation between this material, obtained from the earlier segment of history which has been briefly outlined, and that which comes within humanistic study based on modern man. You may perhaps urge, as in Huxley's remark concerning the significance of information obtained through a "medium," that, whether or not we are truly dealing with "a message from beyond," there may not be in what we learn anything worth attention. It may be thought that remoteness means by definition diminution of value and interest, and that events of ancient history diminish in importance as the square of the distance, or at a more rapid rate. At present my only answer would be that what is first is commonly, if not always, fundamental, though fundamental characters may be overshadowed by superficial.

It is not my purpose to give detailed illustration of present and future use for the facts of history seen in outlines of the longer span secured by study of earth sciences. I may, however, set forth one or two examples.

Of the many elements in the problem of world government which now confronts us, there seems to me every reason to believe that race as a fundamental factor is inferior to no other involved in consideration of unity in organization. Assuming that culture, speech, economic interest and political organization may temporarily overshadow it, in the last analysis we may not avoid reckoning with this factor, not merely in consideration of the organization of the greater groups of human beings, but also in the relations of slightly separated types. The fact that we may refuse to consider it does not prevent its acting as a continuously operating element, which remains while prices go up and down, political parties come and go, and national units group themselves in this way or that.

Race is the product of evolution in a changing environment the conditions of which have been determined by factors of geological significance. As a relatively simple illustration, the history of the original Americans is a tangled web in which is inextricably woven the story of great continental and climatic changes and of vast intercontinental migrations of plants and animals. The history of European and Asiatic races is of like order. The relation between Africans and Caucasians or between Africans and Mongolians is dependent on similar conditions reaching into remoter periods and still more difficult of interpretation.

The Balkans represent the fault-line of Europe, because this is a region of overlapping races and subraces, conditioned in their history by extraordinarily complicated migrations determined and directed in part by physical features and climatic changes. Although the Balkans present a problem of the greatest difficulty in the racial and political sense, they place before us a study simple of aspect and significance compared with the larger race questions which we shall encounter in consideration of world government. The difficulties of this problem we shall not improbably see in larger measure as the centuries pass.

Shall we, in attempting to solve these incalculably complicated questions, look only at the present balance of trade, the dominance of particular political parties, the present grouping of social elements, or the present military strength of the nations involved; or shall we, realizing the vastness and the complexity of the difficulty, bring to the light every element concerned, scrutinizing with especial care those factors which seem to be fundamental and more clearly of permanent significance? Unless the larger or broader view is taken, I feel that we shall fall short of the interpretation of humanity needed in order to fit the nations of the world together into one great unity in which each people supplements the needs of the others, and thus gives to every group, as well as to every individual, the freedom to develop its own peculiar talent and grow into that fullest usefulness which we assume to be the natural right of all.

The question of race just described is only one phase of the historical problem in which the background represented by earth sciences becomes of real significance.

In passing, I may mention only two other examples illustrating the relation of historical data from earth sciences to affairs of life of to-day. I believe I am correct in stating that earthquakes are by most persons considered as extraordinary happenings, without relation to the normal order of events with which we have acquaintance. The geologist, however, recognizes them as the natural corollary of crustal movements. Regarding the continuance of such movements, he must believe that the only basis for considering that crustal activities have ceased is to assume some extraordinary intervention definitely holding back forces which if unfettered would result in further crustal disturbance and in earthquakes. Such disturbances have affected the earth since the beginning of our geological record. The geologist who views the history of crustal movement considers that there is no reason for believing that the crust is now stabilized, and assumes that we may expect other movements and other earthquakes. We know fairly the physical laws that govern earthquakes. We can prepare to meet them in such a way as to eliminate most of the dangers incident to their action, but it will take the passing of another generation before we reach a stage in which the clear lessons of earth history bearing on interpretation of these phenomena will become the basis of common practice, such as dictates the precautions which have made it possible for us to build in summer against the rains of autumn and the snows of winter. Many of us still build as if the last earthquake suddenly ended the series measuring back for tens of millions of years.

Still more difficult may it be for us to make use of the lessons of pre-historic history relating to our adjustment to biological environment. In America we live largely on plants and animals of Old World origin, not because the abundance of these types is so much greater than that of American, but because man has lived a longer time in the Old World, and within the period of his early history, reaching back to past geological periods, he has experimented intentionally or accidentally with Old World plants and animals for a longer time than has been given to contact with the native life of America. There are many who do not recognize this relation to the world of undomesticated organisms about us, and seem to feel that some plants and animals were predetermined to domestication, while others can never serve us.

Left to chance, as during the past millenniums, we may in time develop a series of useful American plants and animals corresponding to those of the Old World; or, recognizing the significance of the historical explanation of our relation to domestication, we may be active and carefully directed research secure results comparable to those of a long period of casual or accidental contact, and obtain a great variety of wild forms for use to meet human needs. Such an example of possibilities seems to be found in the development of the desert rabbit-brush as a source of rubber. An investigation was undertaken as an emergency problem during the World War, when there loomed before us the possibility that submarine dominance would eliminate all possible rubber importations. Recent studies by Hall and Goodspeed have shown the presence of 300,000,000 pounds of rubber in the desert region of the West. At present prices it is not available. In an emergency it might be a factor of first importance contributing to defense of the nation. Future research may also show possibility of large use of this supply through cultivation of the wild stock, thus making the desert an important area of production.

History shows us that sufficient understanding of the natural world about us brings large contribution to human comfort and efficiency; but, in spite of the lesson before us, many feel that the day of discovery of species most useful to man is past.

Returning to the larger view of our problem, the value of ancient history depends on our breadth of interest. If we are to deal only with matters of limited personal or national significance, only for immedate ends, and without reference to other generations; if our democracy is circumscribed in space and time, then lack of perspective and of fundamental laws in history may not be felt. If, on the other hand, we see the impending necessity of full understanding of the world's needs in their present relations and future complications, it behooves us to increase the range of human knowledge and of our comprehension of all factors entering into the problems. To most of us it appears that these great questions require the widest and deepest possible range of human understanding and the labor of generations for their satisfactory adjustment. The world statesman of the future must not only be trained to larger and higher vision, but he must have available an organization of knowledge perfect in its simplicity and infinite in its detail, covering every interpretable phase of the intricate human problem. As we approach the assembling of the data required we recognize at once the limits of the human mind and of human life, and accomplishment seems realizable only through operation in an altruistic democracy, making possible intellectual co-operation covering a wider range of experience than can be available to the individual mind.

If, in consideration of the larger problems suggested, we assume that man was created as we find him and destined to no higher plane, the sequence of history is of little value. If, however, the evolutionary view of life be correct, the continuity of history becomes of great importance, and origins, however far back, interpret the present. Should we recognize man as the product of a long series of changes determined by laws laid down in the record of earth sciences, we would have reason to consider every fact in his history as bearing on his present situation. In this interpretation of the record we view history feeling assured that nothing on the earth or in life stands still, and that the movement means continuous lifting of the plane to the more complex and more progressive.

In the lines which have been read it has been my purpose to indicate the extension of history backward into the earth sciences, and to point out the significance of this sequence as a continuity presenting in its formula an expression of the present. One may not leave the subject without referring also to the possibility of extending this continuing series from ancient geologic time into the future through a span comparable to the past we know.

To one who views the story of the world as presented through the medium of the earth sciences, it must seem unnatural to conceive of the physical and biological forces now in operation as ceasing to act before lapse of many periods like those which we have viewed. Unless there intervenes some extraordinary force beyond the reach of our understanding, the laws which have so long defined the course of nature must continue operation. Without the addition of any power beyond the spring of action furnished by laws now working, the clock of the universe must go for almost infinite ages.

Just as we are not able to conceive of crustal movements ceasing so long as we are subject to physical forces like those now controlling nature, so when we visualize the history of life in the broadest sense we are unable to understand how the biological world, if it continues to be, and if it continues in the environment of physical change, can do other than go on to greater extremes of specialization, to greater range of complication, to greater comprehension, and to greater intelligence. If man of the future continues to maintain the relation between mental and biological which has obtained in the past stages of his evolution, there is reason to believe that he may reach to heights of mental ability, of comprehension, of intellect, of understanding, greater than those yet known. What the ultimate goal will be no one may yet see; without fundamental change of governing laws, the movement must go on.

The Geologist's Rôle of Interpreter

One does not expect a geologist to state his views in philosophy or in phrases aiming at the deeper human understanding, and yet there seems reason for feeling that the wider outlook of science in all of its aspects lifts us up to the identical viewpoint from which the philosopher and the poet obtain their comprehensive vision. Unlike the philosopher we do not reach backward to explain the origin or forward to interpret the ultimate purpose of Nature; nor can we, like the poet, picture in words with fullness of meaning the view which opens to us; but the type of landscape spread before us and the training of the eye which sees it give to our picture a measure of reality which its stupendous magnitude does not lessen.

Of all favored men the geologist and paleontologist see the panorama of the past unrolled in clearest reality. To them the life record is not written in doubtful hieroglyphs and symbols. It represents the imprints of living feet that have never ceased to advance in unbroken procession over a trail that winds upward through the ages. From one glimpse at footprints on these sands of time, a poet, in the person of Longfellow, gave to all generations a Psalm of Life, which has found response in an ever-widening circle of human hearts. Longfellow's poem, suggested by the antiquity of the print of a foot upon the Connecticut sandstone, was based upon a splendid lesson of analogy. He emphasized for us the idea that the influence of each life may reach out undreamed distances through space and time to make the forlorn and shipwrecked take heart again.

Pointing in the same direction, but of infinitely deeper meaning than the lines of the poet, is the reality of the story, the sermon, the poem which the geologist sees, and which must of necessity reach its recognition through his eyes and its expression through his voice. The footprints and the stages of the path on which they appear are to us not merely evidences of an unending influence; they are tangible proofs of progress from eon to eon which might well help a forlorn world to take heart once more. We may not understand the method by which betterment has come, but we see the stages of its movement and realize that, whatever struggles the future may have in store, we shall always be credited with a margin of safety when we risk ourselves in the cause which makes for uplift in the truest sense.

Without assuming more than is involved in the field of his daily work, the geologist stands before the world as the interpreter of one view of great truths fundamental to human interest and belief. It was in large measure this depth of vision that stimulated Darwin to his epoch-making work, giving to biology and to the whole range of human thought his progressive evolution. The story of the Earth stands as the background out of which history emerges and against which its movement must always be projected. The world needs now, as never before, a broad and deep view of all that may concern humankind of the present and future. The student of earth sciences was once a contributor to the wider philosophy of nature and its relation to man. It may be his duty now to make sure, not only that his influence is felt in advancement of material welfare, but that he serve also to point out the lesson of the foundations of the earth and to show that strength may still come from the hills.

RE-SHAPING OUR FOREST POLICY

By Professor J. W. TOUMEY

DEAN OF THE SCHOOL OF FORESTRY, YALE UNIVERSITY

WHAT is wrong with American forestry? For twenty years magazine articles and public print in general were loud in praise of what appeared to the layman to be rapid progress in forestry. To-day these same periodicals are seriously questioning the security of our future timber supply. Our metropolitan press and country newspapers are calling attention to the growing scarcity of forest products, particularly high grades of lumber and wood pulp. Sunday editions of our more important papers are printing articles dealing with the scarcity of wood and the remarkable advance in price and urging the necessity for forest conservation. As a nation we have been prone to look with satisfaction upon the development of the U. S. Forest Service from the small beginnings of three decades ago to a great department of the national government, reaching into every corner of the country and disposing of an annual budget of more than six million dollars. We have pointed with pride to our hundred fifty million acres of national forests all established within the past thirty years and now under management for sustained yield. We have created departments of forestry in many states and acquired several millions of acres of state forests. We have established more than twenty schools of forestry and departments of forestry in our colleges and universities. At present thousands of foresters are coming in contact with our forests where there were none thirty years ago. Forestry is no longer an unknown profession. We have a rapidly increasing forestry literature. The past three decades have seen much water pass under the bridge, yet with all this the problem of our future timber supply remains unsolved. There appears to be no hope for its solution under our present forest policy.

Lumbermen who have been exploiting our forests and transforming them into vast areas of desolation see the end of their supply of raw materials. Some of them have publicly announced that both national and industrial welfare demand the early development of an American forest policy which will substitute for indifference, ignorance and accident, an intelligent, practical, equable and concerted program for the replacement of forests adequate in area and quality for the future needs of the nation. National, regional and local associations of lumbermen and large users of forest products such as the National Lumber Manufacturers' Association, Western Forestry and Conservation Association, the Southern Pine Association and the American Paper and Pulp Association, have recently established forestry committees because they see the imperative need of forest renewal if the industries which they represent are to endure. National and regional associations of professional foresters, such as the Society of American Foresters, and the United States Forest Service, are diligently at work in an effort to create a public sentiment which will force the solution of the problem of forest renewal. Vituperation and condemnation of the lumbermen and private owners will not solve the problem. It can only be solved through change in point of view, through the adoption of a new policy effectively carried out. We must learn to treat the forest as a renewable resource. In my judgment, this can only be attained through the heartiest co-operation between the public and the owners of our forests.

Although the lumberman and layman appreciate the seriousness of present conditions, if these are permitted to endure, they are discouragingly indifferent when it comes to the point of providing an effective remedy. Although they know that the forest influences the life and property of towns and cities, states and nations, each individually "leaves it to George" to change present conditions. Although they know that there is essential need for forests under sustained yield to supply necessary raw materials, to protect water-sheds and regulate the flow of streams, to afford refuge for wild life, to maintain soil fertility and provide recreation grounds for the public; under our present forest policy and forest laws this recognition is not checking forest devastation and there is no hope that it will.

The public have been sitting on the side lines and silently witnessing the disappearance of one of our greatest resources. This is all the more deplorable from the fact that the forest is a renewable resource when given conscious care. Although the lumberman and the private forest owner see the end of the supply of virgin timber the remainder is harvested for the most part with scarcely a thought and entirely without consideration for future crops. The regrettable fact is that while they appreciate the deplorable situation into which we are rapidly drifting, they are not interested in doing very much in the way of forest replacement. It is rare indeed that any provision has been made in the past by private owners for starting new crops, and little effort has been expended in protecting the second growth which follows exploitation. What protection the private owner has given his forest property has centered in protecting his mature timber. He has spent little to keep forest lands in continuous production. New crops have been usually left to chance. In short the private owner of forest property in this country has not been and is not now in the business of growing timber although he often owns vast areas of absolute forest land which ought to be maintained in continuous production.

Evolution of Our Lumber Industry

For a hundred years American lumbermen have been acquiring and bringing together operating units of timberland to be exploited and finally left to become areas of desolation and waste without hope of future crops of essential value. They have accumulated acreage in one locality, devastated it, moved to another and repeated the operation. The process of moving into a virgin forest, destroying it from the standpoint of sustained yield and moving into another has gone on since the settlement of our country. With the reduction in the supply of pine and spruce stumpage in New England, American lumbermen moved into the great unbroken forests of the Lake States. After a few decades they left this region a desert of blackened stumps without reproduction and moved into the southern pineries where vast areas of virgin soft woods awaited them and to-day they are trekking across the plains to our last great bulwark of virgin timber, the Pacific Northwest.

Early in the last century New England supplied the bulk of the forest products consumed by the entire country. To-day her timber needs are largely supplied from outside sources. Thirty to forty years ago the Lake States formed the greatest lumber producing region in the world. To-day they scarcely supply their own needs. A decade ago the South was at the crest of its timber production. The apex has already been reached and the decline in annual yield is well under way. Although this region has been for two decades the greatest producer of high grade timbers of any region in the world it will soon pass as an exporting region and be scarcely able to supply its own needs. Investigations made by the United States Forest Service show that in another ten years more than one half of the localities in the South from which the mills now obtain their logs will be cut out and more than three thousand saw mills operating in pine will be forced into idleness due to exhausted stumpage. It should be emphasized that the present yield cannot be maintained because the stumpage is no longer there. In the place of vast areas of southern pine which for the past quarter century have been the world's chief supply of high grade timber there will be left many million acres of denuded and devastated forest largely without reproduction and an economic waste.

The progressive exhaustion of the forest capital of New England, the Lake States, and the Southern States, particularly the laying waste of a large part of the absolute forest land east of the Great Plains, is now forcing America to draw more and more of her forest products from Canada and the Pacific Coast. In another decade the Pacific

Northwest bids fair to supply the bulk of the nation's high grade timber.

Enhanced Cost of Forest Products

The consuming public do not as yet fully appreciate what this means in enhanced cost of forest products. Lumber is an unwieldly and bulky product. A large part of its cost to the consumer is freight. Even now we pay about one hundred and seventy-five million dollars annually for railroad transportation of forest products. When the bulk of our timber comes from the Pacific Coast our annual freight bill on forest products alone is likely to exceed a half billion dollars. Were the supply of timber on the Pacific Coast unlimited in quantity and in no danger of exhaustion it would still be economically unwise to continue the devastation of absolute forest lands east of the Great Plains and make no attempt to reforest lands now idle. In the long run national economy demands that our forests be well distributed over the country.

The falling off in supplies of stumpage in eastern United States, thus causing the people to depend more and more on the Pacific Coast and importations from Canada, has had an important effect upon values. Furthermore the segregation of the national forests which embrace about one fifth of the total forests of the country from the public domain has left the lumbermen no new fields to conquer, no new sources of supply coming as free gifts from the nation. As the lumbermen cut out their present holdings they will find it increasingly difficult to find new fields for their activities. As a consequence we are at the beginning of keen competition by saw mill operators for our remaining stumpage. Heretofore the price of stumpage has been low. From now on it will increase with more or less rapidity until it approaches the actual cost involved in growing a crop of timber. Stumpage prices are certain to maintain a steady increase even through periods of rise and fall in the lumber market. The peak will not be reached until it sells at or somewhat above the actual cost of its replacement. Measured by this standard, although all classes of stumpage are rising in value, it has not as yet reached a price anything like the actual cost involved in establishing and developing commercial stands under forest management. Stumpage is at the beginning of a steady and rapid increase in price and is destined within the next decade or two *to reach two to four times its present value.*

The increase in lumber prices during the war and since the armistice has not as yet been reflected in the cost of stumpage. Those of us who are consumers of wood are looking for the prices of saw mill products to fall. Although there may be some fluctuations in present wholesale and retail prices, the general trend will not be downward, for the excessive profits now being made by the lumber manufacturers will shortly be transferred to the rapidly increasing price of stumpage. There will be no such thing as a return to pre-war values and we are never again likely to see lumber sell at prices prevailing six to ten years ago.

A few months ago quarter-sawed white oak suitable for furniture sold for four hundred and forty dollars per thousand feet, b. m. in New York City, oak flooring sold for three hundred and forty dollars per thousand feet, b. m., in the Boston market. Second growth white pine box boards have recently sold in New England for sixty dollars per thousand feet, b. m., and chestnut plank from local mills has recently brought as much as seventy dollars per thousand feet, b. m., in Connecticut. Only recently certain grades of Douglas fir in the State of Washington have brought for the first time in history as much as one hundred dollars per thousand feet, b. m. These values are fully three times pre-war prices for the same classes of material.

The Paper Situation

So far as available wood for paper is concerned it is conceded by experts that the visible supply of pulp wood in eastern United States will carry our mills but few years at the most. With the enormous increase in demand for paper in recent years, the mills of New England and New York have been utterly unable to increase their supply of raw products except through importation from Canada. Secretary Houston has recently stated that only one third of the American newspapers issued in 1919 were printed upon the products of our own forests. Although twenty years ago practically all our paper came from our own woods to-day much of it is from Canadian forests. We are even importing news stock from Norway and Sweden.

This is a paper age. The American Paper and Pulp Association states that since 1880 we have increased our annual consumption of news stock alone from three pounds per capita to nearly thirty-five. Our total consumption of all classes of paper is well over one hundred pounds per capita. So far as stumpage for paper is concerned we are already in a serious and critical position. During recent months some of the manufacturers of paper pulp in New York and New England are reported to have paid as high as thirty-nine dollars per cord for spruce.

Only a few months ago the Secretary of Agriculture in calling attention to the large areas of pulp wood along the Alaskan Coast stated that here is a supply to which the nation can turn for immediate relief while it is developing new supplies through forest replacement. *Are we as a nation going to develop new supplies through forest replacement?* We are not unless we re-shape our forest policy.

The Cause of Increased Prices

The recent increase in cost of all classes of forest products can not be entirely credited to the war. The cost of forest products to the consumer has increased more than any other important class of basic resources. Although post-war conditions are to blame for the sudden jump in prices within the past year, a part of the increase must be credited to the rapidly increasing scarcity of commercial timber which had begun to be felt even before the war.

Heretofore only a small number of American citizens whose voices have been like a cry in the wilderness have taken more than a passing interest in our forests and the problems relating to their use and renewal. The average man has been satisfied so long as the market supplied him with forest products at low cost and he was able to find wild places for hunting, fishing and other forms of recreation. The recent public interest in forest renewal is due to what you and I, the average citizen, are forced to pay for wood. When we pay three or four times the former price for a standard product we stop and reflect. Although in this case we appreciate the part that the war has played in increasing the prices we find that back of the war, back of the manufacturers, back of the wholesaler and retailer is the basic problem of raw materials.

The Magnitude of Our Forest Industry

The magnitude of our forest industry and the volume of forest products that enter into our domestic and export trade is shown in our latest census report. In round numbers fifty-two thousand manufacturing establishments in this country, or nineteen per cent of all, are dependent for their continued operation either wholly or partly upon the output of raw products from the forest. These establishments furnish employment for 1,130,000 workers or approximately one-sixth of the seven million workers in manufacturing industries. Our forests supply the raw materials for industries in which a total of three billion dollars is invested. Yet we are without an effective forest policy, without laws or machinery under which adequate forest replacement is possible.

False Basis of Our Lumber Industry

Our lumbering and allied industries have been erected on the basis of the original or virgin forest. Even the average man now sees that we cannot go on indefinitely relying upon the old-growth forests. We have already reached the point where we clearly see the commercial exhaustion of old-growth timber. It has already completely disappeared from many states and in other states only a remnant remains of the vast stands that less than fifty years ago were the most important sources of the world's timber supply. Ultimately all our timber must come from second growth forests. Our attention, therefore, must immediately be directed to the areas from which the old-growth has been removed. It is these areas that must furnish the bulk of our timber supply before the end of the present century. While we are improving and protecting the young growth on these areas and planting new forests, there should be a closer and better utilization, a better protection and more careful husbanding of the remaining old growth in order that it may last until a new growth sufficient to supply a considerable part of our needs is ready for the saw and axe.

Only a few months ago one of our largest private corporations owning timberland in the United States published a prospectus distributed for the purpose of advertising a bond issue in which it was stated that at its present rate of annual cut, its stumpage will last about forty years. Like practically all other private owners of timberland this company considers its stumpage in the same light as the miner considers the mineral in his mining claims. In other words the company considers it exhaustible and pays no heed whatever to the possibility of its renewal. This case illustrates the almost universal attitude that has prevailed heretofore in the management of American timberland by private owners. So long as private citizens control through ownership nearly four-fifths of our forests and so long as the public by co-operation or other means are unable to stop forest devastation on private holdings there will be insufficient reproduction and present prices for forest products are only a fraction of what they are likely to be later.

Our Lavish Use of Forest Products

As a nation we have grown to our present stature lavish in the use of wood and other forest products. Heretofore we have looked for and found our needed supplies in the vast areas of virgin forest which covered nearly fifty per cent of this country when settlement began. We have been favored with relatively inexpensive forest products. We have lavishly used a hundred species of trees, many growing to massive size and splendid proportions. We have had abundance of wood for every need and have become accustomed to using it without stint and without thought for the future. We have led the world in the consumption of forest products and we have gathered them from the abundance provided by nature. So long as unoccupied public domain could be deeded in the form of homesteads and timber claims to the individual and at a cost to them of but a few dollars per acre, stumpage necessarily remained low. There was always a large supply in private hands awaiting a market. The nation in her generosity gave her splendid areas of virgin forests to her citizens. The private owner could well afford to sell timber on the stump for a few cents per thousand feet, b. m. Less than a half century ago virgin redwood stands cutting from fifty to one hundred thousand feet, b. m., per acre, were given away or disposed of by the nation for two and one half dollars per acre on a basis of two and one-half to five cents per thousand feet, b. m. A few months ago British Columbia, which had the foresight to reserve its timber, sold less valuable stumpage for as much as $250.00 per acre.

Forest Reserves

The disposing of absolute forest land for a mere fraction of its real value continued until the Cleveland administration. We never should have permitted any of it to pass to private ownership. Canada did not and to-day is reaping the benefit. Having made this serious economic mistake which has led to extravagance, waste and lavish use, we should have corrected it by creating national forests long before we did. As it is, *our publicly owned forests are entirely inadequate to supply more than a mere fraction of our future requirements.* Unless the area is greatly increased, which can only be done at large expense, what the forester has done in the past and what he will be able to do in the future in their organization and management can have but little effect in solving our forest problem.

It was to the everlasting good fortune of the American people that a rider on an appropriation bill in the early 90's escaped the eyes of Congress and gave authority to the president to create national forests from the unoccupied public domain. It is difficult to say when or how the wholesale misuse of the public land laws would have ended if it had not been for the authority under which about one hundred fifty national forests with an average area of nearly one million acres each have been segregated from the national domain and dedicated to the production of timber under regulation and ownership by the nation.

It is fairly safe to say that if the former policy of the land office had continued until the present day all our forests would ere this be privately owned and our outlook for timber supplies adequate for future needs would be far more discouraging than it is.

Time for the Nation to Act

It is time for the forester, the conservationist, the lumberman, the wholesaler, the retailer and the consuming public to sit down together to consider our forest capital, to work out a form of action, a policy having for its object a form of utilization which will stop further devastation and insure forest renewal. It is some encouragement to know that the lumberman appreciates the necessity of stopping further devastation and beginning the reforestation of the vast areas of idle land which have resulted from past practices. It is unfortunate that although he appreciates the situation he is not as yet willing to undertake forest renewal on his own lands due to his fear of financial loss. It is believed that the more far-sighted, however, are willing to undertake forest renewal if they can secure adequate assistance and financial aid from the public. The public at this time can ill afford to force restrictions and regulations which the private owner can only carry out at large financial loss. The public who are large beneficiaries from forest replacement must bear a part of the burden. With co-operation and generous support on the part of the nation and state in the securing of forest replacement on private forest lands there must be state laws which make it obligatory.

The solution of the very vital and pressing problem of future timber supplies lies first in increasing our public forests,—national, state and communal; secondly in the organization of privately owned forests for sustained yield. We should clearly appreciate, however, that no improvement over our present deplorable situation is possible without liberal financial support on the part of the public. The cost of a single battleship will cover the great burns of the Adirondacks with productive forests; the cost of a single battleship will clothe a million acres of Pennsylvania's areas of desolation and waste with splendid coniferous forest; the cost of a single battleship will develop a forest fire service which in co-operation with the states should effectively protect half the nation's forests.

The Shaping of a Forest Policy

To a measure nations go through much the same processes of evolution in respect to forest renewal. We can look with profit to the experience of the older nations in our effort to attain forest renewal in this country. Practically all forests both public and private in Germany, France and Sweden are organized for sustained yield and the annual cut bears a close relation to the annual growth. In these countries the forest problems of the past century have centered in attaining reproduction of desirable species in fully stocked stands. In order to show what is meant by the reproduction of desirable species in fully stocked stands, let me cite the case of Connecticut. Forty-six per cent of this state is returned as timberland, yet when one goes to our retail and wholesale lumber yards he finds that less than ten per cent of the timber offered for sale comes from Connecticut forests.

For a hundred years France has had a fixed policy with adequate reproduction as its chief aim. Without virgin forests she was able to supply the essential needs of the allies for wood during four years of destructive warfare and without seriously encroaching upon her forest capital. China may be cited as the antithesis of France. She has never practiced forest renewal. Virgin forests disappeared ages ago and with them a great basic resource, the loss of which she most keenly feels to the present day.

The history of the ages demonstrates that in every nation forests decrease in area and in quality and in time disappear when under unregulated private control. History also demonstrates that forests are adequately maintained wherever forest renewal is accepted by the people as a public responsibility and laws are enacted under which it is attainable without serious loss to the individual.

With our relatively small area of publicly owned forests it is short-sighted and most unwise to continue longer our past policy of unrestricted practices of exploitation and devastation of private forest property. The time is at hand when this nation must either initiate a policy of land purchase which will bring under public ownership and control an additional one hundred twenty-five million acres of absolute forest land or else the private owners of the productive forests of America must shift their point of view. They must give up exploitation and devastation because it injures the public. It is not believed the public can secure through purchase, at least in the immediate future, sufficient acreage of absolute forest land to meet our essential requirements. *It is for this reason that we now witness a nation-wide agitation for a national forest policy having for its primary object forest replacement on lands privately owned.*

This agitation was begun by Colonel H. S. Graves, formerly Chief of the U. S. Forest Service, and is being continued in that service by Colonel Greeley, his successor. It has been taken up by the Society of American Foresters, and a few months ago a committee of that society submitted a comprehensive report to its members which has since been accepted by majority vote of the society. Within the past few months more or less complete plans for national and state forest policies have been formulated and advocated by many organizations of foresters, lumbermen and large users of forest products.

The leading forest policy proposals now before the country are three:

(a) The program of the Committee of the Society of American Foresters.

(b) The program of the American Paper and Pulp Association and various lumber interests.

(c) The program advanced by Colonel H. S. Graves.

These proposals have been for the past nine months under discussion in technical magazines, lumber journals and in the public press. All have been criticized more or less severely and each has its advocates. All recognize the necessity for forest renewal. They do not differ in results desired but rather in methods and processes by which results are to be obtained.

The program of the committee of the Society of American Foresters insists that laws should be enacted by the national Congress under which severe penalties are imposed upon the private owners of absolute forest land who do not organize their property and practice forest renewal. *It places the responsibility for sustained yield chiefly upon the private owner of forest property.* This program is more centralized than the others, more sweeping in character and places greater emphasis upon the requirements. This program is radical in that it is centralized in the federal government and combined with a plan for the industrial control of the lumber industry.

The program of the American Paper and Pulp Association insists that the national government should act through the states and that through co-operation and financial support the nation and the state make sustained yield on privately owned forest property attainable without financial loss to the owner. *It places the responsibility for sustained yield chiefly on the public whom they consider the chief beneficiary.* This program does not recognize the mutual responsibility of the private owner and the public and is antagonistic to mandatory state laws for the renewal of forests on absolute forest land that is privately owned.

The program advanced by Graves sets forth a plan under which the national government working through the states provides technical assistance and financial support in effecting forest renewal on private property but at the same time *insists that the state exercise mandatory regulations and provide adequate assistance in co-operation with the national government to make forest renewal certain. It places the responsibility for forest renewal on both the public and the private owner.* Co-operation is the key to this plan. It is to be noted, however, that the idea of mandatory laws to control forest replacement on private lands is basic as it is in the more radical program.

The Program of the Committee of the Society of American Foresters

The committee of the Society of American Foresters has published and widely distributed a most detailed and comprehensive plan. This plan sets forth nine fundamental principles as follows:

1st: Prosperity in peace and safety in war require a generous and unfailing supply of forest products.

2nd: The national timber supply must be made secure.

3rd: The transformation of productive forests into idle wastes impoverishes the nation, damages the individual, is wholly needless and must be stopped.

4th: Unless and until lands can be more profitably employed for other purposes they should be used to produce forest crops.

5th: The ownership of forest land carries with it a special obligation not to injure the public.

6th: The secure and steady operation of the lumber industry is of vital concern to the public.

7th: The lumber industry being nation-wide, uniform and adequate control over it must be national.

8th: National legislation to prevent forest devastation should have three objects:

(a) Control over private forest land.

(b) Only such control as may be necessary to place forest industries on a stable basis.

(c) The transfer of control back to the forest industries as soon as they are willing and able to assume responsibility and respect the public interests.

9th: The national, state and community forests should be maintained and largely increased.

The legislation suggested in furtherance of the proposed plan calls for a national committee in Washington consisting of the Secretary of Agriculture, the Secretary of Labor and the Chairman of the Federal Trade Commission with supreme authority over private timberland, and to operate through regional organizations of government foresters assisted by representatives of the Federal Trade Commission and the Department of Labor.

This commission is political and certain to change with each administration. The legislation proposed goes far beyond that dealing with forest renewal. It provides for reports on the production of forest products from private timberland, reports on sales, stocks on hand, costs and other matters not generally available to the public. It even fixes accounting methods and provides for the control of production when judged desirable by the commission. It permits the government to cut its own timber and provides for the creation of labor councils of employers and workers to consider wages, hours and various other matters. It excludes farmers' wood lots from the legislation proposed and provides penalties for the enforcement of the law. The plan has been severely attacked by the lumbermen of the country and by many foresters as well.

THE PROGRAM OF THE AMERICAN PAPER AND PULP ASSOCIATION

The adherents of this program although fully recognizing that our forest capital is being exhausted much faster than it is being replaced are unwilling that the private owner should assume responsibility for forest renewal. This group has also published and widely distributed a detailed plan for sustained yield. This plan sets forth the following principles:

1st: A program providing for a permanent timber supply must be adequate and practical to produce the needed results, just to all interests concerned and acceptable to the majority.

2nd: There is urgent need for co-operation by the national and state governments to accomplish:

(a) A forest survey and land classification.

(b) A great extension of public ownership through the purchase of cutover lands.

(c) An extension of Federal co-operation with the states in fire protection and in measures which will reduce the fire hazard and afford better opportunities for natural regeneration.

(d) Better forest taxation laws, the establishment of state nurseries and the preparation of working plans for the purpose of encouraging the private owner who wishes to grow timber. A provision that if the private owner of land only useful for growing timber refuses to co-operate, his land be acquired by the public at a fair valuation and made a part of the area of public forests.

(e) A large program of planting on lands which have been so far denuded that there is no hope of securing an acceptable crop through natural regeneration.

Special emphasis is placed in this program upon uniting professional foresters, timberland owners and consumers of forest products upon an immediate plan of greatly increased fire protection and a more general acquisition by the public of cutover lands.

In order to make the proposed plan operative the following national and state legislation has been proposed:

National Legislation

(a) A present annual Federal appropriation of one million dollars to be expended in co-operation with the states for fire protection, care and management, and the distribution of planting material, this sum to be gradually increased to a maximum of five million dollars.

(b) An annual appropriation of five hundred thousand dollars to continue as long as necessary and to be expended in co-operation with the states in making a complete and accurate forest survey and classification of both public and private forests.

(c) A permanent annual Federal appropriation of not less than three million dollars to be expended in extending the area of national forests until their total area reaches a minimum of at least two hundred million acres.

(d) The extension of the general authority of the Secretary of Agriculture to exchange national forest land, stumpage and timber certificates for private timberland within or adjacent to existing national forests.

(e) A present annual appropriation of at least two million dollars for planting operations on the national forests.

(f) A present annual appropriation of five hundred thousand dollars for forest investigation and research.

(g) The extension of the Federal Farm Loan Act to include loans on private forest property and to be expended in the improvement of such lands and in employing measures to promote timber growth.

The appropriations herein requested are modest when compared with the magnitude of the forest industry. There is no doubt that were such appropriations available they would materially improve conditions but in the writer's opinion they cannot in themselves solve the problem of sustained yield on privately owned timberland.

State Legislation

The state legislation proposed in this program is based upon the following principle: If forest land like agricultural land bear its share of the support of the state it is essential that it be organized and developed for sustained yield. It is recommended, therefore, that bills be introduced into the state legislatures embodying principles in harmony with the suggested Federal legislation but applicable to the special needs of each state. These bills should provide for a forest survey of the state in co-operation with the national government; for their organization for state-wide fire protection; for adjustment of taxes; for assistance in the practice of forestry by private forest owners, by supplying planting material, making working plans and supervising silvicultural operations free of charge or at the lowest possible cost. These bills should also provide that private forest land may be taken by the state at a fair valuation and made a part of the public forests of the state only in case the private owner refuses to avail himself of the co-operation and assistance provided by the public. Also that a adequate support be given by the state for educational and experimental work in forestry. Furthermore these bills should provide for adequate state appropriations to make them effective.

It is to be noted that the advocates of this plan are willing to accept generous appropriations from national and state governments for the furtherance of sustained yield on private timberland. They are unwilling to assume a part of the responsibility for attaining sustained yield. The state legislation proposed is weak in that it does not adequately recognize the responsibility of the private owner. It is recognized, however, that the private owner has a moral and legal obligation to handle his property in such a way that it does not become a public nuisance and that the state may require him to conduct his cutting operations in a manner to lessen the fire danger.

The Graves Plan

The immediate program also opposes complete public control of private timberland by a national commission. The advocates of this plan believe whatever control is exercised by the nation must be by the Federal government acting with and through the several states. *They recognize a decided responsibility on the part of the private owner of timberland.*

This program has been fully described by Colonel H. S. Graves (a) in a pamphlet issued from the office of the Secretary of Agriculture under the title, "A Policy of Forestry for the Nation," (b) in a mimeographed report from the U. S. Forest Service under the title "The principles of a program for Private Forestry" and (c) in a mimeographed report by the U. S. Forest Service under the title "The next steps in a National Forest Policy."

Due to the emphasis placed upon co-operation and from the fact that the program involves local plans to fit local conditions it cannot be as specifically outlined as the foregoing plans discussed. It can, however, be best outlined under the two heads (a) Principles involved, and (b) Federal and state action required.

I. Principles Involved

1st. The need of a Forestry program in which it is recognized that no single legislative measure can accomplish the objects desired but that a central national policy is needed adaptable to special regional conditions.

2nd. The object of the program should be to bring about permanent forest production on all lands which are best suited for the growing of timber, and the recognition that this can be done only by adequate protection and by the replacement of old timber when cut with new growth.

3rd. Public forests should comprise critical areas on important watersheds and extensive areas elsewhere to serve for the production of forest products, as demonstration forests and as centers of co-operation with private owners.

4th. The problems of farm forestry should be worked out through the medium provided by the public to educate farmers in better methods of agriculture, and the utilization of commercial timber tracts should require that the public take steps to stop destructive processes and substitute constructive methods of forestry.

5th. That private ownership of forests carries with it certain definite responsibilities, in that private ownership does not give the right to handle forest lands in a way that jeopardizes the public interests.

6th. The character of the forestry problem is such that as a rule the private timberland owner seldom adopts measures tending to the perpetuation of forests upon his own initiative and without direction and co-operation by the public.

7th. The safe-guarding of the public interests in forests requires laws to the effect that the private owner adopt measures for forest replacement but at the same time be given such public assistance and co-operation as may be needed to make such measures feasible in practice; that the mandatory principles in these laws aim to establish uniform requirements to apply to all timberland alike and to be within the possibilities of practical application.

II. Federal and State Legislation Required

A. Federal Legislation

1st. For the extension of national forests.

(a) Authority to exchange national forest land, stumpage and timber certificates for private forests within or adjacent to existing national forests.

(b) Continued appropriations on a generous scale for acquiring forest land by purchase, until ultimately such acquisitions extend into all the principal forest regions in the United States.

2nd. For co-operation with the states in forest protection and silviculture.

(a) Authority to provide the states liberal financial help and technical aid.

(b) Authority to greatly expand the activities of the U. S. Forest Service in co-operation with the states as now authorized by Section 2 of the Weeks law; this authority to carry with it a yearly appropriation by the National Government of not less than $1,000,000 to assist the states in forest protection and silviculture, but the expenditures in any state not to exceed the expenditures of the state for the same purposes, and the benefits of the law limited to the states which establish mandatory laws fixing minimum requirements.

3rd. For the securing of better forest taxation and insurance laws, including legislation carrying a moderate appropriation to devise model forest taxation and insurance laws.

4th. For loans on growing timber, through the extension of the federal law concerning farm loans, but such loans to be issued upon a specific obligation assumed by the owner to retain the land in growing timber and to protect and care for it during the life of the loan.

5th. For land classification, through the states but with federal assistance, in order that all lands be put to the most advantageous use and ill-advised attempts to cultivate land which is not agricultural in character be stopped.

6th. For forest surveys and research including a special appropriation for a comprehensive survey of the forest resources of the

United States in co-operation with the states and private interests, and for aid to enlarge research in forestry and in forest products along the lines already under way by the U. S. Forest Service.

B. State Legislation

Although this program recognizes that the differences in forest conditions in the several states do not make uniform state forestry laws possible, it recognizes that certain main principles are applicable to practically all of the states which contain forest land but variations in methods of enforcing them are necessary.

The state legislation necessary to carry out the foregoing national program is as follows:

1st. The enactment of laws to the effect that the private owners of forest land are legally responsible for preventing their property from being devastated or denuded of forest growth, and that it should be incumbent on the State Forestry Board to enforce this principle.

2nd. That state law in pursuance of the above should make the following measures obligatory, leaving detailed methods of enforcement to the State Forestry Board.

> (a) Organized protection of all forest lands in the state under a system by which the cost is met by the Federal Government, the state and the private owner.
>
> (b) Police regulations for the control of forest fires during critical periods.
>
> (c) Effective disposal of slash in all cutting operations under a method best suited for the particular forest type.
>
> (d) Cutting methods determined and established by the State Forestry Board for application in forest types where protection alone is insufficient for forest renewal.
>
> (e) To provide for assistance to forest owners through the State Forestry Board in the study and classification of land, and for co-operation with the Federal Government in this classification.

3rd. To provide for assistance to the private owners of forest property in attaining forest renewal and to provide for forest investigation and for the systematic planting of denuded lands in state ownership.

4th. To provide funds and the machinery for a large extension of state and communal forests.

5th. To provide a non-partisan control of forestry work in the state through a Forestry Board representing the forest-using, agricultural, and educational interests in the state, with the executive forest officer a technically trained man known as the state forester.

6th. To provide better taxation laws through the creation of a commission in each state to study existing practices and their effect on forest replacement and to recommend to the state legislature a revision of present laws where advisable, the commission to receive co-operation and aid from the Federal Government.

The differences in the foregoing plans can be briefly stated as follows:

The more radical plan proposes national mandatory laws governing privately owned forest lands. Chief emphasis is placed upon specific requirements imposed upon the owners although public assistance is provided in certain matters. *The more reactionary plan* proposes no mandatory laws, makes no requirements whatever but relies upon encouragement and inducements in the way of public co-operation and aid, with the public ownership of forests as an alternative. *The intermediate plan* imposes certain requirements but emphasizes co-operation and public aid. It makes public action an integral part of the plan and recognizes the necessity of the public's sharing the cost and responsibility. The advocates of this plan believe that state legislatures must provide certain mandatory requirements for forest renewal but that both Federal and state governments must provide co-operation and financial support in making effective a system of forest management for each locality which will result in sustained yield without placing an undue burden on the private owner.

It is the writer's judgment that the solution of our forestry problem will be found most likely in the development of a forest policy based upon the principles and legislation now under process of development by the advocates of the intermediate plan. This plan recognizes a dual responsibility resting upon both the public and the private owner of forest property. It recognizes not only the necessity for liberal national and state appropriations and the heartiest co-operation between the public and the private owner but it also recognizes that where there are reciprocal public concessions to be safeguarded reasonable requirements are essential.

Although we are not yet ready for radical Federal coercive laws and it is the writer's hope we never will be, the time will very likely come in the not distant future when the private owner, as in many European states, although permitted by the state to cut by whatever method he pleases, must attain adequate reproduction on cutover areas to satisfy the rigorous examination of a board of foresters. Some day the state will say to the private owner, "We are concerned in keeping absolute forest land permanently under forest. We judge you by the condition of your cutover land. If it is unsatisfactory from the standpoint of public welfare, we will improve it if you do not, and charge the cost against the property."

CONTROLLING THE AIRPLANE AT TWENTY THOUSAND FEET

By Professor HENRY C. McCOMAS
PRINCETON UNIVERSITY

HOW the airplane will sail at twenty thousand feet can be predicted with confidence. How the pilot will sail his ship at that altitude is quite another question. Each year has witnessed improved designs in ships, so that planes to-day climb easily to twenty-five thousand feet; whereas five years ago they rarely exceeded ten thousand feet. During the war the aviator was called upon to drive close enough to the trenches to use his machine gun and to rise to eighteen or twenty thousand feet for combat purposes. Machines assisting the artillery in range finding did not often work above eight thousand feet. The different types of work called for different types of machines. Perhaps we should say for different types of pilots as well. As some machines can not rise to great heights, so too some pilots are incapable of work at great altitudes. General Squier reports that 61 per cent of men examined for altitude work are capable of flying to twenty thousand feet or more; 25 per cent. should not fly above fifteen thousand feet; and 14 per cent. were inefficient above eight thousand feet.[1]

High altitudes impose new conditions upon both the man and the machine. Rohlfs, the holder of the American altitude record, tells us that on a summer's day, when people are sweltering in the heat, he experiences in his climbs a temperature of twenty-five degrees below zero, and a wind of from one to two hundred miles an hour. Of course, the air pressure is greatly diminished. Both pilot and airplane have to contend with greatly decreased temperature and air pressure as they rise. This necessitates certain changes in the machine and certain changes in the man. The carburetor and the water system both have to be adjusted to meet the new requirements. The heart rate, the respiration rate, the blood pressure have to be adjusted to keep the pilot's system working. As the pilot and the plane are a unit in the work they do it is of course as important that the machinery in one should be studied, understood and cared for as thoroughly as in the other.

A great deal of work has been done to select and classify the fliers. Each of the countries in the war had an Air Medical Service

[1]Aeronautics in the United States, 1918. George O. Squier, Proceedings of the American Institute of Electrical Engineers. Vol. 38, No. 2, p. 81.

as a part of their air forces. At Mineola, Long Island, many tests and experiments were made in the Medical Research Laboratory and their results published by the War Department, Air Service Division of Military Aeronautics. Much more, of course, must be done and will be done.

The effect of the lowered temperature upon the aviator has not been thoroughly studied. We do not know just to what extent his senses and his reaction are affected. Certainly there must be some modification of his abilities by the change. The reduction in atmospheric pressure has its greatest effect in the depletion of oxygen supply. The merely mechanical effect of reduced pressure does not seem to affect vital functions. It does, however, cause great discomfort. We must remember the fact that we live at sea level, in an atmospheric pressure of about fifteen pounds to the square inch, and that as we rise this pressure decreases. When we bring this to mind we recognize that nature has provided us with constitutions to resist this pressure. The balance between the pressure of our constitutions and that of the atmosphere is equalized. When we rise to eighteen thousand feet there is just about half the atmospheric pressure to be resisted. The most conspicuous effect is upon the eardrums. Just back of these delicate membranes is the eustachian tube running to the throat, and filled with air. Each time we swallow we open the tube which equalizes the pressure upon the eardrums. As we rise and the pressure in the tube becomes greater than that outside, one experiences a distinct pain which is relieved by swallowing. As an aviator descends quickly he finds it necessary to force the air into the tube against the drum by holding the nose and blowing gently: otherwise a quick descent would injure the drums. Next to the discomfort in the ear is the rather characteristic frontal headache. This is due to the change of air pressure in the sinuses.

The greatest discomfort and detriment are occasioned by the lowered oxygen tension. The pressure of oxygen on the membranes of the lungs is lessened and the blood receives a diminished supply of oxygen. This is all important. Oxygen is indispensable to the nerve tissues, to say nothing of all other tissues. The old saying, "No phosphorus no thought," is absolutely true if oxygen is substituted for the other element. In order to keep the tissues supplied with oxygen, when the supply is being diminished, nature resorts to some interesting expedients. The lungs seek a greater supply by deep respiration. The heart seeks to increase the supply by quickening the blood stream, the blood vessels co-operate, giving an increased blood pressure. The blood itself changes its constituency. The deepened breathing, the quickened heart, the heightened blood pressure are all brought about by stimulating brain centres which control these functions. Should these centres not respond until the blood stimulating them is very depleted in oxygen the compensations would not occur promptly, and the aviator would collapse. For this reason these functions have been carefully studied.

Before the aviator collapses from any fault of his vital functions, he may become so inefficient in handling his controls that he wrecks his machine. In the so-called "rebreather tests" the psychologists would frequently remove the aviator because of incapacity to keep his attention on his work or to control his movements. This condition often occurred, as the man received less and less oxygen, before there was any threat of physical collapse.

Of course, any deterioration in the functions of the nervous system spells disaster to the flier. If we consider the central nervous system as artificially and roughly divided into three parts, one of these would be concerned with sense impressions which carry impulses to the brain and spinal cord, one would gather these impulses centrally, and a third would convey out-going motor impulses to muscles and glands. A study of the sensory nervous system with its end organs under varying conditions would be most valuable to the air man. For example, it seems that one's vision is somewhat better after ascending a few thousand feet. This seems to be due to the increased blood supply, especially in the choroid and retina of the eye.[2] But after rising to fifteen or twenty thousand feet the vision is distinctly impaired. Hearing under high altitude conditions does not *seem* to be impaired at all![3] It would be important to discover the effects of low oxygen supply upon tactual and kinesthenic senses as well as upon the somatic senses, as these play a part in getting the "feel of the ship."

The motor mechanisms are certainly greatly affected by altitude conditions. The loss of oxygen gives the muscles much the same effect as fatigue. I have noticed in the low air pressure chamber that the slightest expenditure of energy, such as gripping the stick hard, or pushing the rudder vigorously, or even moving around in my chair brought a quick, perceptible fatigue. Indeed, one may quickly exhaust his oxygen supply and become unconscious if he exerts himself at all vigorously, around twenty thousand feet. Not only do the muscles become easily fatigued, but muscular coordinations become very poor.[4] This is beautifully illustrated by experiments in handwriting. A few specimens of notes taken by a man in the low pressure chamber under conditions similar to altitudes of six, fourteen and twenty

[2]The *Journal* of the American Medical Association, Vol. 71, No. 17, p. 1394.
[3]The *Journal* of the Medical Association, Vol. 71, No. 17, p. 1398.
[4]Air Service Medical, p. 312 ff.

thousand feet are given on Figure 1. It will be seen that there is a progressive deterioration with decrease of air pressure. The lettering shows the effort required to control the pencil. The men could see the lines they made but found it most difficult to control the finger movements. I am inclined to think there are fluctuations in motor control so that for a moment or two the coordination is quite good and then becomes inaccurate again.

The French and Italian experimentalists early conceived the desirability of testing not simply sensory, or motor factors, but both of these and the central factors too. This they did by the well-known "reaction times" test, which consists in stimulating any sense, usually sight, hearing or touch, and recording the time it takes to make a movement in response to the stimulus; for example, if a light is flashed before the subject of the experiment and he moves his hand the instant he perceives the light, it requires about .19 of a second for the nerve impulse to reach the brain, to be directed to the motor nerves, to descend these nerves and contract the muscles of the hand.[5]

This is a very simple operation of the nervous system. It is almost as simple as a reflex action. It would seem that the most important factor, namely, the central processes, is not sufficiently prominent. A better type of test is one which obtains "discrimination time." In this test several different stimuli may be presented, the subject does not know which one is coming; also, he is required to make a certain type of movement for each type of stimulus. That means he must recognize the signal given and make the appropriate reaction. This involves much more brain activity. It is a far better test of mental alertness.

"A good pilot should feel entirely at ease in space. He should be able to recognize at once the slightest difficulties with his machine in any one of the three dimensions. He should possess fundamentally the skill of command to re-establish equilibrium at any instant, just as a cyclist on his bicycle, but with this difference, that there exists a slight space of time between the moment of the movement of control and that of the effect produced. It is necessary then to correct the movement made, and at that point is the delicate matter of making the movement with too much intensity, or, on the other hand, insufficient intensity.

"In a word, it is the instantaneous transformation of a passing sensation to precise muscular contractions, but of infinite variability, with the purpose of constantly reacting to the invisible movements of the atmosphere and with all the other difficulties which may occur. This capacity, as it seems to me, is, above all, the result of training. Repetition of the same movement results in the formation of a nervous center which commands all the muscles involved in the execution of these movements, and then of centers in the medulla, which become substituted for the brain, in a transformation of a sensation to a movement. This is the theory of reflexes.

"The formation of these reflexes varies with the temperament of each person. The rapidity of acquiring them constitutes what is called aptitude. But in so far as the pilot does not acquire this automatic feature of his

[5]Ladd and Woodworth, Elements of Physiological Psychology, p. 476.

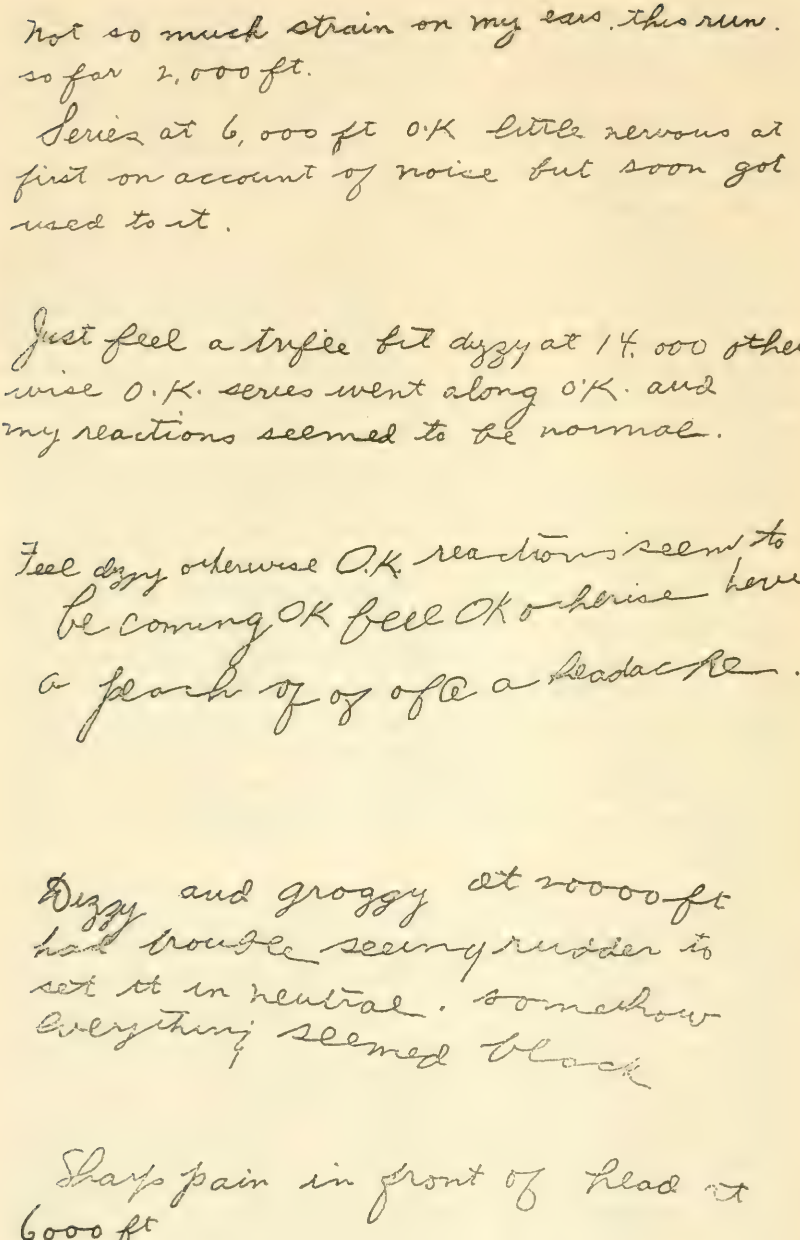


FIG. 1.

The third entry was written at 20,000 feet "altitude."

movements, he will have to furnish in his work a sustaining effort of attention, a great effort of will, which may go so far as producing nervous fatigue."[6]

[6] "Physiology, Physical Inaptitude, and Hygiene of the Aviator," by Dr. Guilbert, of the French Air Service. Air Service Medical, pp. 128-29.

To obtain an insight into the quickness with which a man recognizes a signal and makes the correct response, a form of discrimination time test was used in the Medical Research Laboratory at Mineola. In designing the test I sought to make the reacting movements similar to those of the pilot. An aviator's seat and controls, consisting of the stick and rudder bar, were placed in a large, low air-compression chamber, and electrical attachments were made to those controls in such a way that the time of discrimination was registered on a tape in units of 1/36 sec. Also, the direction of the movements of the stick and rudder bar were likewise registered. Through a window of the chamber a card was displayed which indicated how the stick and the rudder should be moved. When a shutter dropped, exposing the card, the timing device began to run and continued until the subject had reacted with both stick and rudder. The reactions, of course, tell us only how quickly the man made his discriminating responses. They do not tell us *how* he made them. He may have jerked his stick and his rudder with great vigor in such a way that if he had been in a plane instead of a steel chest he would have turned forty somersaults. As a matter of fact some of the men occasionally threw their controls with violence when under low air compression. This trait would disappear as the pressure returned to normal. It was not a constant performance. It, of course, is a result of the muscular incoordination mentioned above.

In determining the quickness of discriminating reactions under reduced oxygen conditions. I was fortunate to have for my subjects six experienced psychologists and one very intelligent enlisted man. Two of the subjects could not complete the series of tests. Four out of the other five continued the tests until their reactions had become quite automatic.

The procedure in the experiments consisted in placing the subject in the aviator's chair, explaining the reactions desired and in giving a number of trial reactions to accustom him to the apparatus and his duties. When he felt at home in the conditions imposed upon him, and had learned the best way in which he could make his responses, the actual testing began. Each subject was given a series of fifty tests at a time, never more than this. Occasionally a man would take but one series in a day; the work was dependent upon the availability of the men for the hours of experimentation. Each man was given his tests until his time of reaction, the mean variations of the time and the per cent of errors he made, all indicated that he had become as quick and accurate as it was possible for him to be. A learning curve was plotted for each man as he progressed. When it appeared that he had reached his highest efficiency, the tests in the low air pressure chamber were given. In most cases, however, the "altitude tests" were given before the learning curve indicated a complete disappearance of improvement.

In the "altitude" tests the subject was first given a series of fifty at sea level, then he was allowed five minutes rest while the air pressure was reduced to an equivalent of six thousand feet altitude. At this point another series of fifty tests was given, followed by another rest of five minutes while the pressure was again reduced, this time to an equivalent of fourteen thousand feet, again a rest and a series at twenty thousand feet, another rest and a second series under the same condition, again a rest and a third series under these conditions. Then, after the usual five minutes rest the pressure was increased to an equivalent of fourteen thousand feet and another series of fifty tests taken, then back to six thousand and a final series at sea level. The nine series would average about eight minutes per series. The compression changes would be made at an equivalent of one thousand feet per minute. One or two physicians accompanied the subject in the chamber during the test. They were supplied with oxygen by means of rubber tubes connected with tanks outside of the chamber. Occasionally they allowed some of the oxygen to leak into the chamber. To allow for this specimens of the air were taken at the beginning of the first series at 20,000 ft. under the low compression and again after the completion of the third series at that stage.

It will be seen that the situation does not exactly duplicate that of the flier in the plane. There is the absence of the high wind, of the great cold, and, of course, the excitement incident to danger. But the most important condition which affects the aviator physically, namely the low supply of oxygen, is the same in both situations. The sort of signals to which the aviator responds when in a plane; slight movements of the ship; the sounds from the engine; signals from other ships when flying in formation; or the appearance of a hostile plane are all very different from the signal cards. But the time of reaction to the signal, no matter what the signal is, is a physiological matter. The time of nerve conduction from sense organs to brain and thence to muscles should remain the same. It would appear then that the effects of low oxygen upon discrimination time in the compression tank should also be descriptive of discrimination times in actual altitudes.

The first subject, A., who took the "altitude tests," did so after going through twenty-three series of fifty tests each at sea level. He did not however reach the equivalent of twenty thousand feet owing to a leak in the oxygen supply. The charts Figure 2 give the results graphically. It will be noticed that his errors in reacting increased greatly during the first run and were very erratic. In the

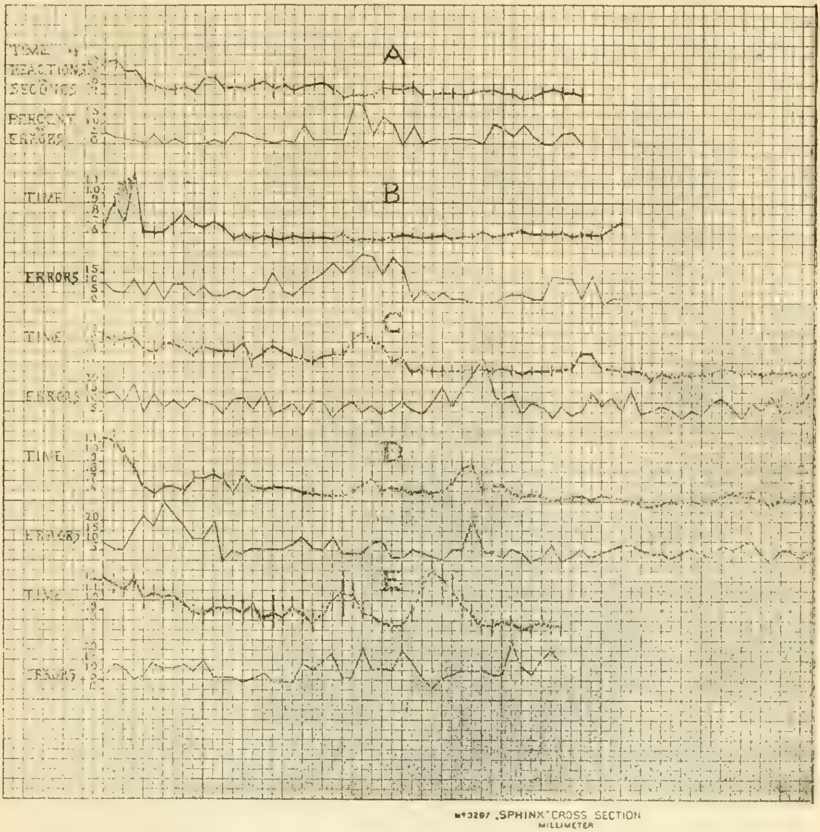


FIG. 2.

The heavy black line represents the average time required to move the controls in response to signals at sea level. The verticals intersecting it indicate the mean variations from the average. The dotted line gives the averages at "altitudes"; the first vertical indicating 6,000 feet, the next to the right, 14,000 and the three following approximately 20,000, then 14,000 and finally at 6,000.

The light line indicates the per cent. of errors made in the responses with the stick and the rudder.

The first "altitude" tests of both A and B show no increase in time required for their reactions, though both scored a larger per cent. of errors. In their second "altitude" tests their promptness and accuracy are quite as good as at sea level.

The learning curve for C and D is longer than for A and B. Two "altitude" tests, made before their reactions had become habitual, show deviations in the time, or error, records from their sea level averages. Their third set of "altitude" tests compare favorably with the sea level tests.

The time averages, mean variations and errors of E show that his reactions were not habitual. Oxygen depletion affected his time of response markedly.

second set of "altitude" series he appeared to be but slightly slower in his reactions, and much more accurate. The explanation of this given by the subject, who is a professor of psychology in a western university with many years' experience, is interesting. He felt that his "range of attention," his "field of attention" appeared to be narrowed when in low air compression. This he thought tended to inhibit distractions, leaving him freer to attend the stimuli. When he returned to sea level conditions he stated that the distraction of his surroundings was greater than under low compression.

This narrowing of the attention may explain a statement which several aviators have made to me concerning their flying at high altitudes. They said that it was easier to fly at these heights because your attention seemed to be on the ship and on nothing else. One naïvely remarked "the earth is so far away there's no use thinking about it." The situation is full of illusions, however, and what a man thinks he is doing when his field of consciousness is actually diminished cannot be trusted very much. When the series under the low compression during the second "altitude" tests are compared with the nine series taken at sea level three days later it appears that the altitude figures are lower than those for sea level. This can only mean that low compression does not affect this man in his quickness and accuracy of discrimination and reaction.

The next subject, B., had also been through twenty-three series of sea level tests before he was given his altitude tests. Like A., he made a great many errors during his first "altitude" runs, but his actual time and his mean variations from that time are not affected by altitude. In his second "altitude" series he made fewer errors but required slightly longer time than in the first set. Six days after the second "altitude" work, his eight *sea level* series give averages for time and mean variations just about the same as his second "altitude," though his errors increased. Here, again, it seems that low pressure and reduction of oxygen to values equivalent to the altitudes mentioned do not result in any appreciable lengthening of time or increase in errors for discriminating reactions.

The third subject, C., required many more practice series before his reactions became automatic. Comparisons of his first, second and third "altitude" runs show a considerable drop between the first and second in time but not in errors, while the third shows a more even distribution of errors and about the same time. Five series taken at sea level the day after the last "altitude" run show a slightly better performance, though insignificant in its difference.

Subject D., also, required a large number of tests before his time and errors reached their minimum. In his first two "altitude" tests his time of reaction considerably lengthened with the decrease of air compression. In the second series the time is longer and the errors more erratic than in the first. After a number of days of testing the third "altitude" series shows very little increase in time and error over the sea level series which immediately preceded and succeeded it. However, a set of five series at sea level taken the next day show an improvement in both time and errors. This indicates that this subject had not yet quite reached his maximum efficiency. He was still improving upon his time slightly.

With the fifth subject, E., it was impossible during the time available to train him to that condition where his reactions were virtually automatic. This shows in the great number of errors he made, in the very wide mean variations from his time averages, and in the rather extreme length of time required by him for his reactions. In both of his altitude runs there is an increase in the reaction times corresponding to a decrease in the air pressure, a situation quite similar to the first two altitude runs of Subject D.

In attempting to interpret these results we must keep several things in mind. The first is that a man becomes accustomed, in some measure through experience, to altitude conditions. He learns the great secret of deep breathing and he learns to conserve his energy. Furthermore, he is not so disturbed by the symptoms of oxygen hunger and he has more confidence in himself. The more frequently he makes his responses to his signals the more automatic do his reactions become. They may, indeed, as Mr. Gilbert states, result in the formation of a nervous centre which commands the muscles involved in the reaction, "and then of centres in the medulla which become substituted for the brain in a transformation of a sensation to a movement." I question the formation of a centre in the medulla, but it does *seem* as though the higher centres of the brain relegated automatic movements to lower centres. In this case, as the men became automatic in their responses to the signals the oxygen depletion affected them less. Indeed, it would seem as though these lower centres with their simple functions are hardly affected under the conditions of the experiment.

Certainly the higher function of the brain are profoundly affected. This appears from the introspection of the men. They all experienced dizziness and a tendency to vertigo, most of them becoming drowsy and only retaining their control of themselves by concentrated effort. The temptation to doze off is very great. Notice in the specimens of handwriting the misspellings and the repetition of a word, which were undetected while the man was writing. These lapses would never occur if the mind were alert. Obviously the mind is not alert. The best demonstration of that is to experience the change which comes over one when he has an opportunity to take oxygen when undergoing such an experiment!

The introspections written by the men during the tests are incomplete. It was feared that any special directions might burden them and distract them from the reaction work itself. For this reason they were told to jot down simply those things which occurred to them by way of observation concerning their feelings, emotions, thoughts, actions, as well as the progress and condition of the tests. However, from the notes made some interesting material is available. Three of the men noticed the unique effect of low oxygen upon their moods. Two felt irritable at lower "altitudes," but quite exhilarated at the higher "altitudes." One simply stated that he felt "just fine," though he was suffering from dizziness and a painful headache. The exhilaration somewhat resembles the feeling of well-being incident to an alcoholic drink. Often it is nothing more than a sort of carefree mood. Five out of eight men whom I have tested in low compression noticed this and mentioned it on their own initiative. As one aviator said who had just returned from France, "I felt as though I didn't give a hang." The same idea was expressed more elegantly by a college professor who remarked that he still tried to do his best, but had a "feeling of happy indifference." This emotional condition is one of the most important things to be noted as the effect of altitude. It easily might inspire the aviator to attempt "stunts" his normal judgment would not permit. This carefree attitude, added to the awkwardness of movements and narrow field of attention, makes a splendid conspiracy for a crash.

The aeronautic engineers believe that they are still in the beginning of their science, though they have accomplished a very great deal. Each year witnesses new discoveries and devices. The airplane is being constantly perfected. Obviously, the air service medical experimentalists are at the beginnings of their science. Certainly it is as important as that of the engineers. Some recognition of this fact is conceded by the government efforts in the experimental laboratory and in the work of the flight surgeons. Probably nothing would promote the science of aviation more quickly than a shift of interest from the machine to the man.

SURVEYS OF THE INTESTINAL PROTOZOA OF MAN, IN HEALTH AND DISEASE

By R. W. HEGNER, PH. D.

DEPARTMENT OF MEDICAL ZOOLOGY

SCHOOL OF HYGIENE AND PUBLIC HEALTH

THE JOHNS HOPKINS UNIVERSITY

and

GEORGE C. PAYNE, M. D.

STATE DIRECTOR, INTERNATIONAL HEALTH BOARD

EVER since the discovery of Balantidium coli in the intestine of man by Malmsten in 1857, more or less interest has been exhibited in this and other species living in the same habitat. For the most part the organisms observed have been recorded from cases of dysentery, diarrhea and other diseases of the intestinal tract, but they have also been found in apparently healthy persons who may act as carriers. A number of investigations have been published, especially since 1914, that add to our knowledge of the distribution of the intestinal protozoa and the extent of infection by them among healthy persons in various parts of the world, as well as among patients suffering from intestinal disorders. Most of these surveys were undertaken with soldiers either in the war zone or in hospitals after their return from the war zone. A few surveys have been made with soldiers before leaving their native country and with civilians, mostly in hospitals. That our knowledge of this subject is still far from satisfactory is evident from a review of the literature. Many species have been seen only once or a few times and hence are not definitely established as such; others seem to be determined satisfactorily but are of doubtful pathogenicity; the life histories of none of the species are sufficiently known to render control measures effective; methods of infection are suspected but not definitely ascertained; the therapeutic agents available are very limited in their application and for most species none is known; and the actual distribution of the different species in health and disease among the general population, with respect to age, sex, race, occupation, etc., is still to be determined.

The principal species of protozoa which have been described from the intestine of man are, among the Sarcodina, Entamoeba histolytica, Entamoeba coli and Endolimax nana; among the Mastigophora, Giardia (Lamblia) intestinalis, Trichomonas intestinalis, and Chilomastix

(Tetramitus) mesnili; among the Sporozoa, Isospora hominis, Eimeria wenyoni, and Eimeria oxyspora; and among the Infusoria, Balantidium coli.

Due to the inaccuracy of present knowledge, there is much controversy as to the pathogenicity of many of these parasites. Entamoeba histolytica and Balantidium coli are parasites of well recognized pathogenicity. Entamobea coli is a well known parasite that is non-pathogenic. Among the parasites of disputed pathogenicity are Giardia intestinalis, Trichomonas intestinalis, and Chilomastix mesnili; in certain localities these three parasites are very common and are supposed to cause severe diarrhea, especially in children. Many of the rare or recently described parasites are of doubtful pathogenicity; there are at least twenty-five species of these, belonging principally to the classes Sarcodina, Mastigophora and Infusoria.

There are also certain bodies which have been frequently found in the feces which are believed by some workers to be stages in the life history of protozoa. The most common of these are Blastocystis hominis, which has been confused with various cysts and has been described as the encysted stage of Trichomonas intestinalis, and iodine bodies of I-cysts.

Statistics from many countries prove that the dysenteries and diarrhoeas are very important causes of death and are especially so in the tropical islands. It cannot be claimed that a majority of these cases are of protozoal origin. It is a fact, however, that we know too little about the causes of these affections and their prevention and treatment. Without knowledge of the real causes and of the methods of diagnosis, efforts at therapy and prophylaxis must be conducted blindly. It appears highly important that we should have more complete knowledge of the origin of conditions which are causing such a large part of our total deaths. Furthermore, the relation between intestinal protozoa and intestinal disturbances that do not cause death nor receive medical attention is in urgent need of investigation. The wide distribution of species of parasites that are passed by unnoticed is evident from a recent study of children in a Baltimore hospital. Here children who were confined for reasons other than the presence of intestinal disturbances were found on careful examination to be infected in a high percentage of cases with an intestinal flagellate, Giardia intestinalis.

A review of over thirty-five papers published by American, English and French investigators during the years 1916 to 1919 describing the results of protozoan surveys has been made by the writers. These reports are based on studies made on all fronts during the war, on examinations of soldiers invalided home for various causes, and on material obtained from various classes of men, women and children who had never been out of their native land. Most of the latter were either recruits or were confined in insane hospitals or other institutions. Although many of these surveys were not carried out as thoroughly as is desirable they furnish very interesting data and point the way for further research.

Multiple infections, that is, infections with more than one species of parasitic protozoon, seem to be quite common. Thus, Fantham found among 1305 soldiers, 18 cases of multiple infection with Entamoeba coli, Giardia intestinalis and Blastocystis hominis, 20 cases with E. coli and B. hominis, 20 cases with G. intestinalis and B. hominis, and several with E. histolytica, E. coli, G. intestinalis, B. hominis and a spirochete. Similar conditions were observed by Carter, Mackinnon, Matthews, and Smith who recorded 14 different combinations in multiple infections; by Hall, Adam and Savage who reported from 388 convalescent soldiers, 21 with E. histolytica and E. coli, 12 with E. histolytica, E. coli and G. intestinalis and 9 with E. coli and G. intestinalis.

Among the rarer intestinal protozoa the coccidian, Isospora hominis, is of particular interest. This species was practically unknown before 1915 (Wenyon) but was found in no less than one-third of the surveys undertaken since then. Two new species of coccidians have also been added to those living in man, Eimeria wenyoni, and E. oxyspora (Dobell).

The percentage of infection with the more common intestinal protozoa among the twenty thousand cases examined is approximately as follows: Entamoeba coli, 20 per cent; Giardia intestinalis, 12 per cent; E. histolytica, 9 per cent; Chilomastix mesnili, 4 per cent; and Trichomonas intestinalis, 3 per cent.

One of the most surprising results revealed by the surveys under review is the high rate of infection with Entamoeba histolytica among classes who had never been out of their own country or who were not suffering from intestinal disturbances, as compared with patients who had or were convalescing from dysentery and diarrhea. Thus Woodcock recorded 1.9 per cent of infection with E. histolytica among dysenteric Indian soldiers, and 20 per cent of infection among Indian soldiers in hospital for other complaints; Smith and Matthews found 7.5 per cent of E. histolytica among 200 non-dysenteric soldiers; Yorke obtained from 1763 people who had never been out of England, 19.5 per cent of infection with E. histolytica among inmates of an insane hospital, 5.2 per cent among army recruits, and 1.5 per cent among civilians in a general hospital; Wenyon and O'Connor reported 5.3 per cent infection with E. histolytica among healthy men in camps, 13.7 per cent among healthy natives in prison, and 6.4 per cent among convalescent soldiers; MacAdam and Keelan recorded

10.1 per cent infection with E. histolytica among dysenterics, 13.6 per cent among non-dysenterics and 17.8 per cent among convalescents; Baylis (1919) concluded from an examination of 400 healthy new entries to the Royal Navy that from 1 to 5 per cent of healthy carriers of E. histolytica exist in England; Kofoid, Kornhauser and Plate found a greater percentage of infection among overseas troops (10.8 per cent) than among home service troops (3.0 per cent). In certain cases also the records indicate a difference between the infectivity of different races. For example, Boulenger reported almost twice as many cases among Indian as among British troops in Mesopotamia. Thus acute Indian dysenterics showed 48.1 per cent of infection whereas acute British dysenterics, only 24.8 per cent, and non-intestinal Indians 10.5 per cent of infection and non-intestinal British, 6.5 per cent. The results obtained by the various investigators indicate how wide spread are the healthy carriers of E. histolytica and other intestinal protozoa. They also show how desirable are thorough surveys of both healthy and diseased persons in the general population.

It is hoped that discussions such as that presented in this paper will stimulate investigations of the intestinal protozoa and for this reason the following brief statements regarding the purposes and methods of conducting surveys of intestinal protozoa are included.

Surveys of intestinal protozoa are desirable in order to add to the present medical knowledge of the incidence of each species according to geographic range, age, race, and occupation. Our present knowledge of the incidence of the intestinal protozoa is based largely on surveys conducted among troops, the majority of whom had suffered from dysentery or diarrhea of some type. We now require more complete information about the incidence of these species among the general population. The examination of specimens from Maryland and other Southern States by workers in the Department of Medical Zoology of the School of Hygiene and Public Health of the Johns Hopkins University has revealed a high percentage of infection with some of these parasites. A remarkably high infection is indicated also by the reports from the Division of Parasitology of the California State Board of Health as published in their Monthly Bulletin. Data regarding the association of the various species, one with another, and with other entozoa are also much needed.

The degree of pathogenicity of the various species is still undetermined and little is known of the lesions caused by any of them except E. histolytica. In a survey valuable information may be obtained by systematic observation of the bowel condition, the blood picture, the nutrition, and the evidence of the presence of toxic substances as shown by disturbances of circulatory, nervous, or other systems. Furthermore a protozoan survey would add to the present zoological knowledge of species and their differentiation, and life cycles, especially as they bear on preventive measures, and as regards the appearance of cysts in stools.

Men need to be trained if practical work on the diseases which are transmitted by soil pollution is to be carried on. Before such training can be given we must perfect methods of diagnosis, and investigate the factors involved in prevention. The attention of physicians must be directed to the prevalence of these parasites, thereby stimulating clinical work on pathogenesis and therapy.

The character of the population and the interests of the investigator determine the method of conducting a survey of intestinal protozoa. It is possible, however, to present certain principles that apply to almost any type of survey. If there is sufficient time and enough assistance is provided, a survey of the general population may be made; but it seems best to limit the work to certain classes. These may be selected according to habitat, race, age, occupation, or physical condition. The number of cases necessary to give satisfactory results cannot be stated with certainty but an attempt should be made to examine at least 1000 of each class. The results of various investigations have shown that three examinations of each case give the greatest return for the effort involved. Perhaps the easiest cases to study are those confined in hospitals, insane asylums, and similar institutions. It is desirable however that we know the relation between the intestinal protozoa and the healthy civilian in order to determine the percentage of carriers and their connection with the dissemination of parasites. Another class that is badly in need of investigation comprises the children with intestinal disorders not of sufficient severity to warrant hospital treatment.

Attention should also be directed toward the study of new species and the supplying of additional information regarding those already discovered and named. Such species are almost certain to be encountered in any survey and afford an opportunity to enlarge our knowledge of the group.

Studies of the effects of therapy should be included wherever possible. The control of protozoan diseases depends in large part on the success of these studies. That this subject is recognized as important is evident to anyone who examines the literature on intestinal protozoa that has appeared within the past few years.

The conditions affecting the transmission of diseases caused by intestinal protozoa are also open for investigation. We think we know how transmission takes place, but have very little data on which to base our beliefs. The most important factors involved in their study are probably soil pollution, contact, and insects and other animals.

The viability of cysts under various conditions of excreta disposal offers a simple and important problem for research.

Records should of course be made of each case and should include the name, sex, race, age, occupation and sanitary surroundings of the patient; important facts of clinical history such as dysentery and diarrhea; abnormal features noted on physical examination; and reports on treatment and their effects.

To make a survey as effective as possible it is desirable to properly prepare and preserve for future reference specimens of the parasites found. The best preparations result from the use of Schaudinn's alcoholic-sublimate iron-haemotoxylin method.

The methods of fecal diagnosis employed depend somewhat on the accuracy of the results desired and the ability to obtain and use special apparatus. The Donaldson iodin-eosin-smear method seems to be the quickest and easiest. Concentration methods give a slightly higher percentage of positives and the Schaudinn iron-haemotoxylin smear method just mentioned is very useful in checking up doubtful cases.

Species of protozoa resembling those that occur in the intestine of man are also present in the lower animals and one who wishes to undertake a protozoan survey will find it helpful to become acquainted with these before undertaking human fecal diagnosis. Parasitic amoebae inhabit the intestine of the cockroach, the frog and the oyster; Giardia is common in the intestine of rats; Trichomonas is abundant in the intestine of the frog; Balantidium occurs in the frog and pig; and Coccidia are very frequently present in rabbit feces.

ON THE CHARACTER OF PRIMITIVE HUMAN PROGRESS

By Professor R. D. CARMICHAEL
UNIVERSITY OF ILLINOIS

THE most remarkable thing among natural processes is the unfolding of the intellect and moral nature of man. Since his emergence from the animal state he has possessed powers comparable to those which he now manifests. Neither history nor speculation can reveal a period in his development when he was not making conquests evincing the same high order of intelligence as that which marks even his later career. In the earliest stages the individual man or the small group in a roving tribe had to approach the problems of life and environment without any effective tradition to guide or sympathetic collaboration with others to inspire. This called for a measure of independence unlike anything manifested by individuals today except in the labors of men of dominating genius. Among ruder peoples, in early times and at the present, the remarkable character of the discovery of truth is signalized by the acceptance of the new vision as something supernormal and sacred, akin to the activity of the gods and directly inspired by them. Though we have ceased to refer it to the supernatural, we ourselves understand it but little better.

Confronted with this problem, the man given to creative thinking seems no more able to effect a solution than another. He realizes that he knows not whence his fertile ideas come. Often they seem to spring up in his mind full grown, coming from depths which are not open to the view of consciousness. The thinker can describe some of the conditions which seem to be favorable to the appearance of the idea; but he cannot surely name its origin.

So has it been also in the appearance of the great motive forces which at different times have modified the whole outlook and prospect of human development as a whole. How they were conceived does not appear. That they have effected revolutions in thought and life cannot be denied. Some of the circumstances of their appearance we can see; but we cannot ascertain the prime source from which they sprang.

The first fundamental conquests over material nature, lost in the obscurity of a past from which not even tradition has come down to us, would now afford a sublime spectacle if the eye of history could find a means to behold them. Standing alone in the presence of nature, enveloped in darkness except for the meager light afforded by the glow of a mysterious genius arising or expanding in himself, primitive man found a means of mastery unlike anything before witnessed on this planet. He took the step on account of which he could cease to be driven about at the whim of circumstance and could introduce into his actions some measure of control over material forces which in themselves were of such magnitude as to overwhelm all physical power in himself and reduce him to mental impotence and mere animality, unless that power were directed by an understanding of himself and of phenomena which was sound in some at least of its fundamental aspects.

It was a marvelous advance when man first realized that he had a power in his being enabling him to bring under control some of these great forces of nature, in the presence of which he had before cowered with fear; and he was a long time in rising to the conception of harnessing these forces to his uses. His earlier advances seem to have been slow and to have been brought about largely by almost accidental discovery. How could it have been otherwise? What, other than unexpected successes, could first have brought man to a realization of the possibility of mastery? What is it in the nature of mind which makes it possible for it to exercise such control over matter? Certainly there is nothing conceived by primitive man which guided him to the realization of his first important successes. In fact, the matter is so difficult to understand that we have not yet formulated a satisfactory explanation, even though for many millenniums man has constantly exercised an increasing control over his environment.

A novel conquest over material things is in itself a victory of mind; and this constitutes one of the central elements in its meaning for the progress of mankind. Certain material things are in themselves essential to our welfare; we must have food and also protection against the discomforts of climate. But, however these may contribute to our physical needs, they can never inspire in us the emotions which constitute our chiefest delights. We instinctively feel that there is something finer in our nature than anything which may be gratified by merely physical satisfactions. The external world and its elements interest us in proportion as they are able to contribute values to our higher life. Whatever may be the material gains arising from increased control over nature—and these are great—more important values overshadow them or displace them in the field of our interest. Until we can extract from the material progress something to advance the interests of our higher nature we feel that it has not rendered us a service of the more vital kind. If the mind has not somehow made a gain in connection with the physical progress the latter is without essential import for us.

Moreover, the physical and the mental, in the stricter meaning of these terms, do not exhaust the whole of human nature and activity. Besides the material and that which is mental in the sense of being actuated primarily by the reasoning powers, there is the realm of emotion and religious experience—what we may call the spiritual aspect of man's nature. We do not understand his development when we leave this out of account. We may tie it up as closely as we please with his physical experience and material environment, we may think of the spiritual as due to a delusion induced in him by phenomena which he does not understand; but we can not dismiss it from consideration. It is one of the great characteristic elements of his nature and must be reckoned with. In fact, it is not too much to say that no element in his development is properly understood in relation to his progress until its colors are seen in the light of his deeper emotional experiences.

The first fundamental step forward in the control of nature, whether taken by the individual or the collective mind, was the most novel mental event occurring after the appearance of life in the process of evolution on this planet. As such it challenges investigation. It marks the beginning of a mastery by the living over the non-living so that the former is no longer to be driven about by the latter but is to come itself into a state of authority. Neither history nor speculation can yield us a well-established opinion as to the stage at which this novel power was first realized by our ancestors; but an analysis of the elements of progress among primitive peoples, both of ancient and of modern times, will help us toward an understanding of this momentous event in our history.

Was the advance first made by an individual who rose far above his fellows and had a grasp of his surroundings unlike anything possessed by his contemporaries, who therefore projected from his personality into the life of man a force which lifted it to a new plane and gave it a new character? Or was it brought about by slow accretions of power accumulated by a sort of collective mind in some advanced tribe which had found a means of preserving its smaller advances and combining them into a whole possessing elements different from any of its parts? Or was it still more complicated than this and required the interaction of tribe with tribe and the accumulation of power through many generations finally to issue in such flower of novel achievement?

The answers to these questions are important for our understanding of the past and of the basic conditions for further progress. The experiments in the laboratory dealing with mental processes are trivial in comparison with this vast social experiment in coming to understand our environment. The former has the advantage that we know the conditions of the experiment; the latter, that the greatest forces of our experience have operated in all the grandeur of their most far-reaching powers. It is hard to conceive a price too great to pay for a better understanding of this colossal experiment.

Man's environment, both that which he has found in the external world and that which he himself has created, has served to release the powers inherent in his nature. It is this which gives to his deeper understanding of it the supreme significance which we find there. The external world has no power in itself by which it can project a force from itself into the mind of man and create there a new character. Neither is there any such potency in the environment of created truth and spiritual forces with which man has surrounded himself. The power is not obtained from any external source which we can bring under observation, either direct or indirect. Whatever we may think about the question as to whether the native force of man is an endowment more or less supernatural, made by a benevolent Creator, we find no reason now for believing that his acts are merely the direct acts of a Being of higher order operating through him. Whatever is the ultimate source of the power he now manifests, it resides at present in him and is not exerted by a supernatural activity governing each separate act.

This leaves to the environment, then, at most the opportunity of releasing this power and setting it into activity. That it has done this in a marvelous manner is apparent from many considerations, but from none more forcibly than from the fact that a novel material conquest has several times in our long history given a new color to our lives and a different character to our outlook.

What stage of development have we reached in this process of unfolding? What proportion of the native endowment of man has already been realized by completed achievement? How nearly has he gained his maximum control over his environment? To what has he reached relative to the fullness of his being, in the understanding of his own nature and powers?

On our answers to these questions will depend the character of our outlook on the future of the race, as to whether it shall be optimistic or pessimistic. If we feel that all, or nearly all, of the fundamental conquests have been made, there will be nothing left to us to give zest and meaning to our lives. No vision of great things to be achieved will stand out as the goal of our labors, inspiring us to efforts realizing the greatest force of our character. As a race we should cease to live in the future or rejoice in the visions of things to come; the activity of life would lose much of its charm for us and we should find our greatest comfort in meditations on the achievements of our ancestors. Nothing could more clearly indicate that the race had come to the period of old age; and we could hardly prevent the feeling that the time of its end was drawing near.

On the other hand, if the evidence should indicate that we are still in a stage of active development and that there is every reason to expect further advances, comparable to the greatest of the past, then the joy of life and labor will spring up and we shall take hold of our several duties with the spirit which arises from the conception of the most worthy things to be achieved. No labor will seem too long or task too arduous if it promises to lead us forward to a realization of things hoped for. Many workers will be ready to consecrate a life of intense application to the study of phenomena of every sort, however far some of them may be removed from the previous interests of mankind. No opening into the unknown will be so obscure or the prospect so dark as to drive away all thinkers. Every possible line of progress will be explored under the enthusiastic hope or expectation that something of value will be found on the way; and man will rejoice in his progress in fields for a long time cultivated and in territory just being opened to exploration.

It is clear that man must somehow obtain power, not merely latent but active, before he can enter upon a control of nature such as he has achieved. No measure of inherent possibilities will be sufficient. They must be realized by an actual grasp of present power in a state of successful activity. It could hardly be conjectured, and there is no reason to suppose, that the release of his energies was sudden like that of a coiled spring. It is far more probable that the process was a gradual one and that the accumulation of power would be better illustrated by the slow increase of force in a water turbine into which is admitted an increasing stream of water from a head which does not sink but perhaps rises slowly. In this figure the effect of the environment is represented by the action of the gate through the slow opening of which an increasing portion of the power in the head of water is admitted to the turbine and is thus released into effective work.

In our present state the greatest inspiration to an intellectual life and hence to an increase of power comes from the interaction of mind with mind. From its very nature this is the kind of influence which the individual primitive man would first be able to realize; for it is an influence emanating from that which is most akin to his own activity and consequently best able to find a means of entrance into his experience. This would lead us to expect that the first fundamental advance would be intimately connected with the relation of man to man in his mental life. Such indeed have been the conclusions of anthropologists, after a careful examination of the relevant facts. To the development of language, the prime means of the communication of mind with mind, has been given the honor of initiating the marvelous release of the powers of man.

Language is so intimate to the deeper experiences of the mental life and exercises an influence so definite and so characteristically its own over the development of an individual that the universal realization in mankind of such effects as it produces tends to increase in a marked degree the essential unity which has its origin in the common ancestry. If language had its beginning in a single center—perhaps the first home of the race—and spread thence throughout the world, then its unifying influence would have the additional effectiveness gained through the transmission to all mankind of the ways of thought first crystallized into its words and forms of construction.

That this unifying influence is highly effective is still manifest today. In many ways we see common elements in the civilizations of peoples possessing a common language which have a tendency to disappear if from any cause one of them comes to use another language. Conquerors have often realized this and have frequently sought to adjust a people to a new rule through forcing upon them the language of the conqueror.

There is a matter of a subtle nature in the way in which language makes it possible to pass the experience of one generation along to the next. The phenomena of nature present themselves to us ordered in space and time, but without apparent logical connections to bind them together. As long as we meet them merely in the multiplicity of their separate existences we can not get far towards an understanding of them or a mastery over them. It is necessary that they shall be ordered into groups or sets each held together by some tie which serves in our minds as a unifying element. Now the combination of distinct elements into a whole and the formation of these groups depends on a process which the mind constructs for itself slowly and only after much labor. Any means of giving a considerable measure of permanence to the constructions of one individual mind or of one age will be of great value in maintaining mastery and effecting its further development.

Now when a tribe of men reach agreement concerning the common elements of a set of objects, as for instance the trees in the forest, and signalize their realization of the common features possessed by them by giving to them some such name as *tree*, they crystallize into definite form a class of experiences felt by each of them in a more or less vague way. The idea denoted by the word becomes more distinct by constant recurrence and both word and idea take their places as part of the mental possessions of man.

Now a word into which so much experience of the race has been instilled can easily be taught to the children of a new generation and be made to serve for them as a nucleus about which they can gather experiences of their own similar to those first embodied in the word. Thus through the various words which they use they have a very subtle means of assistance in organizing their early experience so that they are able to make much more rapid acquisition of knowledge than their ancestors who first had the confusion of unorganized impressions out of which they must construct the first essential organization of truth.

There is another advantage, lying deeper than this need of understanding the material environment, which language brings to the new generation. The way of thinking of their ancestors is preserved in some measure for them in the constructions of their language, in the peculiar ways of expressing thought developed through ages of progress. Thus a certain significant part of the mental development of mankind is summarized into the form and words of language in such a way as to be capable of transmission and to be of unmeasured value in passing on to the children the acquisition of their ancestors.

It is clear that this thing which is of so much value in one respect has in it otherwise certain elements of danger. The prejudices of the past are transmitted along with the accumulated truth. But, in the whole process, the good far surpasses the evil, leaving a large balance on the side of progress.

Among the savages who first developed effective language there was a force of intellect not to be despised, by whatever standard of achievement it may be measured. That it grew up probably by slow accretions from age to age does not detract from its marvelous character. It means merely that it was a product of the collective rather than of an individual mind, as from the nature of things it was necessary that it should be. To separate out ideas of far-reaching importance in practical life and to agree to associate them permanently one by one with such fluid and evanescent things as sound symbols which should call them to the mind of every hearer acquainted with the language was an act which could be performed only in the presence of a deep understanding, dumb though it may have been, of the essential elements involved in the process.

In view of this first magnificent creation of the primitive mind we can not refuse to recognize that early man possessed powers which do not suffer in comparison with those manifested to-day. To be sure, he was in the presence of an environment of which he had little detailed and established knowledge and some of his conjectures went wide of the mark; but, without any tradition to guide, he went about the creation of those means of communication which have since served us in all our activity. It was a long time before systematic methods of investigation were developed; but here at the beginning we see at work the instinct to discern and to grasp the deeper essential matters, and we find it issuing in the wonderful invention of effective language.

Fire occurs in nature. Now and then it is kindled by the lightning from heaven and consumes the forest tree or even sweeps the woods in devastation. Or it may bound forth from the bosom of the earth in volcanic eruption and destroy everything in its path. To the primitive man it was doubtless at first a consuming monster; and he must have stood in awe of its mysterious power. But a tribe which hunted in the neighborhood of a volcano, whose action was regular, would become familiar with it and would learn to appreciate its warmth on a cold and dewy morning. Gradually its value would be perceived and after a time the more adventurous spirits would begin to experiment with it and even to bear it about with them on a burning fire-brand, notwithstanding their occasional experience with its terrible bite. In this way a realization of its uses would begin to develop, and the community as a whole would gradually find new values in the tamed monster. The process was one carried out perhaps essentially by the collective mind of the tribe rather than by individual initiative.

The idea of accumulating power through a long process of tedious labor and storing it, as it were, so that it might be released suddenly with almost explosive force was perhaps first realized in a large way in the invention of the bow and arrow. The significance of this achievement was three-fold: in itself it afforded a remarkable means of mastery over a certain part of the environment; it predicted the discovery of further means for the multiplication of power; it gave man a new sense of the dignity of the character unfolding in him.

These three values are in the order of increasing importance. They exhibit a feature common to all the more profound elements of human progress, namely this, that the scale of values increases rapidly in the direction of a greater emphasis upon mental or spiritual forces. Often it happens that what is material lies close to hand so that it is the first thing found on a superficial examination; but lying deeper are movements of a more profound nature affected in some essential way by the results of the material development and affording to it its principal significance. In order to understand the progress effected one must ascertain the meaning of these deep-lying elements and the way in which they bring about an increase of power or the development of character.

The bow and arrow does not occur in nature. There was a moment when it was used for the first time; in the nature of things it must have been an individual, and not the tribe or community, that made this advance. The original weapon may have been of the crudest construction and have been used merely as a toy; but there was wrought into it the one novel idea which has guided in the making of the most perfect instruments of its class. Whether the idea was arrived at by accident or by deliberate thought, we have here the introduction of a thing of prime importance due to individual achievement. Language was developed and the uses of fire were discovered through the combined activity of the community as a whole; but the invention of the bow and arrow must be assigned to individual genius. It seems to be the first important instance of a kind to be found with increasing frequency as the consciousness of the possibility of such achievement becomes more definite and more widely current and as individual thinkers set about the labor of creative thought with clearer purpose as to the ends to be attained.

The experience of mastery over the clay which took form at their wish and was rendered durable by methods constantly practiced by them, awakened in our ancestors a conception of their power to mold things according to will and to create that which would endure indefinitely. Through this they realized a new possibility in human development and began to reap the fruits of a further release of inherent power.

In their previous progress our ancestors had merely effected new juxtapositions of materials already at hand, as for instance in the construction and use of the bow and arrows; but now in the pottery which they had learned to make they had brought into existence a sort of material not previously to be found in their environment, perhaps not anywhere in the universe—a conquest the novelty of which has since seldom if ever been equalled in the ages of increasing control over nature. Our modern laboratories have carried the processes of the creation of new materials beyond what could have been predicted by the most optimistic prophet of the old time; but in doing so they have only developed the idea which was brought into partial realization by the genius of a remote people.

It appears that the intellect which made the first fundamental advance of this sort was certainly possessed of essential qualities of power not unlike those which have led in recent generations to that development of physics and chemistry which is the marvel of those who take an intelligent interest in man's success in understanding the relations of phenomena in his evironment. There has been a development of mind, there have been acquisitions of new power, especially through a more profound grasp of the essentials of method in discovery; but the fundamental basic qualities of intellect now and in the remote age when the art of making pottery was acquired seem to be of the same nature.

We may take pleasure in such ancestors as our forefathers showed themselves to be even in the periods of savagery and barbarism through which we have rapidly sketched their development. They stood in the presence of phenomena whose nature was awe-inspiring to the creature that first inquired concerning their meaning. With no traditions to assist, with no previous conquests or discoveries of truth to start them out, with only a dumb and undeveloped sense or instinct of the destiny of man to light the way into a darkness of ignorance more profound perhaps than we can conceive to-day when so much of the push of the past has already been realized in our individual lives before we come to contemplate philosophically the nature of our environment and our relation to it, they began a career of development to which nothing else in our ken is to be compared.

SELECTION—AN UNNOTICED FUNCTION OF EDUCATION

By Professor W. B. PILLSBURY
UNIVERSITY OF MICHIGAN

ALL discussions of education, ancient as well as modern reiterate the belief that education is essentially a process of creating intelligence. They assume that a man with no intelligence, if such existed, might be taken by a suitable educational system or machine and in the course of a few years be given a capacity equal to any, while without it he would remain forever unintelligent. This assumption undoubtedly is in partial harmony with the facts. It, however, neglects one phase of the effect of education that is equally true and perhaps even more important, the fact that education merely selects the men who are capable. Instead of taking all men without respect to intelligence, and making those who go far enough intelligent, it takes all, but rejects the unintelligent and graduates or even trains only the intelligent. The educational system does not create capacity, it merely or largely selects the men of capacity.

Back of most of the popular and even many of the technical arguments on educational topics is the assumption that all men are equal in ability, and that what differences exist, are the result of training and of chance factors in the environment. Recently evidence has been accumulating that by nature men have all degrees of intelligence. A few with little training accomplish much; many with all the training of which they are capable never rise to mediocrity. As opposed to the popular belief it is our intention to present the thesis that men are as different in intelligence as they are in stature or as in length of life, and see what conclusions follow.

Only within the last two decades, and mainly within the last few years, has it been possible to obtain any direct experimental evidence of the way intelligence is distributed in the general population. With the development of a psychology of mental measurement, and the wide application of the measures, we can begin to discuss the problem with some basis of fact. To silence criticism by granting the lesser claims of critics and insisting only upon what is assured, we may admit that there are many defects in all the measures that have been applied and that many of the advocates of particular methods have claimed too much for them. We have only the vaguest notion what intelligence is. Our measures serve to distinguish only the more marked differences. We still lack any sufficient criterion, aside from the tests, of what an individual whom we have assigned a position by our measurements will be able to accomplish in any standard practical task. Still they suffice to show what wide gulfs divide the highest from the lowest and even the extremes from the average. We can say in answer to any criticism that psychologists know much more of all this than do the popular writers on educational topics.

In the recent army tests conducted by a number of psychologists and helpers, a million and three quarters men were tested by the same measurements. These were draft men chosen at random, except that the army surgeons were supposed to have eliminated all the mentally defective and inferior. The results of tests were carefully computed and correlated for one hundred thousand men of English names chosen at random from the list. These in turn agreed with and so confirmed the results from other groups similarly treated for preliminary reports. The tests used were also compared with other tests that had been applied to the measuring of a large number of school children, so that indirectly there are a number of cross checks on the method and a possibility of comparing the results obtained with those gained from numbers of school children.

Taken at their face value, the tests give a definite indication of the way the intelligence of the nation is distributed. Even if the tests were sometimes not so very carefully made, as is likely from the number of men who gave them, even though all were thoroughly trained in advance, they still furnish a general idea of the great range of intelligence in the male population. The army tests consisted in part in following directions for simple tasks, perceiving relations, performing simple arithmetical computations, putting words together to form sentences, detecting misstatements, and answering question which measure general information. Altogether an individual might make a score of 212. No one had time and information to answer all. Only 135 was required to attain the highest or A grade. This probably redeemed many of the apparent absurdities of the tests. Some of those, particularly the questions intended to test general information, were of a character that gave no particularly good indication of useful knowledge. With so low a standard, any one should have been able to answer a sufficient number to atone for failure on questions that ought not to have been included in the list.

On the basis of the tests, men were divided into groups that were designated at A, B, C+, C, C–, D, and E. These were defined in terms of ability to reach certain grades in the school system, partly because that offered a convenient means of labeling, and in part because it corresponded on the whole to the grade the men had actually attained. The A group of five or six per cent. do well in college. The B men are less successful in college but do well in high school. The C+ men complete the high-school course, the C men rarely do. The others would not be able to go beyond the grades, the E men not beyond the third grade.

One other convenient and frequently used means of defining or describing intelligence should be mentioned, as we shall have occasion to use it. This is Binet's scheme of measuring and grading intelligence in terms of the stage reached by a child at each year of his age. In the measurement of the feeble-minded, he compared the success of the individual to be tested with the success of the children of different ages in the same tests. Thus we may speak of a mental age of seven, ten, or twelve, indicating that the individual, irrespective of his real or chronological age, has the intelligence of a child of seven, ten, or twelve. And the D. group in the army tests might be said to have a mental age of eight, the E, of seven or below. The average mental age of adult whites of English name was a little below thirteen years.

The most plausible interpretation of the results of these tests indicates that on the average the stage in the school system attained by the average individual corresponds roughly with his capacity. It might be argued that the results of the tests were due to the amount of training given in the schools. That this is not the case seems evident from the fact that the tests were chosen so far as possible, with the intention of requiring no knowledge that would not be thrust upon any individual who lived in the average environment. They were planned to measure ability and not knowledge. It is also confirmed by the fact that a few men who had no educational advantages stood among the highest. They were men from isolated communities who had had no chance to attend school, but who would undoubtedly have done good work if they had been given an opportunity. The close agreement with the grade reached in school is, we may believe, due to the fact that most Americans go as far as they can in the school system, so that the amount of education is pretty closely related to the degree of natural intelligence. Had the men who stood first never been inside of a school room, they would have done as well in the tests as they did. Or, to put it less strongly but in a way that is practically the same from our present point of view, having the ability that they had and living in the social environment that they did, they were sure to reach the school grade that they did.

Accepting these results for the sake of argument, we can draw many interesting conclusions concerning economic and political problems, as well as concerning the problems of education with which we are now dealing. If we have a body politic in which only fifteen per cent. of the citizens can be expected to make any important contributions, and possibly not more than half are able to understand clearly the real problems of the state, have we the machinery for selecting the men who are best fitted for the higher grades of work, or are we allowing our best to waste time with unimportant affairs while lesser intelligences are struggling vainly with the great problems.

We may make illuminating comparison with what was probably the most detailed selective system ever applied on a large scale, the scheme put into effect by Suleiman the Magnificent in the sixteenth century when the Turks were at the height of their power. In broad outline this was completely democratic in the process of selection, although put into effect by one of the most thoroughgoing autocrats of history. It will be recalled by readers of Lybyer[1] that officials and soldiers were chosen for the imperial household from among the best children of the Christian population, and were taken to the court and there systematically trained in the line for which they showed the most aptitude. Agents went through the entire realm at regular intervals, examining the boys between ten and twenty and choosing the most intelligent, the strongest and the fairest for school. Slaves in name, in reality they were students and potential rulers. Once entered in the college of pages or in the corresponding school for soldiers, nothing but their own endeavor and own capacity was permitted to decide how far they might rise. They were slaves in status and worked under compulsion. When started on the career, they had no alternative but to do the best in that line. They could not escape if they would, and there was a fair field and no favor, with the possibility of great rewards and high distinction for the few who showed themselves capable. Selection and the strongest possible incentives, all worked together to make the ruling body and the soldiers of the Ottoman Empire the best that could be provided within the limits of the realm.

This was probably superior to any of the other methods employed at that stage of the development of the world's history. It is due to this rigid selection, probably, more than to any other fact that the Turk came near conquering Europe. Certainly the average ability was no higher, if we may judge from the later course of the empire, than in other portions of Europe. The education was rigidly enforced and was intensely practical. But no one could contend that the education developed the ability. Only the pages who were destined for the offices of the household were taught to read and write. These were also trained in the Turkish law, in the religious books, in the literature of Arabia and Persia, with some smattering of history. All were given rigid physical training, were taught a trade useful in war and one that might at need be relied upon for support.

The rigid selection of the physically and intellectually best was the essential factor. There were numerous grades in each service and a student could rise from one to another only as he excelled in

[1]Lybyer, "The Ottoman Empire in the time of Suleiman the Magnificent."

the lower. Advancement through these grades to the highest places was possible in any service. There was no favor, and any man could rise to the highest position, granted only that he had ability. We have good reason to believe that the power of the Turk depended very largely upon this system of selection, not upon education. This selection was not complicated by any favors to sons of powerful men; since only Christians were chosen and they must become followers of Islam when they were inducted, their sons were ineligible to succeed them. Coupled with early selection of the best was full opportunity to attain the position for which the individual's talents fitted him, with rich rewards for the successful ones. Education may have counted for something, but however important the thorough military drill and the vigorous physical exercises, it was hardly suited to work wonders in what we would call intellectual training.

Is there a similar selection working in a democracy such as we have in America? There is not and probably could not be developed a system that would select youths for training of different forms; that could say to one boy, "You have promise and will be given the training and opportunity of trying for high office," to another "You have only manual skill and shall be trained to a skilled trade, with only sufficient literary education to enable you to read and be a good citizen," and to a third, "You have neither mental ability nor manual skill and can only be an unskilled laborer," and so on through the list, prescribing to each the occupation he shall follow, based upon test or study of his capabilities.

On the other hand, many of the agencies that we regard as having other functions do really serve to sort and sift, and many of the advantages that come from these agencies are due more to the selection they work than to the training they give. The official agencies such as are provided by the civil-service examinations, act too late and are too superficial in operation to have any marked influence. They select on the basis of knowledge rather than ability and are so carelessly administered that they do little more than take the place of the politician in choosing by chance more than by favor. Their only positive advantage is to break up political machines and to prevent the obviously and grossly unfitted from securing positions.

More important and more long continued in its action is the system of education. Although the educational system is supposed to make intelligence rather than to select it, it is certain that selection is a most important feature, even if no attempt were made, as might with considerable plausibility be done, to argue that the primary, if not the exclusive, function is to discover rather than to create, or even to train, intelligence. In any state with a compulsory school system, all grades of intelligence are fed in at the bottom. The worst of them repeat the lower grades, and even with the kind-hearted or indifferent teacher of the least modern school, or of the most modern who works under the training-school dogma that the child should determine the character and amount of instruction, the inferior are excluded after three or four grades. In the more modern schools, tests select these incompetents earlier and they are given training adapted to their capabilities and are not expected or permitted to follow the regular curriculum. They graduate into the ranks of unskilled labor and can never expect to do more than earn a living. Society can ask only that they develop habits that will permit them to live in society without becoming criminals or paupers.

The higher capacities are sorted roughly by the regular school work. Those who find study too hard at any stage drop out and go to work, and when freed from the necessity of attendance at fourteen, only those of more than average capacity are left in the schools. Only the chosen upper 25 per cent. or less can reach the high school or go far into it, and about twenty per cent. do. Of these about half are eliminated before the high school years are completed. A still smaller percentage reaches the universities or colleges of the country. The educational system may be regarded as primarily a sieve for the separation of the competent from the incompetent. It would be very interesting to know if it is effective in this respect, and whether it alone suffices to put the administrative offices into the hands of the best.

Common observation indicates that there are other forces at work in the selection of individuals for the higher educational institutions than the mere ability to pass the work. The cynic can see evidence of the operation of at least two other forces. One is the wealth and advice of the parents, and the other, the social esteem in which education is held by the different grades of society. Certainly the son of a wealthy man is much more likely to go to an institution of higher learning than is the son of a pauper. Even in the least expensive of universities some reserve money is required. At the best, only the youth of exceptional energy as well as exceptional ability will be able to make his way through college without some backing or accumulated family capital. If he could take care of himself, it not infrequently happens that he will have the family in part dependent upon him, and so part of the selection is at best determined by the family finances rather than by sheer ability.

One can argue, and with plausibility, by the support of what statistics are available, that, in the long run and on the average, the men whose fathers are at least moderately well off are more likely to possess a higher degree of intelligence than are those who come from homes of poverty. Accidents such as the death of a parent may well account for families of good ability being without resources. At present, too, the men who go into the professions of teaching and preaching, no matter of how much ability or how successful, seem fairly certain to be unable to educate their children from their earnings. But, on the whole, while selection on the basis of wealth would tend to eliminate some who might succeed, it would not prevent the college men from being a chosen group.

The number of people who go to college would on the whole correspond fairly closely with the number who were capable of profiting by a college education. On a rough calculation, assuming on the basis of the army tests that 10 per cent. are capable of profiting fully by college education and that one twelfth of the population is between the ages of eighteen and twenty-two, we would have less than a million who are capable of doing college work. Of these, approximately a fifth are actually in college or have been in and withdrawn. If no more than four fifths of those capable of profiting by training are lost, we may not be able to boast of perfection, but may be reasonably satisfied, considering the defects in our knowledge of most of the factors that must be considered. This selection may be regarded as fairly effective in spite of the limitations imposed by the varying wealth of the population and the dependence, in some degree, of possibilities of education upon wealth—in spite, too, of the limitations imposed by the uneven development of the schools, the discouragement that comes from bad temper and incapacity on the part of badly selected or poorly trained teachers, and all the other circumstances which may be regarded as chance.

Running parallel with this is selection of the opposite type. In many classes in America, there is a constant temptation to enter occupations that give immediate monetary returns. Many boys in the teens try business and trades for a time in vacations. Many, if not a majority, of the college men in America pay their way, in part at least, by odd jobs during vacations, or in the odd hours of term time. This brings a constant temptation to the more successful to continue permanently in what was accepted as a means to an end. Emphasizing this aspect, one might regard the men chosen for education as the men rejected by the skilled trades. It is undoubtedly true in an industrial community of the middle class that many of the boys try the trades and those who succeed best remain, while the others go on with their studies. In some cases physical handicaps, like the loss of a leg or an arm, will force a man to become a member of the learned professions. Usually, however, the professions are regarded as more honorable and desirable in every way, and this social prestige counterbalances immediate present success. The men of the better mechanical ability, or the men of better address and natural skill in dealing with people, are often trapped by too great initial success, and with the slight training in fundamentals which they have obtained at that time can go no farther than the business into which they have entered will permit. Those who do not chance upon a position early in which they can succeed without training go back into school and continue to the end. It is of course extravagant to say that the professions are filled with the individuals who are rejected by the trades. On the average the selection is the other way round, but, that selection by rejection from the more immediately practical occupations exists, can not be denied.

On the whole, however, there is from this lot rejected by industry another sifting by the need for success in school, which leaves only those who are superior in intelligence, as well as those not particularly skillful mechanically in the list of college students. Then, too, the wealthier men are not tempted by industry although they may be by business and "society" or by mere desire for pleasure without responsibility. These are drawn to educational institutions, first, by the social prestige of the college, and, second, by its reputation as a place for a good time and as a desirable place to make acquaintances. The university or college may do these men no good, but at least their presence insures that the college shall contain a fair sampling of the men of higher intelligence chosen even from the most wealthy classes, from those whose families have been most successful in business, and who, if we accept the two assumptions that the wealthy are the intelligent and that intelligence is inherited, should average among the most intelligent members of the population. From this group come probably a fair number of the professional men, and especially a large proportion of the men who are to conduct the big businesses, or the not inconsiderable number who have not been selected by actual success in the business world itself.

How great is the part of the university in the selection of the men for the prominent places in the general community is evident from the statistics printed in the 1910-1911 edition of "Who's Who in America." This shows that fifty-eight per cent. of the men listed were college graduates, if we include the military men who are graduates of their technical schools, and that seventy-one per cent. had attended college or university for a longer or shorter time. Only ten per cent. had nothing more than a common-school education, and less than one per cent. asserted that they were self-educated. Whether selection or education is more important, the effect is wrought through the educational system. Of course it might be asserted that the 17,000 men in "Who's Who" indicate only a small fraction of the men who are filling important positions and that an undue proportion of these were in literary and academic pursuits, just as on our assumption it represents only a fraction of the men who are capable of attaining prominence. It is fair to say, however, that the proportion of college to non-college men who are in similar positions who are not included in that list will probably be approximately the same as in the list. Our first assumption that twenty per cent. of the men selected for the highest positions are chosen through the educational system seems rather an under than an over estimate.

The other forms of selection are through success in some particular occupation. In every large business there is a constant stream of men who rise from the ranks, and a large proportion of the successful men, who acquire wealth and position and thus become prominent in society or in politics, are chosen in this way. These are made up, in part, of men of high intelligence who for some reason dropped from school early. Many undoubtedly have capacities that would not have led to academic success but are valuable in business. How many of the latter type there are, and what constitutes the means of selection or the measure of ability is, most probably, value to the business in the opinion of the immediate superior. In many departments we find in the amount of business secured or in the actual accomplishment in the individual's own business objective measures of ability. All of these embody tests of energy, of push, and of social capacities that are not involved in the university work or are not important in the same degree. We know only that intelligence is required for a high degree of business success, but courage and energy may compensate in some degree as they cannot in the higher school work.

What relation there may be between success of this type and what we call intelligence as measured by scholastic work, is not definitely known. Probably successful business men are a mixture of those who succeed because of good intelligence, mixed with a certain amount of persistence and fighting qualities, of those who have considerable fighting ability and less intelligence, and of those who know how to get on by taking their opinions and aims and methods from successful men about them. One of the most successful of modern manufacturers showed in a recent court examination that he would not be able to pass at all one of the tests most relied upon in the best known series of mental tests, that of making definitions of abstract terms. Of course, the tests are not so well established that we can regard that as evidence of his defective intelligence rather than of the unreliability of the test. Certainly, if we are to prove that certain of these men lack intelligence, a large part of the population would regard it as a proof that intelligence is an undesirable characteristic.

Very interesting would it be to raise the question whether intelligence is closely correlated with wealth. On the whole, there can be no doubt that the two are connected. We find an occasional exception in individuals of markedly low intelligence who have accumulated considerable wealth, and we have the testimony of Charles Francis Adams that the men of wealth are on the whole stupid. As statistical evidence is the fact that several surveys of the well-to-do neighborhoods indicate that the children there are mentally a year older than are the children of the slums of the same chronological age. This of course, is a comparison between the poor and those of average wealth, but has a bearing upon our problem in so far as it indicates that the well-to-do are more intelligent than the poverty stricken. On the whole it would seem that while a modicum of intelligence is necessary for great wealth, other factors are important Some of these are beneficial to society, others not. Among the most important of these qualities are initiative, persistence, social address, acceptance of conventional ideals, and in many cases an emotional defect or defect of imagination that impairs sympathy for the victims in those instances in which wealth is won at the expense of others. Many intelligent men think that acquiring wealth is not worth the effort required and prefer to apply their energy in other directions; many lack the immediate opportunity, and still others are disturbed by the thought of the men who may suffer in the process. This last attitude is well illustrated by a student who explained his failure to succeed on a summer canvassing tour for an article of luxury, by his inability to talk enthusiastically when he knew that the people to whom he was trying to sell really needed their money for the necessities of life. Men selected for great wealth are above the average in intelligence, but wealth is not a direct measure of intelligence.

We can picture the educational system as having a very important function as a selecting agency, a means of separating the men of best intelligence from the deficient and mediocre. All are poured into the system at the bottom; the incapable are soon rejected or drop out after repeating various grades and pass into the ranks of unskilled labor. The really defective go at once to the homes for dependents and to penal institutions. We are frequently inclined to forget that almost half of our criminals and most of our paupers are mentally deficient. A teacher of an ungraded room in a western city school was twitted by the county attorney with graduating her pupils from the school to the juvenile court. The more intelligent who are to be clerical workers pass into the high school; the most intelligent enter the universities, whence they are selected for the professions. Up to this point the sifting process works with an accuracy that approximates twenty per cent. At least one fifth of those best fitted intellectually find their way to college. Of the best who are shifted into practical work before this stage is reached, some work their way to ruling positions in business and industry, or develop through irregular means into professional men. Others become politicians, to which career neither law nor custom sets definite requirements for admission.

After the university man has been selected by the educational system for his intelligence, coupled to a certain degree with the persistence and other volitional characterstics needed to make his intelligence effective, he must again be passed upon by society at large for his social and more human characteristics. More than a few well-trained physicians fail to obtain patients because they can not inspire confidence in, or arouse antagonism from those whom they would cure, and great success at the bar or as an engineer is only for the relatively few who are selected for social and personal qualities from those passed as competent by the schools. This makes necessary the training of a much larger number of men for each profession than is really needed in the profession, and implies much waste of time and of emotion on the part of the men who are rejected at this final stage. Not all of the training is lost, for it may be applied in other ways. At least no way to prevent it is at present available.

In emphasizing the selective phase of the effect of education, we have no desire to minimize its importance in training or in supplying needed knowledge. Undoubtedly there are ascribed to training many of the advantages that are really the effect of selection, but were the most brilliant men prevented from acquiring knowledge, they would have relatively little capacity. Were the most intelligent man to begin without a knowledge of what had been acquired by earlier generations, he could go no farther than did Thales or Socrates, who would certainly rank well with the highest intellects of this or any other time. Some of this knowledge could be and is picked up from books, more from the activities of everyday life in an environment made possible by and altogether dependent upon the instruments devised by predecessors and contemporaries. Complete mastery is certainly much easier to obtain through, if it does not actually require, systematic training that can best be had in a regular educational institution. Knowledge of methods, of the best usage in every field, comes more surely and easily through instruction of the formal type. Contact with others who are doing the same work is not a small factor in real training. We are not in a position to deny that there may be some general effect of training that may make the individual more effective everywhere because of the habits and particularly the ideals that have been acquired in one restricted field. Our only thesis is that much of what we are accustomed to ascribe to the improvement of the individual through education is due merely to the selection through the educational system of those who were fitted by original endowment to accomplish the tasks we would set them. It should be insisted that this is no mean function. To select the men who are capable of training, even to select the men who are capable of the highest accomplishment, even if their capacity was not increased in the process, is a function of the highest importance.

There can be no doubt that the fact that selection is confused with training constitutes an important fallacy in most educational arguments. All advocates or apologists for educational systems or methods are wont to point to the product as a justification of their existence. The argument is advanced for the Chinese as for the medieval, as well as for the tripos at Cambridge and the honor course at Oxford, to come no nearer home. Each could point to the fact that most of the men who won distinction were products of the school system. We find and are willing to accept the statement that the most successful Indian civil servants are men who stood well in the mathematical tripos, and the implication is that they are excellent civil servants because they studied mathematics thoroughly and successfully. The conclusion is usually drawn that all civil servants should have an equally thorough mathematical training in order to create or develop the power of governing. We are all willing to accept this conclusion. Less evident to the occidental seems the corresponding argument of the Chinaman that true greatness can be the product only of spending years in committing to memory the works of Confucius, although as arguments both are on a par. Each neglects the factor of selection. The mathematical tripos selects men of the highest capacity, perhaps of the highest capacity peculiarly fitted to the exercise of the functions of a civil servant. The Chinese system also selects superior men for the governmental positions. There is nothing in the argument and little in the inherent probabilities of the case to convince one that could these men have been selected in any other way without a knowledge of mathematics, they would not have been just as effective. This confusion of selection with training is what saves ineffective systems of education. Whether they improve the individual who goes through them or not, they do sort the capable from the incapable, and training is given the credit that belongs to selection.

It might be questioned whether it is worth while to spend so much time in selecting through the slow process of the school system if selection is so large a function of that system. One might urge that we develop a set of tests similar to the army tests and apply them to the youth when they present themselves at the kindergarten and then assign them to the form of instruction that they would be capable of or that would prepare them for the function in life that is suited to their abilities. Did we have tests that were accurate, and were there possibility of revising the rating to make allowance for change with increasing maturity, a good case could be made for the early selection. In fact it is already being introduced in varying degrees in several cities. Most now have some degree of elimination of the most feebly endowed from the regular classes, with special more suitable training that shall give the minimum of academic and a maximum of practical work. A few are attempting to make other classifications on the basis of intelligence as determined by test. Both have proven satisfactory so far as developed and more use could be made of them did we have the proper machinery.

There are grave objections, however, to a complete control of selection by one individual or agency, even assuming an entirely adequate system of tests and perfect competence in the administration of them. As it is, tests have, at most, a general significance. They suffice to recognize large differences fairly accurately, but at the border line where small differences are significant they would work many injustices. The effect upon the individual who was misplaced downward would be disheartening, while for the men who were encouraged to go on for work beyond their powers the system would have no advantages over the present method. The present general belief in equality of capacity with the correlate of equal opportunity provides an incentive to endeavor that cannot be overestimated. Were one to be told authoritatively that one had no chance to be more than a day laborer and would be permitted to learn no more than was necessary for that, and was by law prevented from attempting to fit one's self for anything better, most of the joy of living would be eliminated. It would be much worse than to be told that one belonged to an inferior social order. The present system gives occasional reminders that one is not of great ability, but there is always chance of mistake, and the general belief in equality serves as a consolation as well as a constant spur to endeavor.

As compared with the organization of the conquering Turk, our present system works fairly well and through purely democratic means. The schools gather at least a fifth of the capable men, and feed probably half of the men of the very highest capacity into the universities. There they become mutually acquainted, are prepared to be useful in the professions and in controlling the thought and action of the masses through the press and through the educational system and by books. In some degree, although much less than could be wished, they supply the actual rulers of the state. They are impelled to strive to enter through the social prestige that attaches to being a student and to the professions themselves and are held to their tasks by hopes of the rewards that the professions offer. Distribution to the tasks for which they are fitted is not so accurate and certain as in the Ottoman regime, but here, too, there is approximation to adequacy in selection, with gradual advancement of the men who are best qualified. While this is not the only agency that acts in selecting and selection is not the only function of the school, it is sufficiently important to justify the existence of the educational system did that have no other warrant. It also must be said that it is the factor that conceals as well as atones for the faults in the functions that we ordinarily associate with education.

THE GROUP-THEORY ELEMENT OF THE HISTORY OF MATHEMATICS

By Professor G. A. MILLER
UNIVERSITY OF ILLINOIS

FEW mathematical terms suggest such fundamental human cravings as the term group, and few have been more appropriately chosen. Just as human society has led to perplexities which increased with the advance of civilization so the mathematical group-theory has given rise to problems which became more and more difficult with the advances in the development of mathematics. In both cases the primitive stages are comparatively simple and their history throws important light on the later developments.

The history of the mathematical group-theory can be conveniently divided into three periods. The first of these extends from the beginning of mathematical history to about 1770 A. D., and may be called the *implicit period* since the group concept was then employed without being explicitly stated. The second, or *specialization period*, extends from about 1770 to about 1870. During this period the theory of substitution groups was founded as an autonomous science and the usefulness of this theory in the study of algebraic equations was emphasized. The third, or *generalization period*, extends from about 1870 to the present day, and is characterized by increased generalizations by abstraction and the explicit use of groups in each of the large domains of mathematics.

The most fundamental property of the elements of a group in the common restricted sense of this term is that they satisfy the condition that each group contains one and only one element which satisfies the equation

$$xy=z$$

whenever any two of these symbols are replaced by two equal or unequal elements of the group. This condition is evidently satisfied by the members of the number systems of the ancients, including the Babylonians, the Egyptians and the Greeks. On the other hand, the zero of our common modern number system destroys this group property of the entire system. If the zero is excluded the rest of these numbers (real or complex) constitute a group as regards multiplication.

One of the oldest groups of operations in the history of mathematics is the multiplication group whose elements are all the ordinary rational numbers with the exception of zero. This group is used implicitly in the Ahmes papyrus, written about 1700 B. C., since the linear equation and fractions are found frequently in this work. It is an interesting historical fact that for many centuries after this date the ancients seemed to have considered only numbers which are elements of this group, and one is led to inquire to what extent the guiding influence of the group concept was responsible for the late introduction of zero as a number.

It might at first appear that the introduction of zero as a number tended to show that the group concept was not a fundamental guiding principle in the development of arithmetic since it failed to dominate when opposing forces presented themselves. The impression that the group concept did not dominate when zero was introduced is, however, not quite correct, since this number which was rejected by the multiplication group was destined to become the principal element, or the identity, of the addition group. "The stone which the builders rejected, the same is become the head of the corner."

It is an interesting fact that the addition group was made possible by the introduction of zero and by granting full number citizenship to the negative numbers, and the latter was done about the time when the multiplication group was somewhat impaired by the introduction of zero. These important extensions of our number system were completed during the seventeenth century but some steps in this direction had been taken a thousand years earlier especially by the Hindus. In particular, Brahmagupta had already illustrated negative and positive numbers by debts and credits and he observed that a debt subtracted from zero becomes a credit and a credit subtracted from zero becomes a debt, and if one subtracts a debt from a credit or a credit from a debt one obtains the sum.

The long delay in the general introduction of zero as a number seems to show that the ancient peoples held tenaciously to the view that all of the numbers without exception should constitute a group as regards multiplication. It is doubtless true that the group concept was not clearly observed by them and that they could not have given a satisfactory account of the motives which guided them in their efforts for more knowledge about numbers, but the fact that they were guided by this concept seems to be well established.

H. Poincaré pointed out that the same concept guided the ancients in their efforts to secure a knowledge of geometry and he noted that the absence of any direct reference to groups in Euclid's *Elements* was due to the fact that the group notions were among the oldest mathematical notions to be assimilated and hence they did not seem to require explicit mention even at the time of Euclid, notwithstanding the fact that the principal foundation of Euclid's demonstrations is really the group and its properties.[1] In view of the fact that the group notions are so fundamental and elementary that they did not seem to require explicit mention at the time of Euclid it may at first appear strange that during the latter half of the nineteenth century these notions assumed a prominent place in the mathematical literature and that the subject of group-theory began to be regarded as one of the most difficult in the whole range of pure mathematics.

The reason for this change of attitude on the part of the mathematicians is not difficult to discover. As long as only the most general notions of groups were needed the subject was naturally regarded as too elementary to require any special attention. The idea that a set of distinct elements should have the property that any two of them can be combined into one and that this one is also found in the set was illustrated not only by the natural numbers but also by the movements of figures in space, and hence this idea became firmly fixed in the human mind at an early age. It is in accord with the human yearnings for completeness and it is a natural extension of the notion of cyclic changes which were illustrated by the daily and the seasonal apparent movements of the sun.

There is only a short step from this idea of completeness to the idea that a set of distinct elements has the property that when any two of the symbols in the equation $xy=z$ are replaced by distinct or equal elements of the set the resulting linear equation has always one and only one root in the set. If we add to these conditions the condition that the associative law shall be satisfied when the elements of the set are combined we have a complete modern definition of the term group, and it is at once apparent that this definition involves only very fundamental and elementary notions in regard to laws in the world of ideas.

While the general laws of the group are very mild they proved to require exceptions at an early stage in the growth of mathematics. As was noted above the entrance of zero into our number system required some modification of these laws as regards the operation of multiplication. The one law of combination imposed by the group notion was too narrow for the full development of our operations with numbers, where two modes of combination, now known as addition and multiplication, were developed even in prehistoric times. Historically the group concept may therefore be said to embody fundamental laws of combination with which human beings became acquainted in prehistoric times but which had to be violated in certain respects in order to secure the most fruitful mathematical developments.

[1] H. Poincaré, "On the foundations of geometry," *The Monist*, Vol. 9, (1898) p. 34.

As these laws were not formulated abstractly until about 1870 their early violators were naturally unconscious of the significance of their steps as regards the group concept. In fact, these laws might never have been formulated if it had not been discovered that without violating any of them it was possible to develop a very useful and extensive body of knowledge. The mathematical world discovered this fact by accident and at a comparatively late date. The discovery seems to have been due to the development of a large body of knowledge relating to a special class of groups now known as *substitution groups.*

The fundamental ideas involved in this body of knowledge are also very elementary. About 1770 J. L. Lagrange and others were much interested in the solution of the general equation in one unknown. More than two centuries had then elapsed since several Italian mathematicians had discovered algebraic solutions of the general cubic and the general biquadratic equation. All efforts to obtain a solution of the general quintic had failed and the mathematical world was becoming more and more deeply interested in either making further advances along this line or proving that such advances are impossible.

In the study of the methods which had led to success for the lower degrees it appeared that the number of different formal values which certain unsymmetric rational functions of a number of variables assume when these variables are permuted in every possible manner was of fundamental importance. For instance, the expression $x_1x_2+x_3x_4$ assumes the following three values

$$x_1x_2+x_3x_4,\ x_1x_3+x_2x_4,\ x_1x_4+x_2x_3$$

when the four variables x_1, x_2, x_3, x_4 are permuted in every possible manner. As there are 24 possible permutations of these four variables eight of them transform such a function into itself. These eight permutations constitute an important substitution group known as the octic group.

In general, all the permutations on n variables which transform into itself a certain rational function of these variables constitute a substitution group. Hence the study of such groups seemed important for the purpose of proving the existence or the non-existence of rational functions of a given number of variables which assume a given number of values when these variables are permuted in every possible manner. The concept of a substitution group on n variables is thus seen to be a very elementary one but the study of such groups led to a large body of theorems. Some of these appeared elegant even if they were supposed to apply only to a rather special field.

For about a century mathematicians studied these special groups with only occasional glimpses into their deeper meanings and wider applications. E. Galois, A. L. Cauchy, A. Cayley, and W. R. Hamilton made references to these deeper meanings, especially as regards an abstract theory, but none of these men formulated the abstract laws governing this theory. About 1870 an eminent triumvirate of mathematicians, C. Jordan, S. Lie and F. Klein, began to exhibit the applications of the group concept to new fields. In his "Traité des Substitutions" (1870) and in an article on the groups of movements (1868) C. Jordan made fundamental geometric applications, which were greatly extended by F. Klein. About the same time S. Lie founded a new theory of continuous groups of transformations and made extensive applications of these groups in the theory of differential equations and in other mathematical subjects.

It may be of interest to note that during the first, or implicit period, of the development of our subject, groups involving an infinite number of elements exercised the greatest influence. During the second, or specialization period, the attention was centered on groups of a finite number of elements, while during the third, or generalization period, groups involving an infinite number of elements again moved to the foreground, but groups of finite order continued to receive considerable attention. Two types of groups of infinite order were studied during this period, viz., those in which the transformations were continuous and those in which these transformations were discontinuous.

The fundamental abstract notions involved in group theory are so elementary that they can be easily understood by those who are not professional mathematicians. Hence it is the more interesting that these notions were not explicitly formulated before 1870. In formulating these for the special case when the elements obey the commutative law when they are combined, L. Kronecker expressed himself as follows: "The extremely simple principles upon which the method of Gauss is founded, find applications not only in the place named but also in others, and, indeed, already in the elementary parts of the theory of numbers. This circumstance points to the fact, about which it is easy to convince oneself, that the said principles belong to a more general and more abstract sphere of ideas. Hence it appears appropriate to free their development from all non-essential limitations so that one will be spared the trouble of repeating the same method of reaching a conclusion in the different instances of its use. The advantage of this appears even in the development itself, and the presentation gains at the same time in simplicity, and, by the clear exhibition of the essentials only, also in distinctness when it is given in the most general permissible way."[2]

The student of the history of science may be especially interested in the fact that the formulation of a definition of an abstract group came so late in the development of this subject. For a full century

[2] L. Kronecker, Berlin *Monatsberichte,* 1831, p. 882.

mathematicians were dealing with special substitution groups before making a serious effort to develop an abstract theory embodying the fundamental principles of these groups as a special case. It was not until such an abstract theory was being developed that mathematicians began to see that the group concept had been a dominant factor in some of the most important early mathematical work and hence it became an important means not only for suggesting further advances but also for securing an insight into the large body of earlier mathematical developments.

A few statements found in well-known textbooks may serve to illustrate the attitude of leading mathematicians at the beginning of the present century as regards the theory of groups. In the preface of his "Géometrie," 1905, E. Borel says:

> The new foundation (of elementary geometry) has been laid in the nineteenth century by the works of leading mathematicians. It consists of the recognition that elementary geometry is equivalent to the investigation of the group of movements. Such a view is in accord with the characteristic tendency of modern scientists to replace static investigations of the phenomena by dynamic; or, to speak in more general terms, the thought of development penetrates more and more our observations.

In his "Lehrbuch der Algebra" (kleine Ausgabe), 1912, page 180, H Weber notes that:

> There are chiefly two large general concepts which dominate modern algebra. The existence and importance of these concepts could be observed only after algebra was completed to a certain extent, and had become the property of the mathematicians. Only then could be observed the combining and guiding principles. These are the concepts of groups and of domains (koerper) which we now proceed to explain. The more general of these is the concept of group.

In his "Berührungstransformationen," 1914, page 11, H. Liebmann makes the following statement:

> The rules and concept development of group theory may be compared with the organizing laws of nature according to which crystals arise. If it is allowed to continue the figure of speech it may be added that the remaining mother liquor is a rich fostering soil on which luxuriant organized life unfolds itself.

These quotations may suffice to indicate in a general way to what extent group-theory influenced the trend of mathematical progress since the beginning of the third period of its development. The infinite number of finite groups, each of which exhibits special laws of operations, which had been discovered during the second period of the development of this subject, showed that this theory can never be completely mastered in its details. There are, however, large categories of groups which have many properties in common and whose common operational laws throw light on other mathematical developments.

Comparatively little progress has been made in the study of those abstract properties which all groups have in common, yet it is just these common properties which were popularized by the mathematical literature of the last quarter of the nineteenth century. While they are so simple that the ancients did not consider it necessary to mention them explicitly it was found that they furnish a point of view which offers many advantages. For instance, few mathematical terms are more useful than the term equivalent, and one of the services which group-theory has rendered is to give this term a flexible yet perfectly definite meaning by noting that the equivalence of two objects implies that one can be transformed into the other by the operations of a certain group.

Hence the term equivalent is relative to the group under consideration. For instance, in Euclidean geometry two figures are equivalent if they can be made to coincide by operations of the group composed of displacements and symmetries. The distance between any two points is an absolute invariant under this group. On the other hand, in elementary geometry two figures are equivalent when they can be transformed into each other by the operators of the group composed of the similarity transformations which includes the preceding group as an invariant subgroup. In elementary geometry all circles are equivalent, and all squares are equivalent, but this is not true in Euclidean geometry.

Euclid's "Elements" could have been enriched not only by the explicit use of groups of infinite order but also by the introduction of groups of finite order. In particular, the five regular solids which play an importane roôle in Greek mathematics and in Greek philosophy represent three interesting groups of finite order. In the words of E. Picard:

> A regular polyhedron, say an icosahedron, is on the one hand the solid that all the world knows; it is also, for the analyst, a group of finite order, corresponding to the divers ways of making the polyhedron coincide with itself. The investigation of all the types of groups of motion of finite order interests not only the geometers, but also the crystallographers; it goes back essentially to the study of groups of ternary linear substitutions of determinant unity, and leads to the thirty-two systems of symmetry of the crystallography for the particular complex.

While it seems impossible to establish the reasons why Euclid did not make explicit use of groups of finite and of infinite order in his "Elements," the fact that Aristotle frequently expressed the view that mathematics has to do with the *immovable* objects except such as relate to astronomy, is suggestive. While movements were used to illustrate the demonstrations of theorems the Greek philosophers seemed to hold the view that geometry itself was essentially a static subject. It is difficult to overestimate the great influence which this view had on the later history of mathematics.

If Euclid had emphasized in his "Elements" the dynamic rather than the static elements of mathematics it is likely that his work would have exerted a more vigorous influence. The cube of Euclid, for instance, is of great interest but it is not so inspiring as the cube composed of the twenty-four movements of space which leave Euclid's cube invariant. These movements affect all space and convey big and far-reaching notions. Moreover, they suggest many questions as regards subgroups and abstract laws of operation. In particular, this group of order 24 is completely defined by the fact that it contains two operators of orders 2 and 3 respectively whose product is of order 4.

While a group-theory of the third century B. C. is conceivable it could not have been the group-theory of the nineteenth century, since the latter century had a much richer mathematical heritage. The rapid strides of group-theory during the last century were largely due to the utilization of old results as is always the case in generalizations by abstraction. The soil had been prepared by the labors of earlier centuries and it was only necessary to sow on it the new seed to secure the bountiful harvest with which the labors of many workers in this field were rewarded, especially during the last decades of the ninteenth century.

When group-theory appeared explicitly it naturally took a form which was in accord with the spirit of the times. Substitution groups constitute a type of combinatory analysis and arose about the time when the Combinatorial School flourished in Germany under the leadership of C. F. Hindenburg (1741-1808). Abstract group-theory is a type of postulational mathematics and its early development during the middle of the preceding century was in the van of the postulational activity which was so prominent during the second half of the nineteenth century. Continuous and geometric group-theory are mainly applied group-theory and their rapid development during the latter quarter of the preceding century is in accord with the spirit of this age when the fear of mathematical isolation through overspecialization tended to make the study of applications especially popular.

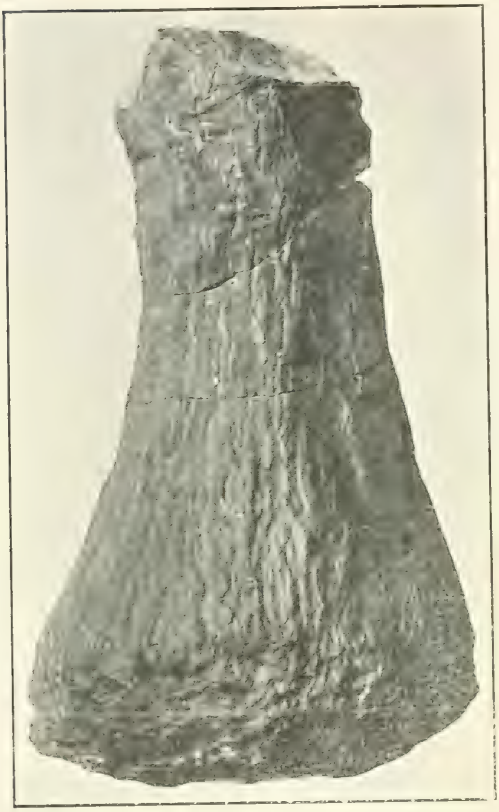
THE OLDEST OF THE FORESTS

By DR. JOHN M. CLARKE
NEW YORK STATE MUSEUM, ALBANY, N. Y.

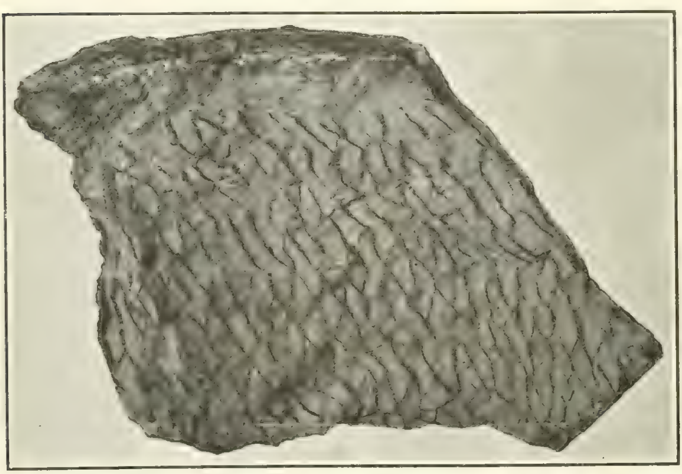
THE chief signal officer of our army, General Squier, has demonstrated the reality of what we might well have regarded an almost fanciful conception—one that might have emerged from the rosy mists when fairies had not been reduced to formulas and the notes of Pan were still to be heard in the forest aisles. The trees of the forest, says this distinguished academician, are antennae of the wireless telegraph and conductors of messages which can be interpreted by human ears if they are in human language. Their other messages, untranslatable to our ears, are left to our fancy, but the trees stand reaching their sensitive finger tips out into the sky and it would be strange indeed if they did not catch and draw down other messages which had to do with their own concerns and upbuilding. The picture is a pretty one and a legitimate fancy indeed if we let the trees in their own silent passages carry on the gossip of the woods, their conversaziones among themselves and the world of life which they shelter.

The fool hath said in his heart that we have passed the age of miracles and that all the phenomena of Nature can be reduced to terms of human understanding. But in the apostolic sense I speak even as a fool in restating so elementary a thought as that the farther we go into the exact interpretation of the facts of Nature, the more deeply the honest mind becomes impressed with the ever enlarging evidence of the miraculous, the processes in Nature which the best of human intellect can not compass or explain. Let the whole organism of the tree be put in terms of chemical and physical reactions, of tissue structure and biological explanation, and the question remains still nakedly unanswered—what is the tree, whence and how has it come, and must remain so until we apprehend the genius and spirit of the tree as well as its substance.

With this short sermon I introduce the brief story I have been asked to tell about the oldest of our forests whose remains are none the less expressive for being turned to stone. The petrified forests of the world have filled museums and homes with fragments of their beautiful woods, often brilliant in the colors of jasper and chalcedony and iridescent with the tints of the opal or their flaming



ONE OF THE SMALLER TREES FROM THE UPPER LEVEL



THE OPEN MESH OF VASCULAR BUNDLES INSIDE THE CORTICAL LAYER heart cavities lined with crystals of amethyst, and to a mineralogist all these are only simple evidences of "replacement" by slow process of the woody tissue by silica with various coloring metallic oxides in regions where thermal and alkaline waters abound. It is easy to wave aside such beauties as these with the best explanations we have at hand, but there still remains the greater fact that these objects of our admiration are beautiful and that beauty is not explained by equations. Perhaps among all the worlds of fossil life nothing is quite so impressive to the observer as a petrified tree trunk standing erect in the rocks in the very place where it grew, its roots still running out into the underclays. It conveys a singular conviction of the fact that the embedding rocks about it are after all but the hardened muds in which it grew and which have gradually and quietly overwhelmed it, and there remains no doubt in the observer's mind that he is standing amongst the trees of an earlier order of Nature, amongst the forest groves which in their day must have heard the sound of many voices whose "stilly influences" are still stored away in those very tree trunks. Such an impression is lessened when the stony trunks are in fragments scattered about and prostrated by changes which have befallen since they turned to rock.

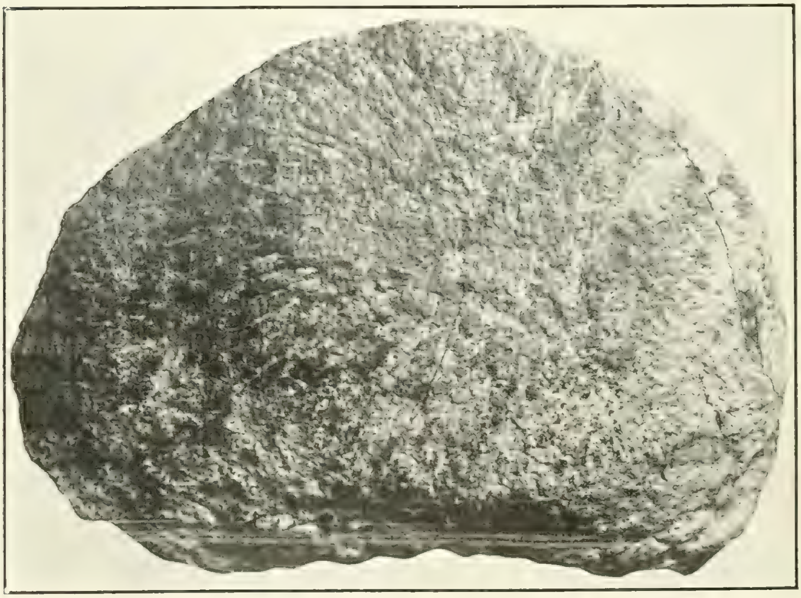
In the midst of the vast and brilliant array of disjected timber in the Arizona forests about Adamana and Holbrook and in spite of the profound impression the mind receives before this unique manifestation of Nature's procedures, the observer has nevertheless the feeling that, as has been often said, he is looking at a great petrified "timber-drive" and a timber-drive is but a raft of chopped down trees. Let the eye catch the marvellous exhibit of the Early Tertiary forests of the Yellowstone National Park, at Junction Butte, at Cache Creek and on the slopes of the Thunderer where the fossil trees stand erect to heights of 20 to 30 feet and the forest bottoms rise from one level to another over not less than fifteen different forest areas which have been buried, each in turn, by the outpourings of volcanic ashes. Here the impression is of so enormous magnitude that the mind can never release itself from the sight enforced; of an earth clothed over all its dry lands with forests giving shelter to hordes of animal life which together were working out the destinies of their evolution untouched and untrammeled by the influence of man.

If such an impression is in any way impaired it may come from the thought that these Yellowstone forests are made up of trees not very unlike those which today help to compose our northern forests. Then, as now, sequoias, other conifers and dicotyledons grew side by side. Even so the much older trees of the Arizona stone timber drives. They are of Triassic age but mostly belong to the race of Araucarian pines, still growing in the mountains of South America

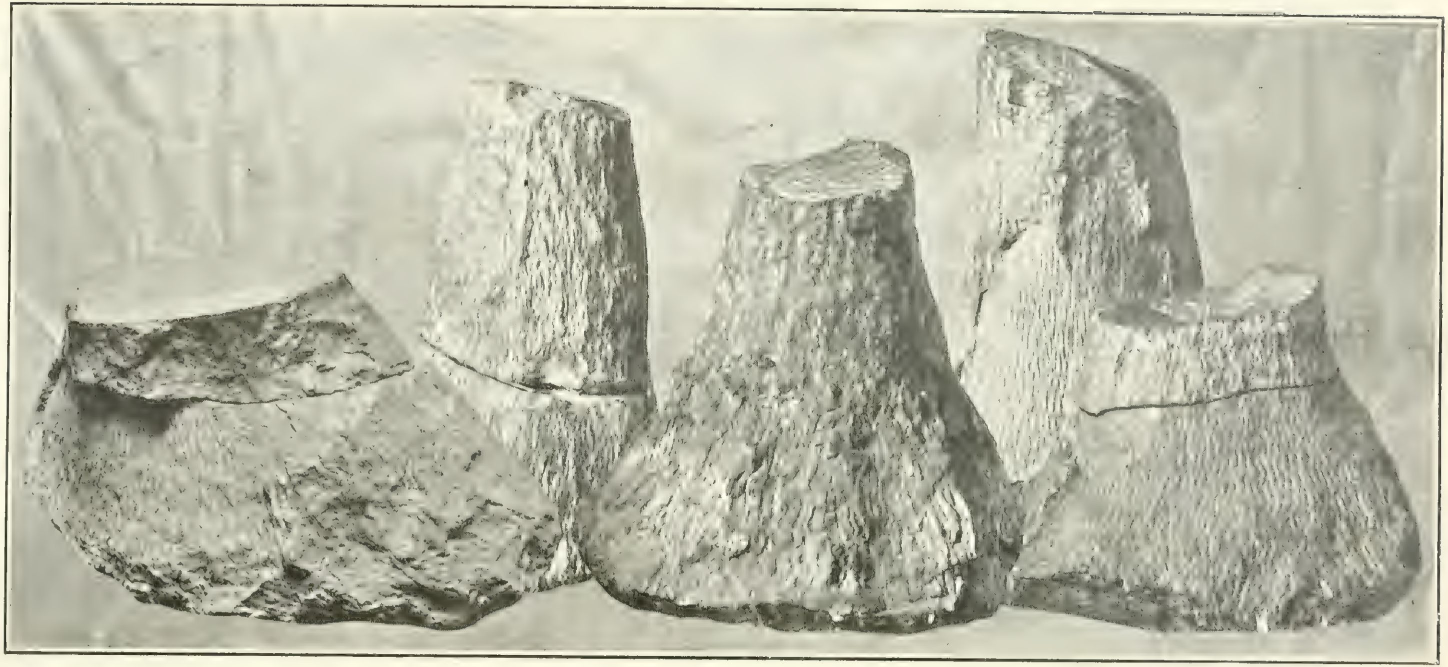
A LARGE STUMP FROM THE UPPER LEVEL. HEIGHT, 38 INCHES and Australia. Fifty thousand feet of sediments have been laid down by the waters since these trees were growing, yet a sensation of a different order comes to the thoughtful observer who beholds in a rock wall of the Coal Period the standing trunks of Lepidodendron and Sigillaria, masters of the coal forests, which have left no descendents among the trees of the living earth. When Sir Charles Lyell in 1842 first saw the petrified Coal forest of the South Joggins, in Nova Scotia, he declared it the most wonderful phenomenon he had ever seen; trees standing perpendicular to the strata to heights of twenty-five to forty feet, piercing the beds of standstone and ending downward with their roots in the coal beds. "This subterranean forest," wrote Lyell, "exceeds in extent and quality of timber, all that have been discovered in Europe put together." The South Joggins coal forest is still on view and a really vast number of trees has been recorded from there. They rise in tier above tier in the rocks, having in their successive lives sunk below the old waters which preceded the Bay of Fundy, while the sand piled up about them and another forest grew at the old level, till all were sunk and all again raised as rocks to where they now stand.

As we move still further back into the history of the earth to years when the trees were of still simpler character and a steeper topography seldom brought them into such easy reach of the recording waters as did the low and swampy sea shores of the Carboniferous period, we have been able to learn of the nature of the Devonian vegetation chiefly from the fern-like stems, Lepidodendron branches and other twigs and stipes which were carried out to sea by the flow of the rivers from the Devonian hills. The trees of the Devonian forests were not sparse and scattered. We may have come to think them so because geologists have usually happened on their remains when looking for other things among the marine deposits. The well known "Naples tree," the Archaeosigillaria, from these Devonian rocks, which rose to a height of 25 feet and is now mounted in the State Museum at Albany, is such a tree trunk carried out to sea by the flow of some forest-lined river. The rivers of the Devonian time which tore their westward way down the wooded slopes of the Old Land where the Southern New England states and their buried Atlantic remnants now lie, emptied themselves of a vast burden of sand which is now piled up to great thicknesses in the Catskill region of New York, the hills and valleys of which now bound what was the seaward edge of that ancient land. Until recently we have never quite realized the richness of these Catskill hills in the relics of the Devonian forests, but an expedition among them this year, brought into the State Museum five thousand pounds of their remains, aside from the story I am about to tell.

THE BASES OF TWO TREES FROM THE UPPER LEVEL, VIEWED FROM THE UNDERSIDE. THE ABSENCE OF ROOTS IS CLEARLY INDICATED, BUT THERE ARE TRACES OF ROOTLETS, AND THE RADIAL RIDGES SEEM TO BE CONTINUOUS WITH THE RIDGES OF THE TRUNK. DIAMETER 25 AND 38 INCHES.

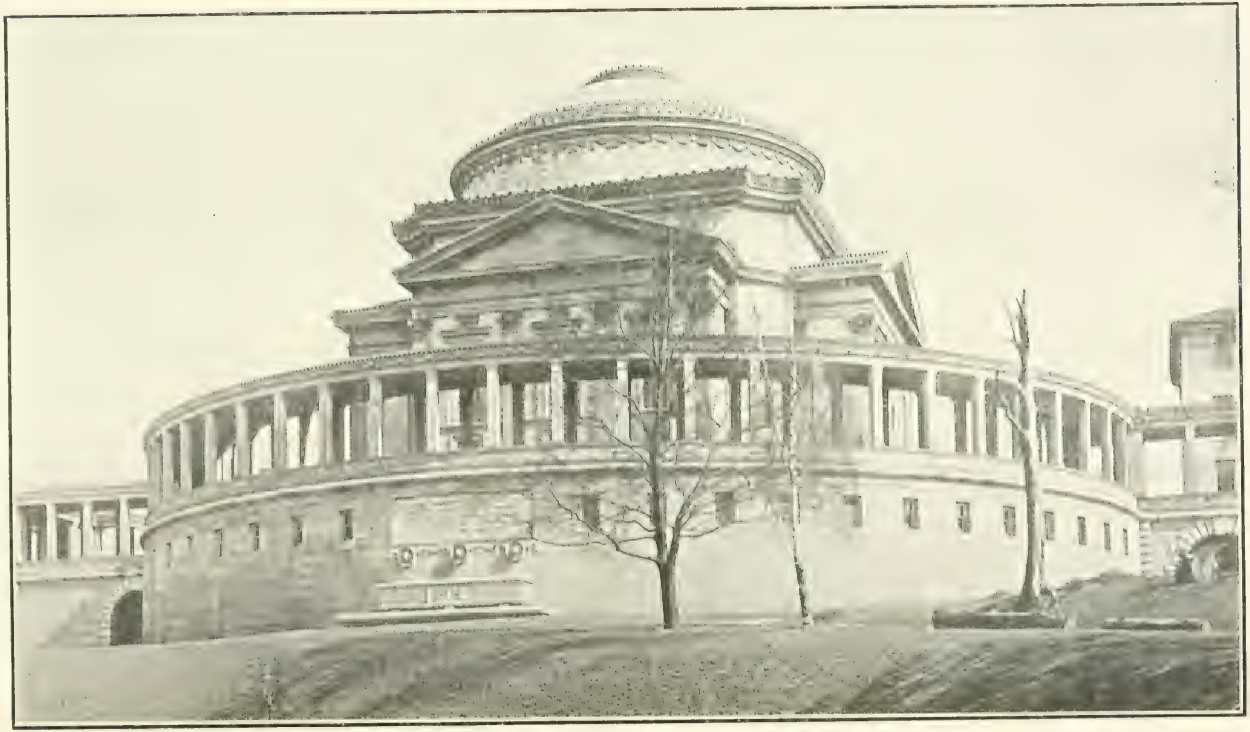


A great autumn freshet in the upper valley of the Schoharie Creek in 1869 tore out bridges, culverts and roadbeds around the little village of Gilboa where now the City of New York is impounding waters for the use of its own future citizens, and exposed in the bed rock of the hills a series of standing stumps of trees. These stumps stood all on the same level in the rocks and their rootlets ran down into the original mud in which they had grown, now turned into a dark or greenish shale. All had been cut off by some ancient flood at the same height above the base, some three or four feet; some were large and others smaller, the largest having a diameter in the shaft of two feet or more with broad expanding root-base like a flattened turnip. Thus were brought to light the standing remains of the most ancient forest growth known in the geological records in any part of the world. Ten of these tree stumps were taken out from their ancient forest, all at the same level in the rocks, and they have long constituted one of the remarkable exhibits of the vanished flora of the Devonian age. The old locality has long been deeply covered and the rocks of that level which carried these trees do not come to the surface again in the vicinity. But an effort of rediscovery made this year has been attended with unexpected results in finding the stumps of other trees of the same sort at a level sixty feet higher in the rock beds, giving evidence that the forest growths here, like the successive coal forests of the Joggins, had reappeared in the same region at a later stage in Devonian history after the first growth had been buried beneath the sea. This Schoharie Forest, earliest of all recorded forests of the earth, is of very great interest from a scientific point of view, though we are puzzled not a little to comprehend just the nature of these shore-growing woods. These trees are most nearly comparable to the tree ferns of existing tropical forests but no botanist would be content with this comparison, as they have a fructification in distinct sporangia or double purses not unlike the "keys" of a maple, quite unlike the spore-cases of the ferns; "seed-ferns" whose leaves were apparently narrow and strap-like, branching simply and rarely and terminating in these twin fruit-cases. If the diameter of the trunks is carried upward in a tapering slope these trees must have reached the very considerable height of 20-30 feet, but it is possible that the trunks broke up not so far above their base into a shrubby or bushy cap. Their real nature is still a problem for the student of fossil plants. They have been called Psaaronius, but this name has not meant very much to botanists except as an expression for a fern-like plant of unsettled affinities. Now however, as the fruit of this Devonian tree is known, that and the character of its rutabaga-like base taken in connection with what have been supposed to be aerial rootlets running up the trunk, may prove the entire combination to show affinities with the cycads. But in any case we are pretty certain



SOME OF THE TREES FROM THE LOWER LEVEL, ALL FOUND AT THE SAME HORIZON. THE HEIGHT OF THE CENTRAL TRUNK IS 2 FEET, WIDTH AT BASE 22 INCHES of having here a composition of structures wholly primitive among upstanding trees and hard to interpret in the light of existing plants. This will be disclosed in time but, whatever the nature of this primitive forest growth may prove to be, we may think of it as being almost the earliest expression of the successful effort in the plants to acquire and keep an upright position. Not long before, as geologic time is reckoned, the plants had been wholly aquatic. They had been living in the ponds of the old land and the estuaries of the coast-line. Their original home, it would seem, had been the soils of the ancient continents whence they had in a primitive day, migrated in some part into the sea itself. But the picture is presented to us now of the upward struggle toward better opportunity of growth and freer development into the all surrounding air. Dr. Berry, of Johns Hopkins, a brilliant paleobotanist, has suggested that the plants of the earth began to burst into flower at about the time the type of man, the primate, disclosed itself in the progress of life. And it may be said, I think, with the same approximation to truth that the plant sought and reached its upright position just as the vertebrate type of life became established on the earth.

At any rate our ancient New York forests afford an index to the geography of the western Catskills and the Schoharie valley during the Late Devonian Period to which they belong. We have said that the tree stumps were found in places where they grew, that the shales under them are the muds in which they were rooted and that they are preserved at at least two levels in the rocks one sixty feet above the other. Not far under the lowest forest the rocks carry true marine fossils. Tangled in the rootlets of the lower trees were found the remains of some brackish water crustaceans. These facts of themselves show that the sea which covered this region slowly withdrew and the trees crept down from the land to the water's edge, or grew over the delta plain of the fresh water streams flowing in from the old land at the east. Then for a long time the first forest must have been flooded by the waters, probably by the rising of the sea which deposited the 60 feet of overlying rocks, until another retreat of the water again brought the forest down to the shore. There was an oscillation of the coast-line, the sea rising and falling and the trees approaching, receding and approaching again toward the edge of the water. Thus the full story of this primitive forest is rich in the promise of an instructive chapter in the progress of that great division of the kingdom of life, which, though rooted and fettered from almost the beginning of its history, has kept pace in its own way with the progress of that subkingdom to which we belong.



THE HALL OF FAME OF NEW YORK UNIVERSITY

THE PROGRESS OF SCIENCE

SELECTIONS FOR AN AMERICAN VALHALLA

The Senate of New York University has announced the report of the official canvas of ballots received from the electors of the Hall of Fame in the fifth quinquennial election. The electorate consists of 96 men and 6 women. Ballots were received from 95 men and 6 women as follows: University and college presidents, 27; professors of history and historians, 18; scientists, 11; authors and editors, 14; high public officials and men and women of affairs, 19; actual or former justices, national or state, 12.

It was possible this year to elect to the Hall of Fame for Great Americans 20 men, and to the Hall of Fame for Great American Women, 10 women, sixty-eight votes or two-thirds of the 101 votes cast were required to elect a name unless that name bore the marking M. J. F. (more justly famous, but we are not informed in whose opinion), in which case 51 votes, or a majority of the votes cast, were required to elect. The result of the canvass showed that of the 177 names of men voted for, the following six were chosen:

MEMORIAL BUST OF HORACE MANN IN THE HALL OF FAME


MARY·CLARK·THOMPSON
NATIONAL ACADEMY OF SCIENCES

Name	Class	Votes Received
Samuel Langhorne Clemens	I—Authors	72
James Buchanan Eads	VI—Engineers	51
Patrick Henry	XII—Statesmen	57
William Thomas Green Morton	VII—Physicians	72
Augustus Saint-Gaudens	XIV—Artists	67
Roger Williams	III—Preachers	66

Of the 27 names of women voted for, the name of one woman was chosen for the Hall of Fame for Great American Women, that name bearing the M. J. F. marking and, therefore, requiring only 51 votes; the successful candidate being Alice Freeman Palmer, Educator, with 53 votes.

Prior to this election fifty men and six women had been elected to the Hall of Fame, the total now being fifty-six men and seven women. The sixth quinquennial election will take place in 1925. In the interim the Hall of Fame idea will be developed in various ways along educational lines to the end of stimulating interest in American history and inculcating reverence for our great dead. In May, 1921, there will be a public unveiling at the Hall of Fame on University Heights of twenty-six bronze tablets bearing the names of men and women who have been elected in this and previous elections, thirty-seven tablets having already been unveiled.

The votes for men of science in the recent election were as follows:

Class V—Scientists

Samuel Pierpont Langley	20
Matthew Fontaine Maury	20
Samuel Newcomb	44
Benjamin Thompson	38
Scattering	18
Total	140

Class VI—Engineers, Architects

James Buchanan Eads	51
Henry Hobson Richardson	11
Scattering	12
Total	74

Class VII—Physicians, Surgeons

Charles T. Jackson	10
William T. G. Morton	72
Walter Reed	14
Benjamin Rush	14
Scattering	14
Total	124

Class VIII—Inventors

John Ericsson	10
Charles Goodyear	16
Cyrus Hall McCormick	43
Scattering	22
Total	91

The selection of Dr. Morton as one of the sixty-two greatest Americans illustrate the inadequacy of the method of selection used by the Senate of New York University. Davy discovered the anaesthetic properties of nitrous oxide (laughing gas) in 1800, and Faraday showed that the inhalation of the vapor of ether produced anaesthetic effects in 1818. Which American physician or dentist from Dr. Godman in 1822 to Dr. Warren in 1846 deserves most credit for the introduction of anaesthetics is a question that even twenty-seven university presidents would find it difficult to decide by a majority vote.

THE THOMPSON MEDAL FOR GEOLOGY AND PALENO-TOLOGY

We give here obverse and reverse views of the medal to be awarded by the National Academy of Sciences for distinguished achievement in the sciences of Geology or Paleontology or both. The medal is established on a foundation provided by Mrs. Mary Clark Thompson of New York, and is to be struck only in gold, the intention of the foundress being that it shall constitute a reward and recognition for work done rather than an encouragement to further achievement. The designs are the work of Theodore Spicer-Simson of New York, who has expressed on the faces of the medal the symbolism of the two sciences.

The conception of "Paleontologia" is the development and emergence of life from the rocks. The female figure portraying the attainment of life, high in promise and fertility, is struggling to release herself from her ancestral environment, the rocks of the earth, and strains upward with exalted face toward the rising sun whose beams are breaking away the mists of the morning; about the rock ledges the eternal sea is pursuing its endless work of erosion and deposition. This central device is framed by representatives of lower forms of life, the encircling margin being a graceful crinoid with its stem, the branches of its calyx merging delicately into the crests of the waves.

The reverse is a more purely conventional and simple conception expressing the outweighing importance of practical observation and determination over against the deductive and speculative treatise.

The pictures here given are the full size of the medal which it is planned to award annually and these awards will be of international scope.

THE ENGINEERING FOUNDATION

An anonymous gift of $200,000 toward a five-million-dollar fund for the promotion of research in science and in engineering is announced by Engineering Foundation at its headquarters in the Engineering Societies Building, New York City. This contribution brings the foundation's fund to $500,000. It is the aim of the foundation to obtain one million dollars by January first.

The Engineering Foundation was organized to care for the gifts aggregating $300,000 of Ambrose Swasey, of Cleveland, Ohio, the income from these gifts being devoted to research. Since its organization as a trust fund in 1914, the funds of the foundation have been used to aid the National Research Council and others in performing research directly connected with engineering. Mr. Swasey's gifts were made to United Engineering Society as a nucleus of a large endowment "for the furtherance of research in science and in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind."

The Engineering Foundation is administered by the engineering foundation board composed of members from the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers and members at large. The board is a department of United Engineering Society. It is the instrumentality of the founder societies named for the stimulation, direction and support of research.

SCIENTIFIC ITEMS

The only scientific men of distinction whose death has been reported during the past month is Theodore Flournoy, formerly professor of physiology and psychology at the University of Geneva.

Dr. Edward Rhodes Stitt, head of the Naval Medical School at Washington, D. C., has been appointed Surgeon General of the Navy, to succeed Surgeon General Braisted, who retired on November 26.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1921

HISTORY OF GEOLOGY*

By Professor HERBERT E. GREGORY

YALE UNIVERSITY

Introduction

THE history of geology is essentially the history of the intelligent observation of rocks, fossils and land forms. Progress is marked by progressive increase in exactness and completeness of observation. In an atmosphere saturated with tradition and personal bias the making of observations and the interpretation of observations present but a sickly growth; and when the intellectual environment includes authority and a complete outfit of supernatural causes, growth is stopped entirely. This may in part account for the interesting fact that philosophy and literature rather than observational science represent the intellectual efforts of the ancients. Poetry and musings about the nature of things require no special technique, no collections of materials for comparison. A gifted mind is the essential equipment; and such minds may appear anywhere and at any time. But the development of natural science involves critical observation of a variety of things from many places, the interchange of ideas among many workers, the making of hypotheses, the formulation and selection of method, and the invention of apparatus. It is natural that this group of requirements should come together slowly.

In no real sense can the obvious geological truths irregularly interwoven in the interesting fabric of myth and fact which constitutes Greek, Arabie, Indian, and Chinese thoughts on Nature be considered the beginnings of geology. The traditions of the Mediterranean peoples, of the Hebrews, Babylonians, and Hindus, are rich in speculation and in the making of hypotheses regarding earth origin, but poor in logical deduction from exact observation. They show little interest in the earth itself and no inkling that the history of the earth is to be deciphered by means of fossils, knowledge of the earth's crust, and the action of rivers and waves. The test is the extent to which

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the contributions of the ancients were utilized as stepping stones. In geology progress has been attained without regard to or even in ignorance of observation and theories recorded before the late Middle Ages. Cuvier established paleontology without reference to the teachings of previous times and even in ignorance of the work of his contemporaries, and Darwin acknowledged his indebtedness to Lamarck, not to Aristotle, whose theory of evolution lacked little of being complete. Likewise structural geology, stratigraphy, and physiography have grown up without assistance from classical and Middle Age scholars. The fifteenth century student of earth science enjoyed a surprisingly meager heritage from classical and early Christian days. In the sixteenth century Leonardo da Vinci stands alone. During the seventeenth century many sciences made great strides forward; new facts were unearthed and methods established. Physics received the contributions of Galileo, Kepler, Newton, Torricelli, Guericke, Boyle, Huygens, Hooke. Astronomy, already far advanced, was revolutionized by the development of the telescope, and biology by the microscope. Chemistry found a place apart from alchemy and medicine. In geology, on the other hand, the seventeenth century scholar was groping in darkness scarcely less dense than that surrounding his predecessors of the sixteenth and fifteenth centuries.

Toward the close of the eighteenth century many of the facts and principles and methods which constitute geology were assembled but geology as taught today is essentially a nineteenth century product to which many of the most significant contributions have been made by scholars of the present generation.

The subject matter of geology is so varied and the introduction of new views so irregularly placed in time, that no chronologic sequence appears in the growth of the science as a whole. Development may best be shown by tracing the growth of certain fundamental ideas: the origin of the earth; the meaning of rocks, mountains, surface features and fossils; and the geologic time scale.

Origin of the Earth

From direct observation geology knows nothing of the original earth; no part of its first formed surface has been seen or is likely ever to be seen. The oldest rocks known have doubtless been derived from rocks yet older, and the oldest fossil undoubtedly descended from a long line of still older organisms. The evolution of the physical earth and of life clearly point to a period charged with dynamic and vital forces long antedating the most ancient legible records.

It must be admitted that so far little clear light has been thrown on the origin and primeval condition of the earth. For the geologist there is little choice between the childlike myths of the Eskimos, Bushmen, and Micronesians, the grand poetic conceptions of the Hindus, Babylonians, and Hebrews, and the pseudoscientific teachings of the Greeks and medieval churchmen.

An advance is recorded during the seventeenth century in the contributions of Descartes (1596-1650) and Leibnitz (1646-1716) who traced the development of the earth from a disordered mass of glowing material to a smooth, solid globe, the exterior of which had cooled. These ideas were expanded and built into a consistent theory through the labors of Kant (1755) and especially of Laplace (1796)[1], whose views of earth origin received well-nigh universal acceptance during the nineteenth century. In essence the nebular hypothesis of Laplace assumes the existence of highly heated gaseous nebulae slowly rotating about a central mass which eventually became the sun. As this nebulous material rotated, cooled, and contracted, rings of matter were detached one after another furnishing the stuff for planets and satellites. One of these rings, gathered into a spheroid, became the earth. The original earth, therefore, was a luminous star surrounded with a heavy vaporous atmosphere. The ball passed from a gaseous to a liquid state and developed a wrinkled crust of igneous rock like granite. Later the atmosphere gave rise to oceans and streams, agents for the production of sedimentary rock.

The nebular hypothesis is the crowning achievement in cosmical geology up to the end of the nineteenth century, but its value lies not so much in its inherent probability as in the absence of a better theory. It violates the principles of thermo-dynamics and of celestial mechanics and is out of accord with the present knowledge of nebulae, planets and satellites. Furthermore, the theory demands progressive cooling of the earth, and an arrangement of rock masses amply disproved by geological evidence. Without radical reconstruction, the nebular hypothesis can no longer serve as a reasonable theory of earth origin.

The underlying conceptions of the nebular hypothesis are: first, the condensation of diffuse matter under the action of gravity, and second, nebulae distended by heat and revolving as a unit mass. But the researches in astronomy and physics during the past quarter century have accumulated evidence to show that disruption and repulsion, not attraction, are the dominant forces in the stellar universe. The tails of comets turned away from the sun, streamers thrown from the sun itself, and the shape of certain star clusters and nebulae point to prodigious repelling forces within the luminous bodies making up the universe. On such evidence the planetesimal hypothesis of Chamberlin and Moulton is founded.[2] Under this theory the earth was once

[1]Laplace, P. S., Exposition du système du monde, Paris, 1796 and 1824.

[2]Chamberlin, T. C., The origin of the earth, University of Chicago Press, 1916.

a spiral nebula composed of matter "thrown out" by some ancestral sun. The scattered particles, or planetesimals, of the parent nebula were drawn into nuclei which became part of the planetary system. At this stage the cosmic history of the earth passes into the geological history. The original earth is conceived as a ball 2,000 to 3,000 miles in diameter, which grew to its present size by the addition of more planetesimals. The heat of the earth comes from self-condensation and progressive close-packing of its constituent planetesimals. Under this theory vulcanism was active long before the earth attained its present size, and an atmosphere appeared as soon as the earth possessed sufficient gravitative power to retain it. When the atmosphere became saturated with aqueous vapor, water was formed and occupied depressions in the earth's uneven surface.

The truth of the planetesimal hypothesis remains to be separated from its errors by a long period of testing and developing. Its value lies in the fact that it explains a great number of geological observations and suggests lines for future investigation.

Meaning of Rocks

The origin of the earth and the history of life on this planet are involved in religious and philosophic views and therefore precede in point of time the study of the materials of which the earth is composed. At the beginning of the nineteenth century some progress had been made in the knowledge of minerals[3] but so little was known of the composition and texture of rocks that masses of igneous origin were confused with strata laid down by water or by wind, and the existence of vast exposures of metamorphic rocks was not recognized. The distinction between a rock and a geological formation or group of strata had not been fully established, and many fine-grained rocks were classed as minerals. As late as 1837 the Munich chemist, Johann Fuchs, contended strenuously for the view that mica schist, granite, and porphyry were the results of the consolidation of a watery paste. Only within the past fifty years has the systematic investigation of rocks—their composition, relations and origins—reached a stage that justified the recognition of a distinct branch of geologic science. Since the importance of its contributions has been demonstrated, the study of rocks has experienced two somewhat distinct but logical periods of development. *Petrography*, the description of rocks, is a necessary forerunner to *Petrology*, researches in the origin and broader relations of rocks.[4]

[3]Ford, W. E., The growth of mineralogy from 1818 to 1918: A century of science in America, pp. 268-283, Yale University Press, 1918.

[4]Pirsson, L. V., The rise of petrology as a science: A century of science in America, pp. 248-267, Yale University Press, 1918.

Cross, Whitman, The development of systematic petrography in the nineteenth century: *Jour. Geology*, X, 332-376, 451-499, 1902.

The stages of advancement in petrography may be traced by noting the systems of classifications in vogue at different periods, for classification involves the application of all known facts about all known kinds of rocks and also a consideration of existing theories and assumptions. The classifications of rocks based on hardness, specific gravity, and geographical location, are obviously superficial and one may dismiss as a humorous but futile notion the dictum of Jameson that there is but one species in mineralogy, namely, the globe, and the wordy argument of Pinkerton (1811) that no *species* of minerals exist for no mineral has the capacity to reproduce its kind. It is easy to understand, however, that students of rocks should have placed different emphasis on chemical composition, texture, mineralogical composition, age, mode of occurrence, and origin, as criteria, and should be of different minds regarding the desirability of a "natural classification" as opposed to an artificial one.

Early in the eighteenth century contributions to the knowledge of rocks were made by the few men who resisted the temptation to speculate and to dogmatize about things in general, and who confined their attention to a particular topic or a particular locality. In 1768 Linnaeus (1707-1778) extended his *Systema Naturae* to include the inorganic kingdom which he divided into rocks, minerals, and fossils. To each of these subdivisions was assigned an incongruous group of materials. As remarked by Cross, the most visible effect of this pioneer attempt to force inorganic substances into the scheme of species and genera provided for plants and animals was to furnish a theme for controversial debates and arguments for a century to come.

The outstanding figure among students of rocks of the eighteenth and early nineteenth centuries is Abraham Gottlob Werner (1749-1817), professor of mineralogy at Freiberg, whose enthusiasm, eloquence, skill in teaching, and clear methodical presentation attracted learners from all parts of Europe. Werner's views of rock genesis and of geological processes were antiquated even for his time, but his painstaking systematic examination of rocks led to a classification based on mineral composition (1786)—a feature common to modern schemes. He distinguished "simple" from "compound" rocks, recognized that some minerals were "essential" components of rocks and others "incidental" or "accessory," and clarified the subject by drawing the distinction between rock masses or strata (formations) and the rocks composing them, thus laying the foundation of modern descriptive petrography. During the first two decades of the nineteenth century, the knowledge of rocks as summarized in systems of classifications was carried as far as possible under the Wernerian scheme by Haüy (1801), Brongniart (1813), Cordier (1815), and their contemporaries who relied upon mineralogical composition and structure to indicate relationship to the exclusion of age, origin, and mode of occurrence.

But even during this period the problem of rock origin was prominently in mind. Were all rocks deposited by the ocean as chemical precipitates, as taught by Werner, or do deep-seated igneous rocks and lavas and sedimentary rocks indicate three modes of origin as taught by Hutton? Do the different kinds of rocks represent merely different ages of accumulation or are granite and sandstone made in all ages, even today? Are gneiss and schist original igneous rocks or altered sedimentary rocks? As if by common consent, the origin of the lava, basalt, was taken as a test case, and geologists, chemists, physicists, and even literary men and politicians divided into two camps—the Neptunists who contended that basalt is deposited from sea water were vigorously opposed by the Plutonists who believed in an igneous origin. Peace was declared in favor of the Plutonists soon after it was agreed that field observations were better weapons than arguments concocted in the library.

A distinct advance in the knowledge of rocks is recorded by two publications in the third decade of the nineteenth century.[5] Von Leonhard's "Characteristics of Rocks" (1823) is listed by Cross as "the first fairly consistent treatise on rocks" and its author as "unquestionably the foremost petrographer of his day, sharing with Alexander Brongniart the honor of placing the classification of rocks on a firm basis as a systematic science." Through the work of these able minds the confusion heretofore existing between minerals, rocks, and assemblages or groups of rocks (terranes and formations) was eliminated; the study of rocks as rocks (petrography and petrology) was shown to be a branch of learning with methods and purposes different from the study of strata and masses composed of rocks (stratigraphy); and the biological scheme of genera and species was discarded as inapplicable. These workers showed that structure, as well as mineralogical composition, is a significant feature and Brongniart suggests that geological origin may have value as a principle of classification. Both authors state with refreshing candor that fuller knowledge will show that many rocks have been given inappropriate places in the scheme of classification. To his major divisions, (1) heterogeneous rocks, (2) homogeneous rocks, (3) fragmental rocks, (4) loose rocks, Von Leonhard added a group, "rocks apparently homogeneous," to care for serpentine, pitchstone, and certain schists whose constituents were not visible to the unaided eye but which were not minerals. Brongniart subdivided "homogeneous rocks" into those with distinct known mineral species and those whose density precluded the recognition of constituents.

[5]Von Leonhard, K. C., Charakteristik der Felsarten, 1823.
Brongniart, Alexandre, Classification et caractères minéralogiques des roches homogènes et hétérogènes, Paris, 1827.

A new mode of treatment was introduced into the science of rocks by Carl Friedrich Naumann (1850 and 1858)[6]. Under the name *Petrography* he defined the scope of the science of rocks as a branch of Geology (or *Geognosie* as the term was then used) which could be studied from six standpoints: the constituents of rocks, the texture and structure of rocks, manner of occurrence, systematic description, genesis of rocks, and alteration of rocks. He introduced the classification: (1) crystalline rocks, (2) clastic rocks, (3) rocks neither crystalline nor clastic.

Von Cotta's contribution[7] (1855 and 1862) was the emphasis placed on geological mode of origin and the clear expression of the modern view that molten material poured from volcanoes and molten material formed deep within the crust of the earth may be crystallized into rock during any geological epoch and are not therefore indicative of age.

Frederick Senft (1857), probably impressed by the difficulty of determining the characteristics of dense rocks, minimized the value of mineralogical composition, texture, and structure as interpretative guides and developed an elaborate and highly artificial scheme based on chemical composition. But the master mind of the group whose attention was directed to the chemical relationship of rocks was Justus Roth. From a careful study of nearly 1,000 analyses he reached the conclusion (1861) that rocks cannot be represented by chemical formulae which coincide with mineralogical composition, and that the application of the chemical factor as a criterion in classification serves to separate rocks otherwise closely related. As a substitute he proposed that igneous rocks be grouped with reference to the abundance and kind of feldspar crystals contained within them.

An opposite conclusion was reached by Sheerer (1864) who expressed the belief that igneous rocks could be satisfactorily grouped in nine chemical types.

Zirkel's *Lehrbuch der Petrographie* (1866) and the philosophical discussions of Von Richthofen (1868) are substantially restatements of earlier views but are worthy of study as expressions of the usages and beliefs of the time and as the culmination of efforts to describe and to interpret rocks on the basis of superficial characteristics and approximate chemical analyses..

By 1870 the possibilities of increase of knowledge through the study of rocks appeared to have been exhausted; no further steps of advance seemed possible, for the components of fine-grained rocks, lavas, and schists were beyond the reach of observation and there ap-

[6]Naumann, C. F., Lehrbuch der Geognosie, 1850.

[7]Cotta, Bernhardt von, Rocks classified and described; a treatise on lithology (trans. P. H. Lawrence, 1866).

peared to be no satisfactory means of distinguishing the varieties of feldspars, the most abundant ingredient in the commonest rocks. Petrography had come to a blank wall. Further research involved the discovery of some method for more complete and exact observation. The need was met by the introduction of the compound polarizing microscope which brings to view and differentiates minerals even in apparently homogeneous rocks. The development of this instrument and of the means of preparing rocks for study marked the beginning of the golden age of descriptive petrography, the last quarter of the nineteenth century. The way had been blazed by Professor Nicol, the Scotch geologist, who invented the Nicol prism for polarizing light, attached it to a microscope, and devised a method for preparing thin sections of fossil wood (1828). The success of this method led Ehrenberg to the epoch-making discovery that chalk and marls and some limestones were composed of skeletons of organisms. Sorby (1850) used this method for determining the composition of sandstone and discussed its value for the study of igneous rocks. But to make a chip of hard rock sufficiently thin to be transparent seemed a hopeless task. It is a triumph of technical skill to cut from a black dense rock a section 1/1000 of an inch thick through which print may be read and which reveals to the microscope the minutest structures. The seemingly impossible has been accomplished and the modern geologist is placed in the position of the biologist with respect to the examination of microscopic objects of natural history. This method of research under the lead of Zirkel and Rosenbusch in Germany, Michel-Lévy, Barrois, and Lacroix in France, Bonney, Judd, and Rutley in England, E. S. Dana, G. H. Williams, and Iddings in America, promised so much that it soon enlisted an army of workers who added enormously to the knowledge of rocks and of the minerals composing them. During the closing years of the nineteenth century, microscopic description of rocks appeared to be the chief aim of petrographers.

About the beginning of the present century *Petrography* became *Petrology;* the science of the exhaustive description of rocks became the science of relations and meaning of rocks. The genesis of rocks and the factors that have brought about their geographic distribution and produced the hundreds of varieties are topics of interest to a modern student of petrology. The goal is in sight, but the best means of reaching the goal is not apparent. As in other lines of research, progress depends upon choice of method. Reliance on the petrographic microscope has revealed a new world to geologists, but it has obvious limitations. It is an instrument for collecting data, for refined and accurate description rather than for determining origins, and after all known rocks and rock-making minerals have been studied this method has served its main purpose. This stage nearly has been reached. Twenty years ago most minerals, certainly all those of wide distribution, had been exhaustively studied and igneous rocks by the thousands had been minutely described and built into schemes of classification. Many sedimentary rocks and schists and gneisses also have been added to the list. Progress has been attained by the development of chemical methods of research in rock origins and rock-relationship. The pioneer work of Bischof (1846), the founder of chemical geology, Bunsen (1851) and Senft (1857), led the way to the researches of Roth, Clarke, and Hillebrand, and culminated in Washington's awe-inspiring volume "Chemical Analyses of Igneous Rocks" (1903), Cross, Iddings, Pirsson, and Washington's "Quantitative Classification of Igneous Rocks" (1903), and Clarke's "Data of Geochemistry" (4th ed. 1920)—three American works which are essential handbooks for geologists and chemists of all countries.

But while it is generally admitted that chemical composition is the most fundamental characteristic of rocks, it is obvious that the most precise determination of the chemical constituents of all the rocks in existence would not in itself explain the origin of rocks or contribute more than unrelated facts to the history of the earth. In order to gain the truths of rock history it is necessary to know the processes which cause the results and the conditions under which these processes operate. On the basis of chemical composition, by theoretical and to a small extent by experimental methods, interesting attempts were made during the last quarter of the nineteenth century to determine the order in which minerals crystallize from a molten mass (magma) and the conditions responsible for the differentiation of magmas into chemical groups. As at other stages in the history of petrology, the problem was recognized but the known methods were inadequate.

The gateway to further research was opened by physical chemistry. With the development of this new science and the consequent improvement in experimental methods came the possibility of reproducing in the laboratory the work of underground forces and of recording the stages through which rocks and minerals pass from undifferentiated masses of molten or liquid material to their final form as quartz, granite, or marble.

In view of modern developments it is interesting to recall pioneer experiments. To disprove the teaching of the all powerful German School of his day that basalt (lava) was precipitated from water, Sir James Hall in the year 1800 melted lavas from Etna and Vesuvius and allowed the mass to cool. Solid crystalline rock material resulted. Daubrée (1857) made quartz and feldspar from an aqua-igneous complex, proving that the conditions necessary to produce "granite-grained" igneous rock were moderate temperatures and presence of water vapor. Fouque and Michel-Lévy (1878) produced augiteandesite with well-developed crystals by fusing selected ingredients in a dry state holding the fused mass at a high temperature for forty-eight hours then allowing it to cool. These brilliant researches of French geologists were carried still farther by Vogt and by other European scholars. But the world center for the experimental study of rock genesis is the Geophysical Laboratory at Washington[8] where under ideal conditions a corps of physicists, chemists, mineralogists, and petrologists are solving the deeper problems of rock genesis and rock relationship.

The Making of Mountains

Since the dawn of human history, even the uncritical observer must have noted that rock masses differ not only in color and composition but also in attitude; that some strata lie flat, others are tilted, still others are folded and buckled or broken. On the theory of a ready-made earth such facts occasioned no comment but as the evidence accumulated that changes large and small have affected the earth's surface, speculations regarding the causes and processes of rock disturbance and of the origin of mountains were in order.

To observers of the seventeenth century earthquakes were an all sufficient cause. Hooke (1688)[9] expressed the belief:

> Earthquakes have turned plains into mountains and mountains into plains, seas into land and land into seas, made rivers where there were none before, and swallowed up others that formerly were.

Woodward (1695)[10] cut the knot with the statement,

> the whole terrestrial globe has been taken to pieces at the flood and the strata settled down from this promiscuous mass.

Burnet[11] took the same view, and the state of knowledge of the times may be judged from the fact that his theory of the earth (1690) thoroughly unsound in matter, method and conclusions was praised in a Latin ode by Addison and highly commended by Steele.

During the eighteenth century the view prevailed that all rocks were originally horizontal and that departures from this attitude were local and sufficiently accounted for by landslides, by cavities into which rocks fell, by volcanoes, and by original deposition in addition to the ever ready earthquake or flood which played the title rôle. As late as 1823 the easterly dip of the Connecticut River sandstone is ascribed by Hitchcock to "some Plutonian convulsion."[12]

[8]Carnegie Geophysical Laboratory, Washington. For a sketch of the scope and contributions of this institution, see Sosman, R. B., The work of the geophysical laboratory of the Carnegie Institution of Washington: A century of science in America, pp. 284-287, Yale University Press, 1918.

[9]Hooke, Robert, Posthumous works, ed. R. Waller, London, 1705.

[10]Woodward, John, Essay towards a natural history of the earth, 1695.

[11]Burnet, Thomas, Telluris theoria sacra, or Sacred theory of the earth, London, 1681. Eng. trans. 1684-1689.

[12]Hitchcock, Edward, Geology, etc., of the Connecticut Valley; *Am. Jour. Sci.*, VI, 74, 1823.

Toward the close of the eighteenth century belief in the ability of streams and waves to corrade the surface, and to carry debris into the ocean, gained general acceptance. This belief carried to its logical conclusion meant that all dry land would ultimately disappear unless some forces were acting to re-elevate the continents. Earthquakes might break strata and volcanoes scatter the material about, but their effect is local and it was difficult to imagine how they might raise and depress the sea floor, build high mountains, or even produce the folds and contortions characteristic of many regions. Even the advocates of the Noachian flood were forced to depart from the literal description and call in comets and sudden shifting of the earth's axis to account for the seemingly disorganized earth with marine shells miles high on mountains. It was seen that some new mechanism must be devised, but the accepted teachings of the eighteenth and early nineteenth centuries allowed no place for an additional agent. Out of this impasse geology was led by James Hutton—successful physician, farmer, and manufacturing chemist. Discarding speculation and tradition and all concern for origins of things, this "patient, enthusiastic, level-headed devotee of science" observed phenomena and processes, and developed a logical theory which lies at the base of modern dynamical geology. Hutton's "Theory of the Earth with Proofs and Illustrations" (1795) and its companion volume, Playfair's "Illustrations of the Huttonian Theory" (1802), are classics in geologic literature, which are scarcely out of place in a modern class room. The scheme as outlined by Hutton is simple and convincing. Observation taught him that the features of the earth are not rigid and immutable but are continuously undergoing changes. Rocks decay, soil is swept away by streams, coasts are worn down, and all loose material is carried to the sea. In time the solid lands must disappear. The debris is deposited on the ocean floor forming layers in which remains of organisms are embedded. The material for making future lands is thus prepared. But to be recovered from the sea and built into continents these sediments must be elevated. In searching for an agent capable of causing uplift, Hutton dismissed as phantoms the "convulsions of nature," "emanations," and "universal debacles" of his contemporaries and predecessors. Going once more to the field, he observed that many rocks are not stratified and many are bare of fossils and that these rocks show unmistakable evidence that they were once in a molten state; in fact, that some of the igneous materials have come up from below, penetrated the surrounding rocks, and altered their appearance and composition. Deep within the earth, therefore, heat must prevail and the sudden expansion of rocks induced by heat not only produced volcanoes but lifted the overlying rock masses. Rugged mountains, broken and tilted strata, and folds are witnesses to these gigantic upheavals.

Hutton's teachings were a half century ahead of his time and made slow headway. Though supported by the nebular hypothesis of a cooling globe, by the testimony of miners that heat increases with depth, and by the evidence of volcanoes as presented by Desmarest (1725-1815) and by Scrope (1823), the hypothesis of universal and subterranean heat was ignored or combatted by the strongly entrenched Wernerian school which clung to the view that all rocks are formed from water, that mountains are gigantic crystalline aggregates made where they stand, and that the earth is cold to the center. Professor Jameson, a colleague of Playfair at Edinburgh University, writing in 1808[13], calls the researches of Hutton, Playfair and Hall "monstrosities" and remarks: "It is therefore a fact that all inclined strata with few exceptions have been formed so originally and do not owe their inclination to subsequent change." Fortunately for science Hutton was followed by Lyell (1797-1875). Taking for his text the saying of Hutton, "Amid all the revolutions of the globe, the economy of nature has been uniform," Lyell expounded and systematized the theories of his master, gathered new facts, pointed out errors, and through his "Principles of Geology" guided the thought of students during the second quarter of the nineteenth century. Lyell's chief contribution was the development of the thesis that the forces operating on and within the earth during past time are the same as those of today; that knowledge of past events is to be gained by studying present processes. The building of mountains and continents, the folding and breaking of strata, the making of igneous and sedimentary rocks, and the entombment of fossils are proceeding as rapidly and in the same manner as in other ages. There have been no "gigantic cataclysms" or "devastating floods"; all processes have been orderly and uniform in degree and in kind. The emergence and submergence of coasts, the changes of level associated with earthquakes, are the rule not exceptions, and do not involve unusual forces.

> The land has never in a single instance gone down suddenly for several hundred feet at once. . . Great but slow oscillations have brought dry land several thousand feet below sea and raised it thousands of feet above. Places now motionless have been in motion and places of present active movements were formerly stationary.

Although this doctrine of "uniformitarianism" was carried by Lyell somewhat beyond the modern viewpoint the road to progress was cleared of fantastic speculations.

Hutton and Lyell considered heat combined with pressure sufficient cause for vertical uplifts of parts of the earth's surface. The analyses of these processes have absorbed the attention of structural geologists down to the present day. In 1833 the brilliant French scholar, Elie de Beaumont (1798-1874), expressed the view that the earth is a fused

[13] Jameson, Robert, Elements of geognosy, Edinburgh, 1808.

mass covered by an envelope of cooled rock "thinner in proportion than the shell of an egg." In adjusting itself to the cooling interior this crust became wrinkled. From time to time portions of the crust collapsed along definite lines of fracture. At such times the rocks are subjected to great lateral pressure; the unyielding ones are crushed, the pliant ones bent and forced to pack themselves into smaller space. The readjustment of the shell to the shrinking interior causes portions of the crust to be squeezed upward as wrinkles or folds which we call mountain ranges. By reference to the surrounding rocks, the date of the mountain's birth is obtained.

These theoretical views although erroneous and discounted even during the life time of their author marked an important advance, for through them came the idea of mountain folding by lateral compression. As treated by James D. Dana,[14] this conception grew into a consistent theory of mountain origin and structure which has received universal acceptance. In brief, this theory is as follows: Materials for the future mountain system are eroded from a land mass and deposited in a progressively sinking trough to thickness of thousands of feet. After long ages the sediments in the trough are compressed laterally against the relatively solid old land; the shortening, amounting to many miles (Appalachians, 40 miles; Alps, 74), is made possible by folding or by forcing parts to override other parts. During and after the periods of folding and faulting the newly born mountain range is eroded into features which are recognized as ridges, peaks and valleys. These processes, which in detail are enormously complicated, involve regional upwarps and downwarps which are recorded over wide areas. Largely through a study of mountain ranges with their faults and folds and enormous thicknesses of disturbed sedimentary and igneous rocks has come the modern view of the fundamental structural relations: that the earth is not a liquid or molten mass covered with a crust, but a globe as rigid as a ball of steel or glass of equal dimensions yet "elastic" or "pliable" enough to yield under the weight of even a moderate load.

Interpretation of Natural Scenery

A discussion of the principles and processes involved in sculpturing the earth surface was futile on the hypothesis of a ready-made earth whose features were unchangeable except when modified by catastrophic action. The belief in the Deluge as the one great event in geological history effectually checked investigation of the work of rivers, glaciers, wind, and the atmosphere in producing the variety of forms that constitute natural scenery. It is therefore not surprising that physiography, whose essence lies in the belief that present land forms rep-

[14]Dana, J. D., Manual of geology, Philadelphia, 1863, 3d ed., 1880.

resent merely a stage in the orderly development of the earth's surface features, should have attained the dignity of a science within the past quarter century; nor that the speculations of Aristotle, Herodotus, Strabo, and Ovid, and the illustrious Arab, Avicenna (980-1037), unchecked by appeal to facts but also unopposed by priesthood or popular prejudice, are nearer to the truth than the intolerant controversial writings of the intellectual leaders of the late Middle Ages whose touchstone was orthodoxy. Steno (1638-1687) mildly suggested that surface sculpturing, particularly on a small scale, is largely the work of running water, and Guettard (1715-1786) grasped the fundamental principles of denudation; but nearly eighteen centuries had elapsed before Desmarest, the father of physiography, presented proofs that valleys are made by rivers and that a landscape passes through clearly defined stages of development.

Desmarest's teachings were strengthened and expanded by DeSaussure (1740-1799)[15], the originator of the term, "geology," who saw in the intimate relation of Alpine streams and valleys the evidence of erosion by running water (1786).

These works from the acknowledged leaders of geological thought of the period aroused singularly little interest on the Continent, and Lamarck's volume on denudation (Hydrogéologie), which appeared in 1802, although an important contribution, sank out of sight. But the seed of the French school found fertile ground in Edinburgh, the hub of the geological world at the close of the eighteenth century. Hutton's "Theory of the Earth, with Proofs and Illustrations," in which the guidance of DeSaussure and Desmarest is gratefully acknowledged, appeared in 1795. The original publication aroused only local interest, but when placed in attractive form by Playfair[16], the problem of the origin and development of land forms assumed a permanent position in geological thought. Steps in the analysis and solutions of these problems may be illustrated by tracing the growth of ideas regarding valleys and features produced by glaciation.

In the interpretation of valleys little progress was made during the first fifty years of the nineteenth century. Physiographic literature shows that the clear reasoning of Desmarest, DeSaussure, Hutton, and Playfair, firmly buttressed by concrete examples, was insufficient to overcome the belief that valleys are ready-made or result from cataclysms and that the corrugations and irregularities of mountain surface are remnants of the primeval earth. The principles laid down by these clear-sighted leaders were too far in advance of their time to secure general acceptance. In a paper with the significant title, "Burst-

[15]Saussure, H. H. de., Voyage dans les Alpes, 1779-1796.
[16]Playfair, John, Illustrations of the Huttonian theory, 1802; trans. into French by C. A. Bassett, 1815.

ing of Lakes Through Mountains," Wilson (1821) asks: "Is it not the best theory of the earth, that the Creator, in the beginning, at least at the general deluge, formed it with all its present grand characteristic features?"[17]

In 1823 Buckland[18] wrote:

> . . . The general belief is that existing streams, avalanches and lakes, bursting their barriers, are sufficient to account for all their phenomena. It is now very clear to almost every man, who impartially examines the facts in regard to existing valleys, that the causes now in action . . . are altogether inadequate to their production; nay, that such a supposition would involve a physical impossibility. . . . We do not believe that one-thousandth part of our present valleys were excavated by the power of existing streams.

Similar views expressed in scientific journals of Europe and of America by the leaders of geologic thought, including Hitchcock (1824),[19] Phillips (1829),[20] Lyell (1833), Conrad (1839),[21] Darwin (1844),[22] Warren (1859),[23] and Lesley (1862).[24]

By the middle of the nineteenth century opinion regarding valleys had become standardized somewhat as follows: the position of many valleys is determined by original surface inequalities or by later fractures in the earth's crust; most of them are intimately associated with earthquakes, bursting of lakes, or the sudden upheavals or depressions of the land; valleys of erosion are chiefly the work of the sea, but rivers may perform similar work on a small scale.[25] The extent of the wandering from the guidance of DeSaussure and Playfair after the lapse of fifty years is shown by students of Switzerland. Alpine valleys to Murchison (1851) were bays of an ancient sea; Schlaginweit (1852) found regional and local complicated crustal movements a satisfactory cause; and Forbes (1863) saw only glaciers.

The truths expounded by Desmarest and Hutton were reestablished by James D. Dana,[26] who in 1850 amply demonstrated that valleys on

[17]Wilson, J. W., Bursting of lakes through mountains: *Am. Jour. Sci.*, III, 253, 1821.

[18]Buckland, William, Reliquiæ diluvianæ: *Am. Jour. Sci.*, VIII, review, 150, 317, 1824.

[19]Hitchcock, Edward, Geology, mineralogy, and scenery of regions contiguous to the Connecticut River, with a geological map and drawings of organic remains (etc.): *Am. Jour. Sci.*, VII, 1-30, 1824.

[20]Phillips, John, Geology of Yorkshire: *Am. Jour. Sci.*, XXI, 17-20, 1832.

[21]Conrad, T. A., Notes on American geology: *Am. Jour. Sci.*, XXXV, 237-251, 1839.

[22]Darwin, C. R., Geological observations, etc., during the voyage of the "Beagle," London, 1844.

[23]Warren, G. K., Explorations in Nebraska and Dakota: *Am. Jour. Sci.*, XXVII, Review, 380, 1859.

[24]Lesley, J. P., Observations on the Appalachian region of southern Virginia: *Am. Jour. Sci.*, XXXIV, 413-415, 1862.

[25]For a fuller statement of the views regarding origin of valleys, see Gregory, H. E., Steps of progress in the interpretation of land forms: A century of science in America, pp. 124-152, Yale University Press, 1918.

[26]Dana, J. D., On denudation in the Pacific: *Am. Jour. Sci.*, IX, 48-62, 1850.

————————, On the degradation of the rocks of New S. Wales and formation of valleys: *Am. Jour. Sci.*, IX, 289-294, 1850.

the Pacific islands owe neither their origin, position nor form to the sea or to structural factors, but are the work of existing streams which have eaten their way headwards. Even the valleys of Australia cited by Darwin as type examples of ocean work are shown to be products of normal stream action. Dana went further and gave a permanent place to the Huttonian idea that many bays, inlets, and fiords are but the drowned mouths of river-made valleys. The theory that valleys are excavated by streams which occupy them received strong support from study of the Rocky Mountain gorges (1862) and gained all but universal acceptance after Newberry[27] called attention to the lesson to be learned from the canyons of Arizona:

> Like the great cañons of the Colorado, the broad valleys bounded by high and perpendicular walls *belong to a vast system of erosion, and are wholly due to the action of water.* . . The first and most plausible explanation of the striking surface features of this region will be to refer them to that embodiment of resistless power—the sword that cuts so many geological knots—volcanic force. The Great Cañon of the Colorado would be considered a vast fissure or rent in the earth's crust, and the abrupt termination of the steps of the table-lands as marking lines of displacement. This theory though so plausible, and so entirely adequate to explain all the striking phenomena, lacks a single requisite to acceptance, and that is *truth.*

With these stupendous examples in mind, the dictum of Hutton seemed reasonable: "There is no spot on which rivers may not formerly have run."

Contributions to physiography between 1850 and 1870 reveal a tendency to accept greater degrees of erosion by rivers, but the necessary end-product of subaerial erosion—a plain—is first clearly defined by Powell (1875),[28] who introduced the term "base level," which may be called the germ word out of which has grown the "cycle of erosion," the master key of modern physiographers.

Analysis of Powell's view has given definiteness to the distinction between "base level," an imaginary plane, and a "nearly featureless plain," an actual land surface, the final product of subaerial erosion. Following their discovery in the Colorado Plateau Province, denudation surfaces were recognized in Pennsylvania by McGee,[29] and in Connecticut by Davis (1889)[30] who introduced the term "peneplain," "a nearly featureless plain," for the upland of southern New England developed during Cretaceous time.

Long before the days of Powell "plains of denudation" had been clearly recognized by English geologists who considered them products of marine work. The contribution of American students is not that peneplains exist but that many of them are the result of normal

[27] Newberry, J. S., Colorado River of the West: *Am. Jour. Sci.,* XXXXIII, review, 387-403, 1862.

[28] Powell, J. W., Exporation of the Colorado River of the West, 1875.

[29] McGee, W. J., Three formations of the Middle Atlantic Slope: *Am. Jour. Sci.,* XXXV, 120, 328, 367, 448, 1888.

[30] Davis, W. M., Topographic development of the Triassic formation of the Connecticut Valley: *Am. Jour. Sci.,* XXXVII, 423-434, 1889.

subaerial erosion. More precise field methods during the past decade have revealed the fact that no one agent is responsible for the land forms classed as peneplains; that not only rivers and ocean, but ice, wind, structure, and topographic position must be taken into account.

The recognition of rivers as valley-makers and of the final result of their work necessarily preceded an analysis of the process of subaerial erosion. The first and last terms were known, the intermediate terms and the sequence remained to be established. Significant contributions to this problem were made by Jukes' (1862) discussion of "lateral" and longitudinal" valleys, Powell's description of antecedent and consequent drainage (1875), and Gilbert's analysis of land sculpture in the Henry Mountain (1880). But the master papers are by Davis,[31] who introduces an analysis of land forms based on structure and age by the statement:

> Being fully persuaded of the gradual and systematic evolution of topographical forms it is now desired . . . to seek the causes of the location of streams in their present courses; to go back if possible to the early date when central Pennsylvania was first raised from the sea, and trace the development of the several river systems then implanted upon it from their ancient beginning to the present time.

That such a task could have been undertaken only three decades ago and today be considered a part of every-day field work shows how completely the lost ground has been regained and how rapid has been the advance in the knowledge of land sculpture since the canyons of the Colorado Plateau were interpreted.

One of the most interesting chapters in geological history is the origin and development of the theory of continental glaciation, which grew out of the attempt to explain the presence of "erratic" bowlders strewn over the surface in "obviously unnatural" positions. As stated by Silliman (1821):[32]

> The almost universal existence of rolled pebbles, and boulders of rock, not only on the margin of the oceans, seas, lakes, and rivers; but their existence, often in enormous quantities, in situations quite removed from large waters; inland,—in high banks, imbedded in strata, or scattered, occasionally, in profusion, on the face of almost every region, and sometimes on the tops and declivities of mountains, as well as in the valleys between them; their entire difference, in many cases, from the rocks in the country where they lie—rounded masses and pebbles of primitive rocks being deposited in secondary and alluvial regions, and vice versa; these and a multitude of similar facts have ever struck us as being among the most interesting of geological occurrences, and as being very inadequately accounted for by existing theories.

To this list of features now recognized as characteristic of glacial drift are to be added jumbled masses of "diluvium," ridges of gravel, "kettles" in sand plains, polished and striated rock, and thick beds of

[31]Davis, W. M., The rivers and valleys of Pennsylvania: *Nat. Geog. Mag.*, I, 183-253, 1889.

————————, The rivers of northern New Jersey with notes on the classification of rivers in general, ibid, II, 81-110, 1890.

[33]Silliman, Benjamin, Review of Hayden's geological essays: *Am. Jour. Am. Jour. Sci.*, III, 49, 1821.

"unhardened pudding stone" (till). Even Lyell, the great exponent of uniformitarianism, appears to have lost faith in his theories when confronted with facts for which known causes seemed inadequate.

The interest aroused by the phenomena now attributed to ancient glaciers is attested by scores of titles in scientific and literary periodicals of the first four decades of the nineteenth century. With little knowledge of existing glaciers, of areal distribution, structure and composition of drift, all known forces were called in: weathering, catastrophic floods, ocean currents, waves, icebergs, glaciers, wind, and deposition from a primordial atmosphere. Even human agencies were not discarded. But the controversy ranged chiefly about floods, icebergs, glaciers, and earth shaking catastrophes.

The catastrophes favored by most geologists were the Deluge, and floods of water violently released from the interior of the earth or caused by sudden upheaval of mountains. "We believe," says Silliman (1824) "that all geologists agree in imputing . . . the diluvium to the agency of a deluge at one period or another"[33]—a conclusion which rested in no small way upon Hayden's[34] well-known treatise on "diluvium" (surficial deposits, glacial drift). The objection to the theory of "debacles" and resistless world-wide currents is not only its grotesque assumptions and processes but also its complete disregard of observable phenomena. Its strength lay chiefly in its supposed confirmation of the Biblical record and it is perhaps natural that the way to a saner view should have been pointed out by intelligent laymen rather than by leaders of thought bound by authority and tradition. Unbiased observation is an essential condition of progress.

In 1823[35] Granger speaks of the glacial striæ on the shore of Lake Erie as

> having been formed by the powerful and continued attrition of some hard body. . . To me, it does not seem possible that water under any circumstances, could have effected it. The flutings in width, depth and direction, are as regular as if they had been cut out by a grooving plane. This, running water could not effect, nor could its operation have produced that glassy smoothness, which, in many parts, it still retains.

The first unequivocal statement that ice is an essential factor in the formation and transportation of drift comes from another layman, Peter Dobson (1826),[36] who concludes a series of accurate detailed observations on the polished and striated bowlders embedded in the Connecticut till with the remark:

> I think we cannot account for these appearances, unless we call in the aid of ice along with water, and that they have been worn by being suspended and carried in ice, over rocks and earth, under water.

[33]Silliman, Benjamin, Review of Hayden's geological essays: *Am. Jour. Sci.*, VII, 211, 1824.

[34]Hayden, H. H., Geological essays, 1-412, 1821: *Am. Jour. Sci.*, III, 47-57, 1821.

[35]Granger, Ebenezer, Notice of a curious fluted rock at Sandusky Bay, Ohio: *Am. Jour. Sci.*, VI, 180, 1823.

[36]Dobson, Peter, Remarks on bowlders: *Am. Jour. Sci.*, X, 217-218, 1826.

The glacial theory makes its way into geological literature with the development by Agassiz (1837) of the views of Venetz (1833) and Charpentier (1834) that the glaciers of the Alps once had greater extent. The bold assumption was made that the surface of Europe as far south as the shores of the Mediterranean and Caspian seas was covered by ice during a period immediately preceding the present. The kernel of the present glacial theory is readily recognizable in these early works, but it is wrapped in a strange husk: the Alps were assumed to have been raised by a great convulsion under the ice and the erratics to have slid to their places over the newly made declivities. The publication of the famous "Etudes sur les Glaciers" (1840), remarkable alike for its clarity, its sound inductions, and wealth of illustrations, brought the ideas of Agassiz into prominence and inaugurated a thirty years' war with the proponents of floods and of icebergs. The outstanding objections to the theory were the requirement of a frigid climate and the demand for glaciers of continental dimensions; very strong objections for the time when fossil evidence was not available, the great polar ice sheets unexplored, and the distinction between till and water-laid drift had not been established.

So fully does the glacial hypothesis account for observed phenomena that it received the sympathetic attention of leading geologists especially in America. As the evidence accumulated opposition disappeared and by 1875 the belief in the former wide extent of land ice was firmly established.[37] The next step forward was the determination of the extent of glacial drift—a series of field studies that have produced the modern maps of glaciated areas and led to the interesting conclusion that the "ice age" was not the record of the advance and retreat of one great continental glacier, but that it is divided into epochs; that several retreats are required to account for the phenomena of buried soils and overlapping ice laid deposits. In 1883 Chamberlin[38] presented his views, under the bold title "Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch," which initiated the discussion that led to the recognition of glacial deposits of different ages and the features of interglacial periods. Field studies during the last quarter century have demonstrated five glacial stages in America and four in Europe.

Within the present generation sculpture by glaciers has received much attention and has involved a reconsideration of the ability of ice to erode which in turn involves a crystallization of views of the mechanics of moving ice. The inadequacy of structural features or of

[37]Gregory, H. E., Steps of progress in the interpretation of land forms: A century of science in America, pp. 122-152, Yale University Press, 1918.

[38]Chamberlin, T. C., Preliminary paper on the terminal moraine of the second Glacial period: *U. S. Geol. Survey, Third Ann. Rept.*, pp. 291-402, 1883.

river corrasion to account for flat-floored, steep-walled gorges, hanging valleys, and many lake basins, has led to the present fairly general belief in the long neglected views of Ramsay that glaciers are powerful agents of rock sculpture. The details of the process, particularly of cirques, are not yet fully understood.

Meaning of Fossils

From the time when fossils received general recognition as the remains of extinct organisms, they have been examined from two viewpoints. One group of students (stratigraphers) are interested in fossils as objects which characterize geological epochs and by means of which true succession and relative ages may be determined. The other group (paleozoologists and paleobotanists) find the supreme value of fossils in their bearings on the problems of origin, development, and evolution of living forms. It is this biological aspect which has aroused an almost universal interest in fossils, brought the teachings of geology into zoological laboratories and medical schools, and furnished material for controversy to theologians and philosophers. The founders of paleontology, Blumenbach (1803-1816), Schlotheim (1804), Sternberg (1804), Cuvier (1808), Lamarck (1815-1822), and Brongniart (1822), attained success by applying the methods of comparative anatomy and botany, and the subject found an assured position through the work of Buckland (1836), Mantell (1844), Pictet (1844-1846), Geinitz (1846), Quenstedt (1852), and Richard Owen (1860)—all primarily biologists. Vertebrate paleontology especially has been treated as a branch of comparative anatomy concerned primarily with fossil bones and teeth, but its contributions have brought the civilized world to a belief in the theory of organic evolution.

Fossils were correctly considered by the Greeks and Romans as remains of plants and animals, but their presence in the rocks was ascribed to gigantic inundations which had brought marine animals far inland. Avicenna (980-1037), the great Arabian scholar, thought fossils were the unfinished work of *vis plastica*, a creative force that changed inorganic substances to organic; the living form had been produced but no life given it. To George Bauer [Agricola] (1494-1555), and to Mattioli (1548) fossils were "solidified accumulations from water" like limestone, or converted into stone by a certain *succus lapidescens* believed to reside in water; to the anatomist Fallopio fossil teeth were concretions and fossil shells the result of "fermentations" and "exhalations from the soil"; to Olivi of Cremona they were mere sports or freaks; Lister (1638-1711) taught that each rock stratum produces its own fossils; Mercati, museum assistant to Pope Sixtus V, thought them seeds of the stars; and the English antiquary

Lhuyd (Luidius) sought their origin in seed-bearing vapors originating in the sea. These typical seventeenth century ideas of the nature of fossils are to be contrasted with those of Leonardo da Vinci (1452-1519) and Fracastora (1483-1553) who insisted that fossils are organisms which once lived where now found, and which owe their preservation to burial in mud.

The conclusions of these Italian scholars who ridiculed the notion that fossils descended from stars or were formed in the earth by some mysterious creative force were disregarded or treated as "vaporings of disordered minds"; Bernard Palissy (1499-1589) who near the close of the sixteenth century gave a correct explanation of petrified wood, fossil fish and molluscs was vigorously denounced as a heretic. Even the teachings of the remarkable scholar, Nicholaus Stensen (Nicolas Steno, 1631-1687), whose little pamphlet "*De solido intra solidum naturaliter contento*" (1669) is the high water mark of seventeenth century geology, made little impression and was soon forgotten, and at the beginning of the eighteenth century fossils were generally considered mineral curiosities—"formed stones," "figured stones"—and chance imitations of living forms.

Fortunately the disputes regarding the nature of fossils encouraged the search for fossils and led to a number of valuable works in which fossils were faithfully described and represented by drawings. Publications descriptive of fossils of particular regions, monographs on selected groups, and general treatises on classification and nomenclature appeared in France, England, Germany, Switzerland, and Italy during the early part of the eighteenth century. Through the labors of Scheuchzer[39] and many supporters, Johann Baier[40] and especially John Woodward,[41] and Knorr and Walch,[42] whose handsome four volume treatise is the paleontological masterpiece of that period, trilobites, brachiopods, molluscs, crinoids, sponges, crabs, fishes and vertebrate bones were made known to the scientific world. The accumulated evidence was conclusive and at the middle of the eighteenth century no scholar of repute looked on fossils as the result of inorganic forces.

With the recognition of fossils as the remains of living beings, the three century discussion of the origin of fossils assumed new form. Are these objects the *relictae* of animals and plants now living or do they represent peculiar races of animals and plants which formerly inhabited the earth? Have they originated where found or have they been transported to their present resting places, and if transported,

[39]Scheuchzer, J. J., Specimen lithographie helveticae curiosae, 1702.

[40]Baier, Johann, Oryctographica norica, 1712.

[41]Woodward, John, Natural history of the earth and terrestrial bodies, etc., London, 1695.

[42]Knorr, G. W., and Walch, J. E. F., Die Sammlung von Merkwürdigkeiten der Natur und Alterthümer des Erdbodens.

by what agency? With the fauna of half the earth's surface and the life of the ocean unknown it was but natural to assume that fossil snails and oysters and leaves belonged to species of animals and plants which still flourished in some unexplored part of the world. It was commonly believed that the only animals in existence were those made during the days of creation and that none had disappeared from the world. Thus the bones of the ground sloth (*Megalonyx jeffersoni*) described by Thomas Jefferson were believd by him to be the remains of some sort of a lion still living in the Allegheny Mountains. But the hope of finding living specimens to match the skeletons embedded in the rock resulted in disappointment and in the search for other explanations the theory of great catastrophes which overwhelmed the inhabitants of all or parts of the earth gained the support of the leading minds toward the close of the eighteenth century. Great inundations of the sea, terrific earthquakes, and gigantic volcanic eruptions all had their supporters, but the belief in Noah's flood enlisted the most faithful adherents. The biblical flood not only swept the earth of living forms, but scattered their remains far and wide and left them buried in jumbled heaps in the sands and muds deposited by the onrushing currents. Warmly approved by the church, the "diluvialists" occupied a strong position in the scientific world well into the nineteenth century. Even the great Cuvier (1821) lent support to the believers in the flood and Buckland's treatise on the *Organic Remains contained in Caves, Fissures and Diluvial Gravel, and on other phenomena Attesting the Action of a Universal Deluge*, bears the date 1823.

With a wider recognition of the fact that fossils are not restricted to sands and gravels and muds which might have been deposited within the past few thousands of years, but are found embedded in firm rock on plains and seashore and mountain tops and are revealed by mine shafts, wells, tunnels, and excavations for buildings, the diluvial hypothesis assumed yet another form. Noah's flood was retained, but was given the position of the last of a series of great catastrophes which overwhelmed the world.

Under the lead of the French paleontologists, cordially supported by their English and American colleagues, the "catastrophists" held sway during the first six decades of the nineteenth century. They clearly recognized that fossils in a given formation differed in kind from those in the overlying and underlying strata, but explained these facts on the theory that the period represented by each of these formations witnessed the complete disappearance of animal and plant life of the world. The fossils of the next higher strata were the remains of newly created beings. Each species was a separate creation. The simplicity of forms of the earlier creations compared with the complexity of form and structure of the fossils of later creations appears to have been ascribed to progressive skill of the Creator rather than to the progressive development of species.

Cuvier, the leader of the catastrophic school, is the outstanding figure among the paleontologists of the first half of the nineteenth century. As a biologist he established comparative anatomy as a distinct branch of science and formulated the principles and methods still in vogue for the study of fossil vertebrates. Through his influence systematic research replaced disorganized observation. His conception of the correlation of parts, that structure and function are interdependent, is the guiding principle in modern paleontology, and makes it possible to reconstruct an extinct animal from fragmentary remains found in the rocks or even from a single bone or tooth. His work shows a progression from description of individual bones to reconstruction of whole skeletons, and on to the grouping of extinct forms into species, genera, and orders. The wealth of fossil material embedded in the gypsum deposits of the Paris Basin "enabled him to prepare the first reconstructions of fossil vertebrates ever attempted and to bring before the eyes of his contemporaries a world peopled with forms which were utterly extinct."[43] To bring to the laboratory a miscellaneous assemblage of fossil bones and by the strict application of scientific method supply the missing parts until there appears an animal never before seen by human eye, may be considered one of the great achievements of the human mind. Little wonder that Cuvier's demonstrations revolutionized the thought of his day and made a deep and lasting impression. Paleontological views before the days of Darwin were essentially the views of Cuvier and his devoted disciples. Most of the epoch-making contributions of the Cuvierian school have remained undisputed but the contention that species are immutable is strangely out of harmony with modern views.

When the Cuvierians left the solid ground of their field of comparative anatomy they parted company with contemporary thinkers in other branches of geology and entered the bog already thickly populated with philosophers, theologians, and mystics of ancient and medieval times. Unconsciously and with different terminology, they gave their approval to Indian, Egyptian, and early Church beliefs in earth catastrophes followed by recreations—periods of disaster interspersed with millenia. There was no recognition of the orderly development of the earth and its inhabitants resulting from the operation of natural laws.

The publication of Darwin's "Origin of Species," 1859, marks the beginning of the evolutionary period in the study of fossils. The fixity of species was replaced by the evolution of species; recurrent

[43]Lull, R. S., On the development of vertebrate paleontology: A century of science in America, Yale University Press, 1918, p. 219.

catastrophes which necessitated new creations retired in favor of orderly development; and supernatural agencies were discarded. This revolutionary change in thought was foreshadowed by the teachings of a few bold spirits and the transition from catastrophism to evolution made easier by evidence accumulated during previous decades.

By 1856, two thousand fossils from strata later than the Carboniferous were known in America; in Europe more than 20,000. A study of this material led to the recognition of the facts that the individuals that compose a species are "endlessly diverse" (Dana); "that fossils from two consecutive formations are far more closely related than are the fossils of two remote formations" (Asa Gray); "that when species are arranged in a series and placed near to each other with due regard to their natural affinities they each differ in so minute a degree from those next adjoining that they almost melt into each other" (Lyell). And during the catastrophic period men were not lacking who accepted the evidence of transition in the organic world and followed it to its logical conclusion. Aristotle's views are singularly like those of modern time and Erasmus Darwin (1731-1802), grandfather of Charles Darwin, consistently taught that variations in species arise within organisms in response to environmental influences. Comte de Buffon (1707-1788) grasped the idea that life descends continuously from other life and is modified by geographical isolation, but only the industrious and serious-minded can separate the wheat from the chaff in the 44 volumes of his entertaining Histoire Naturelle (1749-1804).

Among evolutionists of Pre-Darwin days, Chevalier de Lamarck 1744-1829) stands first. For fifty years he was a firm believer in catastrophes and recreations but in later life, in the face of strong opposition, he gave the full weight of his knowledge and experience to the support of the theory of descent and inheritance of acquired characters. His teachings are so unmistakably clear and so sharply contrasted with the contentions of the catastrophists that Lamarck is justly regarded as the founder of the evolutionary school. Lamarck's ideas were kept alive by a group of earnest but unconvincing followers including Geoffroy Sainte-Hilaire and the poet Goethe, but such men were no match for the gifted scientists of the catastrophic school, supported as they were by the church and by public opinion. Even the *Vestiges of the Natural History of Creation* by Robert Chambers (1802-1871), the most discussed book of the time, failed to uproot traditional beliefs, and by 1850 the evolutionary theory was pronounced "dead" by the leading writers of the time.

The resurrection came with the publication of Darwin's *Origin of Species*, doubtless the most influential book of the nineteenth century. No wonder that Darwin's views were received with dismay and aroused strenuous and bitter opposition, for their acceptance gave the death blow to creationists, placed man among the animals, and otherwise undermined the supposedly plain teachings of Scripture. The theory early received the support of Hooker, Huxley, and Herbert Spencer in England, and Asa Gray in America. Among its American opponents were James D. Dana, who later modified his opinion, and Louis Agassiz, who held his disapproval through life. That part of Darwin's theory which related to the progressive development of *living* plants and animals aroused little opposition, for improvements produced by the breeding of domesticated animals were well understood; but the testimony of the rocks that the lineal ancestors of existing animals are constituents of strata laid down millions of years ago was quite another matter.

The scientific opponents of evolution relied mainly on the fact, uncontested by geologists, that the successive strata did not disclose an unbroken series of modified forms—there were many "missing links" in the supposed chain of development. In this connection the discoveries of American vertebrate paleontologists make an interesting chapter. Beginning with 1870, Leidy, Cope, Marsh, followed by a group of workers of the present generation, unearthed the profusion of vertebrate remains from Tertiary, Cretaceous, and Jurassic beds which have made famous the collections in the American Museum of Natural History and the Peabody Museum at Yale. Professor Marsh alone found the remains of about 200 birds with teeth, 160 mammals, and hundreds of flying, swimming, and walking reptiles varying in size from guinea pigs to monsters 80 feet long. These collections bridged the gap between reptiles and birds and indicated the common ancestors for animals now recognized as distinct species.

Down through successive geological epochs the modern horse was traced through transitional forms to a four-toed ancestor, the size of a fox, which flourished during the Eocene. Such evidence could not be disregarded. In reviewing the work of Marsh, Huxley who previously had pointed out the insufficiency of the paleontological evidence, declared that "the evolution of existing forms of animal life from their predecessors is no longer an hypothesis but an historical fact" (1876).

Like other animals of the modern world, man's ancestry has been traced far back. The discovery of human bones and implements intermingled with the remains of animals long extinct proved a human habitation in France (Abbeville); Germany (Neanderthal: Fuhlrott 1857); and England (Piltdown: Woodward 1913) during Pleistocene time, and in Java (Do Bois 1891) at perhaps an even earlier date.

The Geologic Time Scale

Since the beginnings of field observations it has been known that many rocks are arranged in layers and that in many places strata of different colors and texture and composition are piled one upon another in a regular series. But nearly 18 centuries elapsed before it was realized that the stratified rocks contain within themselves the evidences of their origin and reveal a record of alternating lands and seas, of volcanic outpourings and desert winds, of changing climates and surface forms. A yet longer time was required to grasp the stupendous truth that the history of life on the earth is to be deciphered from the organic remains embedded in the hardened sediments.

The true meaning of chronological sequence, the recognition of the fact that the debris of lower strata has been utilized in building the strata next above, was first made clear by Arduino (1713-1795) who separated the rocks of Northern Italy into Primitive, Secondary, Tertiary, and Volcanic (1759). The field methods and manner of presentation developed by Arduino are not unlike those employed today and entitle this pioneer worker to a prominent place among stratigraphers.

An advance is shown in the work of Füchsel (1722-1773)[44] who analyzed the sedimentary masses of Thuringia. By his painstaking field mapping, his insistence that groups of strata have definite chronologic value, and especially by his clear distinction of stratum (Schicht) and formation (*Series montana*), were laid the foundations of stratigraphic geology in Germany.

The high priest of stratigraphy for the eighteenth century was Abraham Gottlob Werner (1749-1817), professor in the School of Mines of Freiberg—the first geologist to obtain world-wide prominence. Werner's contributions to literature are of small importance; his strength lay in his familiarity with the geological researches of his time and even more in his remarkable ability in teaching which made of Freiberg the Mecca for European students. Based on the conception of universal formations as developed by Füchsel, and on the systematic arrangement of minerals as outlined by the Swedish mineralogist, Tobern Bergman,[45] Werner erected the study of rock formations into an independent branch of geology. The essence of his teaching lies in the view that all rock formations are world-wide and that all are chemical precipitates; that the world is like an onion to which successive layers have been added. He conceived of a primeval ocean completely enveloping the earth. From this shell of water were precipitated first the granites and associated green stones, hornblende schists and porphyries, then slates and greywackes, followed in turn by limestone, coal, basalt, and ores; by sand, clay, soapstone, and finally by volcanic ash, some lavas, and jasper. Obviously, all igneous

[44]Füchsel, G. C., Historia terræ et maris ex historia Thuringiæ permontium descriptionem erecta (*Acta Acad. elect. Moguntinae*), 1762.
————, Entwurf zur ältesten Erd und Menschen Geschichte, 1773.
[45]Bergman, Tobern, Physical description of the globe, 1766.

and metamorphic rocks found place with the sediments for there was no place in this scheme for igneous activity, nor for structural changes in the earth's crust. To Werner volcanoes were "burning mountains" —the evidence of spontaneous combustion of buried beds of coal precipitated by an ancient sea. To him the world is the handiwork of Neptune; Pluto was disregarded. In spite of fundamental errors Werner's teachings were dominant to the close of the eighteenth century, and in the early nineteenth century had the backing of leading scholars of Europe, and guided the work of Maclure, Eaton and Silliman, the first American geologists. Only after a contest lasting for two decades did the opponents of the Wernerian School succeed in establishing the difference between igneous masses and sedimentary rocks in the geological series.

This prolonged discussion greatly stimulated observation and encouraged attempts at subdivision of stratified rocks which, however, showed little improvement over the work of Arduino and Füchsel. Progress depended on the development of new methods. The man and the method appeared in an unexpected place. William Smith, a civil engineer (1769-1838), had been quietly at work in all parts of England noting the position, extent, and composition of sedimentary rocks, collecting fossils from each stratum, and recording his observations on colored geological maps and sections. As part of his daily routine Smith noted that certain fossils reappear in the same beds at different localities and that each fossil species is entombed in a definite formation. From this he drew the obvious inference that sedimentary formations may be recognized by their fossil content, and showed that one succession of sediments extends across England from south to east. In this matter-of-fact way the sure foundations of modern stratigraphy were laid; a modest lover of nature had found the way to read the history of the earth—one of the truly great contributions to science. Before William Smith, stratigraphic position and geologic age were based on chemical and mineralogical composition and attitude of rocks; fossils were incidental. Since his day fossils are the final court of appeal for questions of time and order of succession, and correlation of widely separated beds. The adequacy of Smith's methods was amply demonstrated in Conybeare and Phillips' "Outlines of the Geology of England and Wales" (1822)[46] and with the wide distribution of Lyell's famous "Principles of Geology" (1830-1833) came universal recognition of the fact that fossils provided the surest means for comparative study of sedimentary rocks.

Primitive, Transition, Secondary, Tertiary—the recognized subdivisions of the first quarter of the nineteenth century—gradually gave

[46]Conybeare and Phillips' "Outlines of the geology of England and Wales" was the first widely used treatise in the English language.

way to the ages and systems of the modern time-scale. In 1830 the three divisions of the Tertiary based on relative percentage of existing species were established by Deshayes after a comparative study of the Tertiary rocks of England, France, Belgium, Poland, Hungary, and Italy. Lyell (1833) gave them the names now in use: Eocene, Miocene, Pliocene, and later added the term Pleistocene for the most recent alluvium and for the deposits now classed as glacial drift. The equivalents of certain English formations described by Smith were recognized in the Jura Mountains and in 1829 given the name Jurassic. With the addition of Triassic in 1834, the earlier "Secondary Class" became Triassic, Jurassic, and Cretaceous periods of Mesozoic (medieval) time. The analyses of the "Transition Class" of Werner and his contemporaries began with setting limits to the Carboniferous (1821) and continued through the establishment by English workers of the Cambrian (1833), the Silurian (1835), the Devonian (1839), and the Permian (1841) as periods of Palaeozoic time. Even the "Primitive or Primary Class," supposed by the earlier stratigraphers to be the veritable bed-rock of the earth, was resolved by Logan into Huronian (1852) and Laurentian (1853) systems as periods of Archaean (Pre-Cambrian) time. It thus appears that during the forty years following the publication of Smith's geological memoir, English geologists had developed a time-scale by which the relative age of all the sedimentary and igneous rocks of the world could be measured.

Stratigraphic research during the second half of the nineteenth century has added volumes to the history of the earth. The increase in the number of gathered fossils from thousands to tens of thousands permits closer discrimination of horizons and with added knowledge of the breaks in the sedimentary record has led to a recognition of subdivisions in the Silurian, Carboniferous, and Cretaceous. By far the greatest contributions during the past half century came from America. Through state and federal surveys,[47] and university activities, the condition of the earth during Cretaceous, Triassic, and Carboniferous times has been written into the record, and the work of James Hall[48] and his associates has made the stratified rocks of New York State the standard Paleozoic section for the world. American stratigraphers like American paleontologists have advanced from learners to teachers.

During the past quarter century attention has been directed to determining the physical conditions surrounding the deposition of sediments with a view to picturing more clearly the distribution of seas and lands, of streams and mountains, and separating areas of erosion from regions of deposition. The history of climates is also receiving atten-

[47]Government geological surveys: A century of science in America, pp. 193-216, Yale University Press, 1918.

[48]Zittel, Karl von, History of geology and paleontology, p. 442, 1901.

tion and one of the most striking results of modern methods is the proof of glacial conditions not only in the Pleistocene but in the Permian of India, Africa, Brazil, Australia, and Massachusetts, and even among the oldest rocks of China, Norway, and Canada.

It is thus seen that fossils in a modern sense are more than proofs of evolution and more than markers which indicate relative age. They aid in writing the physical geography of the time in which they flourished.

If the record were complete enough it should be possible to locate the seas and lands, the lakes and rivers, reconstruct the mountains and plains, and restore the inhabitants of each geological period. Even with the meager fossil record, geologists are drawing coast lines of the earliest lands, pointing out deserts where rainfall is now abundant and marking ancient tropical seas where cold winters now prevail. One of the most promising developments of the twentieth century is the preparation of physical geographies of important geological eras under the joint authorship of stratigraphers, paleontologists and physiographers.[49]

Age of Earth

The attractive myths of earth origin formulated by most uncivilized races wisely refrain from giving quantitative values to the expression "long ago." The philosophers of India regarded the earth as eternal; the Chaldeans set 2,150,000 years as the age of the earth; Zoroaster was satisfied with 12,000 years, and with the establishment of Christianity in Europe, the Hebrew chronology prevailed and the limiting dates of earth history rested firmly on the recorded teachings of Moses. The views of the Christian world well into the nineteenth century were fairly represented by Bishop Ussher who in 1650 fixed the date of the creation of the earth at 4004 B. C. Strangely enough this figure founded on no facts and no arguments rose to the dignity of a doctrine. For 200 years it appeared on the margin of our English Bibles and was the test of orthodoxy. Even today this date or the corresponding Byzantine date 5509 B. C. is accepted by half of the Christian world. Under the influence of these ideas geologists up to the beginning of the nineteenth century felt compelled to squeeze all geological history into six or seven thousand years. This severe restriction could be harmonized with the growing body of geological fact only by the formulation of extraordinary hypotheses, a state of affairs that led to the magnification of Noah's flood and similar catastrophes as the all powerful agents in molding the surface of the earth.

The scientific world was released from this thraldom by the bold teachings of Hutton that the present slow rate of geological processes must have been the rule since the dawn of geologic history. No wonder

[49]Schuchert, Charles, The progress of historical geology in North America: A century of science in America, pp. 60-121, Yale University Press, 1918.

that this view encountered opposition; it appeared to shake the very foundations of Christianity. The adherents to the established Church chronology had scarcely recovered their breath when Darwin's "Origin of Species" brought from the biological realm data in support of the physical evidence developed by Hutton, Lyell, and others. The theory of evolution obviously demanded enormous drafts on time and was utterly inconsistent with previously accepted views. By the third quarter of the nineteenth century the conclusions of geologists and paleontologists had become too well grounded to permit of substantial modification, but happily the first three words of the Bible, "In the beginning," and the "days" of creation were subject to new interpretations and the smoke of battle cleared away.

During the last half of the nineteenth century the advocates of a very ancient earth found themselves out of accord with the teachings of physics. Under the leadership of Lord Kelvin, mathematical proof was presented that the sun could not have been giving out heat for more than 100,000,000 years, perhaps only 40,000,000, and since the sun must have been producing heat for untold millions of years before life could have existed on the earth, only 10,000,000 to 20,000,000 years could be allowed for geological history. This amount of time is altogether too short for known geologic processes and for the evolution of living forms. When it is realized that the Cretaceous period alone may have had a duration equal to that allowed by Kelvin for all geologic time, the inadequacy of the physical estimates is apparent.

Though viewed with suspicion, the physical evidence appeared for a time irrefutable. Darwin was led to abandon his figures and some geologists undertook to speed up geological processes. In 1895 a reexamination of the physical data by Professor Perry revealed the weakness of Kelvin's arguments and modern students of radio-activity give the geologists not only the one or two hundred millions of years for which they have been contending, but allow 185,000,000 years since Carboniferous time and more than a billion years since the earth's first rocks were formed.[50]

The history of the earth as written during the past century is a fascinating story which has profoundly affected the world's thinking. Some chapters are complete, some need revision, many remain to be written. The interior of the earth and half of the surface of the earth await geological exploration; the mechanics of earth movements are not understood; the causes of variation in climate are imperfectly known; and the origin of life on the earth is shrouded in mystery. The chief problems awaiting solution call for assistance from chemistry, physics, biology, and astronomy, and further advance involves sympathetic coöperation.

[50]Holmes, Arthur, Age of the earth, Harper and Brothers, New York, 1912.

IS DARWIN SHORN?

By Professor C. C. NUTTING
STATE UNIVERSITY OF IOWA

NO one likes to criticise such a man as John Burroughs. His charming portrayal of the ways and manners of our birds and chipmunks and other "wee beasties" has endeared him to all of us. We who are naturalists are grateful for his keen observation and accurate descriptions, and most of all for his refusal to be lured into the path of the nature faker that has led to the discrediting of some of our most promising writers on natural history subjects.

But the more he is admired and respected, the greater his following among lovers of good literature, the subtler his power to mislead when he goes astray. This he certainly does in his paper "A Critical Glance into Darwin," which appeared in the August number of *The Atlantic Monthly*.

In the very first paragraph he says: "It is with Darwin's theories that I am mainly concerned here. He has already been shorn of his selection doctrines as completely as Samson was shorn of his locks."

This is a rather serious statement to be made in an off-hand manner; moreover it is far from true. I believe that I have a sufficiently wide acquaintance with working naturalists of the present time and a sufficient knowledge of their attitude towards the theory of natural selection to justify this rather blunt expression.

De Vries regarded his own mutation theory as a contribution to the theory of Natural Selection. Jennings, one of our foremost protozoologists says, "Evolution according to the typical Darwinian scheme, through the occurrence of many small variations and their guidance by Natural Selection, is perfectly consistent with what experimental and paleontological studies show us; to me it appears more consistent with the data than does any other theory." Castle, one of our leading geneticists, believes in continuous variations not following a single necessary trend, but guided by selection; and E. B. Wilson, among the most honored of all American biologists, says: "And yet, as far as the principle is concerned I am bound to make confession of my doubts whether any existing discussion of the problem affords more food for reflection, even today, than that contained in the sixth and seventh chapters of 'The Origin of Species' or elsewhere in the works of Darwin."

The chapters referred to are captioned "Difficulties of the Theory" and "Miscellaneous Objections to the Theory of Natural Selection." Here Darwin has gathered together all of the criticisms that had appeared up to the edition of 1896, twenty-eight years after the first publication of the theory, and has answered them with the utmost fairness and candor.

In this connection I can not refrain from quoting from my revered teacher, Dr. David Starr Jordan. Speaking of the "Origin," he says: "There is in it no statement of fact of any importance which, during the twenty-five years since it was first published, has been proved to be false. In its theoretical part there is no argument which has been proved to be unfair or fallacious. In these twenty-five years no serious objection has been raised to any important conclusion of his which was not at the time fully anticipated and frankly met by him."

No one can dispute the authoritative position of these men among American zoologists. Numerous others could be cited, and I am confident that none of them would subscribe to the statement that Darwin's selection doctrine has been overthrown. More than this; there is no doubt in my mind that if the entire membership of the American Society of Zoologists could express their opinion an overwhelming majority would assert that natural selection as proposed and elaborated by Charles Darwin is still the best explanation of organic evolution. No discarded theory could command so great a following among professional naturalists as does this.

Mr. Burroughs objects strenuously to Darwin's statement that he saw one of the chief factors of evolution in fortuitous or chance variations, and declares: "I can no more think of the course of evolution as being accidental in the Darwinian sense than I can think of the evolution of the printing press or the aeroplane as being accidental, although chance has played its part."

Now what is "chance" in the Darwinian sense? Darwin himself gives an explicit answer at the beginning of his chapter on Variation: "I have hitherto sometimes spoken as if the variations so common and multiform * * * were due to chance. This is, of course, a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation." Nothing could be more honest and straightforward than this; and it is manifestly unfair to accuse Darwin of using "chance" as if it meant lawless or opposed to law. The friends of Darwin have a right to insist that fair-minded critics refrain from this sort of misrepresentation.

The majority of present day zoologists and botanists do not talk much about Darwinism or Natural Selection; not because they do not believe these things but because they regard them as virtually settled and have turned to other matters, particularly the mechanism of heredity and the causes of variation, matters which Darwin did not explain satisfactorily because knowledge of these has been almost entirely the result of post-Darwinian investigation. At present most biologists believe in Mendelism and many of them have accepted as true the mutation theory. For all of these the chromosome looms so large as to obscure most of their mental horizon. I have seen a twenty-foot chart of a chromosome fully eclipse a map of the world, and thought it emblematic of the present situation.

It seems evident that a large number of our younger generation of biologists have fallen into strange confusion owing to a lack of appreciation of the difference between "variation" as used by the mutationist and the same word as used by Darwin. The mutationist uses the word in the sense of fluctuating varieties as opposed to mutations, while Darwin did not so restrict its use and, as will be shown, included what are now known as mutations in his "individual variations." De Vries, the father of the mutation theory, was entirely without mental confusion of this sort, and I can best make my point by quoting him. He says:

"Darwin discovered the great principle which rules the evolution of organisms." In discussing the steps by which progress is made he says: "On this point Darwin has recognized two possibilities. One means of changes lies in the sudden and spontaneous production of new forms from the old stock. The other method is the gradual accumulation of those always present and ever fluctuating variations which are indicated by the common assertion that no two individual of the same race are exactly alike. The first changes are what we call 'mutations,' the second are designated as 'individual variations' or, as this term is often used in another sense, as 'fluctuations.' *Darwin recognized both lines of evolution.*" The italics are mine.

What I am driving at is this. Many mutationists have become so accustomed to the word "variations" as synonymous with "fluctuations" that they assume that Darwin used the word exclusively in that sense when he speaks of individual variation as one of the main factors in natural selection. They therefore erroneously conclude that the mutation theory is squarely opposed to natural selection and in adopting the former suppose that they thus abandon the latter.

II

The work of DeVries, Morgan, Castle and a host of other men who have gone deeply into the mechanism of heredity and have been particularly interested in the behavior of the chromosomes as expressed by the Mendelian Law, has shown very conclusively that a majority of mutations are exceedingly minute, and that they range from hardly detectable changes to the much rarer great mutations recorded of the evening primrose. The difference between fluctuations and mutations is not quantitative but qualitative, the latter only being inheritable although they may be quantitatively no more conspicuous than the slightly different color of the eyes of *Drosophila.*

Now we must remember that all slight variations, be they mutations or fluctuations, were simply "individual variations" in Darwin's time. and both were included in his term "variations." In speaking of variability, he says: "In all cases there are two factors, the nature of the organism (heredity) *which is by far the most important of the two,* and the nature of the conditions (environment)." The words within parentheses and those in italics are mine. It is quite evident that the modern geneticist would interpret variations due to the former of these "factors" as mutations and those due to the latter as fluctuations, and that Darwin distinguished between the two so far as the knowledge available in his time permitted. He also plainly regards the mutations as much the more important.

De Vries, therefore, had keener vision than some of his followers when he said: "My work claims to be in full accord with the principles laid down by Darwin and to give a thorough and sharp analysis to some of the ideas of variability, inheritance, selection and mutation which were necessarily vague in his time." It seems quite certain that the founder of the mutation theory did not regard Darwin as "shorn of his selection doctrines."

III

In 1903 Professor T. H. Morgan published his "Evolution and Adaptation" containing the most elaborate criticism of Darwin's work that has appeared in America. This book has won high praise and deserves it, for Morgan performed a distinct service in gathering together and presenting in good form all that could be said against Darwin and his theories. It is imposing in mass but hardly convincing in detail, giving an impression of painstaking special pleading rather than the judicial attitude which Darwin so successfully maintained throughout his work. Moreover, one has the feeling that the outcome is something of an anticlimax; because the author, if he gets anywhere, simply arrives in the camp of the mutationists, who, like their leader, De Vries, are mainly Darwinian in their belief now as they were then.

In 1903 mutations, so far as they were known, were relatively large jumps, while subsequent investigations have shown them to be entirely comparable, phenotypically, with the "individual variations" of Darwin, and they would have been so regarded by him. There was therefore a much greater apparent difference between fluctuations, or individual variations of Darwin, and the mutations of De Vries in 1903 than there is now; for these differences, so far as outwardly shown, (and these were all that Darwin did, or could deal with) have practically disappeared.

It can not be too strongly insisted upon that the great proportion of the mutants of the present time were included in the variations of Darwin.

At the conclusion of Morgan's work we find the following statement which is most significant from the standpoint of this paper: "Their (the Darwinian school's) opponents, on the other hand, have, I believe, gone too far when they state that the present condition of animals and plants can be explained without applying the test of survival, or, in a broad sense, the principle of selection among species." "I am not unappreciative of the great value of that part of Darwin's idea which claims that the *condition* of the organic world, as we find it, can not be accounted for entirely without applying the principle of selection in one form or another. This idea will remain, I think, a most important contribution to the theory of evolution." Now the *condition* of the organic world was just what Darwin was trying to explain.

I have dwelt at some length on Morgan's work because I suspect that he is largely responsible for the attitude of Burroughs. But in the quotation just given Morgan admits a belief that Darwin's idea of selection is a most important contribution to the theory of evolution. After a somewhat relentless attempt to tear down most of Darwin's work, he allows his particular thing, *selection,* to stand with his approval; reluctantly and with reservation, it is true; but still to stand. It does not appear, then, that even the most iconoclastic of Darwin's critics would go so far as to regard Darwin as completely "shorn."

IV

A majority of naturalists are at present much impressed by the mutation theory and, if not fully convinced, are quite willing to be convinced of its truth. But it is also true that most of them are both Darwinians and mutationists, a position in which they but follow the lead of the master mutationist, De Vries. A still larger number of biologists are willing to subscribe to a belief in the Mendelian theory; and here, too, there is no quarrel with the idea of Natural Selection. The law of Mendel has given us a new insight into the mechanism of the germ cells and of heredity where Darwin had no means of pursuing his researches. But these more recent investigations have revealed nothing antagonistic to an acceptance of Natural Selection, which can now be regarded as a selection of the fittest mutants. And here again we must insist that the mutants of De Vries should properly be regarded as included in the individual variations of Darwin, with the exception of the very pronounced mutations, such as those of the evening primrose, which would have been regarded as "saltatory evolution" by earlier naturalists.

Such authorities as Castle and Jennings believe in Mendelism, but not in mutations. These also are far from believing that natural selection has been discarded.

Another writer who doubtless contributed ammunition for Mr. Burroughs' assault on Natural Selection is Professor H. F. Osborn, one of America's leading paleontologists. He also, it seems to me, does not deal quite fairly with the author of the "Origin," for he says: "Chance is the very essence of the original Darwinian hypothesis of evolution." In view of Darwin's frank and explicit explanation of his use of the word "chance," it is inexact, to say the least, to insist on a literal use of the word which he expressly disclaims and emphatically disavows. I do not believe, moreover, that Professor Osborn would fully endorse the unqualified statement regarding the shorn condition of Darwin; for he distinctly admits the importance of Natural Selection in his book "The Origin and Evolution of Life." He says:

"Upon the resultant actions, reactions and interactions of potential and kinetic energy in each organism selection is constantly operating." Again he says, and still more explicitly: "Whenever such changes of proportion weigh in the struggle for existence they may be hastened or retarded by Natural Selection."

As a matter of fact it is very doubtful if any leading zoologist would at the present time be willing to make so positive a statement as has John Burroughs regarding the "shorn" condition of Darwin so far as Natural Selection is concerned. Practically all of them regard Natural Selection as an important contribution to our understanding of organic evolution.

V

Indeed I must confess to a degree of skepticism regarding the mental attitude of the distinguished author of "A Critical Glance into Darwin" himself, for there are some rather glaring inconsistencies in his paper. After declaring the shearing process complete he finds himself unable to get along without appropriating some of the shorn locks to his own use. For instance: "And though I believe that *the accumulation of variations is the key to new species*, this acumulation is not based upon outward utility but on innate tendency to development." The italics are mine. No one, so far as I know, has proposed any method by which an accumulation of variations can be brought about except by the action of Natural Selection.

Again, he says: "Natural Selection turns out to be of only secondary importance—Natural Selection gives speed where speed is the condition of safety, strength where strength is the condition, keenness and quickness of sense-perception where these are demanded." Such expressions seem to indicate that Natural Selection functions in some rather important matters after all, indeed that it is of at least secondary importance.

After criticising Darwin for presenting an anthropocentric view of Nature, he naively remarks that it (Natural Selection) "is Nature's way of improving her stock." Just the picture that Darwin drew!

But, as it seems to me, he practically abandons his whole case when he says: "What I mean to say is that there must be some primordial tendency to development which Natural Selection is powerless to beget. It can not give the wings to the seed, or the spring, or the hook—*but it can perfect all those things. The fittest of its kind does stand the best chance to survive.*" Again, the italics are mine.

Now if there be any one thing about which all biologists and physicists are in thorough agreement, it is the belief in the uniformity and continuity of law in the universe. All believe that Nature's laws have worked in the past just as they are working now. In other words, if Natural Selection is at present engaged in perfecting animals and plants, she has been doing just that thing throughout the ages since life first appeared.

But we must remember that, although this perfecting is continuous, the standard of perfection is constantly changing. Perfection is always relative and never absolute. The first true winged bird, the Archeopteryx, was doubtless a very imperfect, even crude, creature according to our notions; but it was in its day an immense advance over its competitors and the best animated flying-machine of its time. It was practical, too. It did the business of flying better than any of its rivals. It was fittest to survive and it did survive, in its modern descendants, from far-away Jurassic time to this. And during all these countless centuries Nature has been at work "perfecting" this uncouth creature; keeping its descendants, or some of them, ahead of the game and thus making it perpetually the "fittest." And from this absurd creature have "radiated" as Osborn would say, various sorts of winged creatures each adapted to its manner of life or environment. These radiating lines ended in such marvels as the man-o'-war bird, that master acrobat of the air; and that dainty flying jewel, the humming-bird, poised apparently motionless in space; and, in short, all of the aerial artists that we call birds.

One can not help wondering just what Burroughs' position is when he says: "They (organic beings and structural changes) are adaptive from the first. They do not need Natural Selection to whip them into shape," and then declares: "Natural Selection perfects" these things. It seems that the same agency does not "whip into shape," but it does "perfect" things. This leaves us somewhat dazed.

VI

What appears to bother Mr. Burroughs most of all is the seeming lack of any directive force in the process of evolution. He balks, as countless others have, at the idea that "This is a world of chance into which Darwin delivers us," and adds: "What can the thoughtful mind make of it?" Darwin himself balked at it, but was honest enough to admit that he saw no way out of the dilemma, and others have had like experience. Some sort of orthogenesis has appealed to many; but the trouble is there is little to prove its existence, however devoutly we may desire such proof. Darwin was too intensely honest in his intellectual processes to incorporate any such idea without some sort of evidence that would appeal to him as likely to carry conviction; but he found none, nor has any one else, so far as I can see. Can we doubt that he would have gladly welcomed and used such proof, had it been forthcoming?

What is Burroughs' proposal by which he seeks to satisfy this longing for something better than a world of chance? He says: I am persuaded that there is something immanent in the universe, pervading every atom and molecule in it, that knows what it wants—a cosmic mind or intelligence."

This must be pantheism, if I understand it at all; but there is little that is soul-satisfying about pantheism, and a religion that does nothing for the soul is poor stuff. Moreover, such a belief has no scientific sanction.

The groping of the thoughtful mind for some directive force in evolution, whether in the form of an entelechy, orthogenesis, predetermination, Providence, or the "horse impulse" of Burroughs, has in it something of pathos and reminds one of the statue to "the Unknown God" at Athens; but thus far there has appeared no Paul to make him known unto us. I am sure that Darwin would have welcomed him, but would have demanded some rather convincing credentials. The God that Paul did propose to the Athenians answers, in the minds of Christian evolutionists (and there are many of us) to the God of the second moollah in Burroughs' article for "He is so wise that he makes all things make themselves."

But it is utterly unnecessary to inject pantheism or any other first cause into a discussion of Natural Selection. Darwin did not attempt anything of the sort and therein showed his wisdom. He found that there are three fundamental laws of living things, each so obviously true as to be axiomatic. Nor was it germain to his purpose to go back of these laws and discuss ultimate causes. He simply took the world as he found it and explained how diversity of species had been brought about. The three laws are:

1st. *The Law of Heredity,* which works to make the progeny resemble their parents. No one doubts the *fact* of heredity whatever its mechanism may be. Darwin did try to imagine a sufficient mechanism and called it "pangenesis." This theory has been largely discarded; but, whether true or false, it has little direct bearing on the theory of Natural Selection, nor could it invalidate that theory in the least. This law is the *conservative* factor.

2nd. *The Law of Individual Variation.* No one doubts that this is a fact, whether he calls the variations "individual variations," "fluctuating varieties" or "mutations." They are all simply variations in the Darwinian sense. Darwin did not explain the origin of variations, nor did he need to. I have little sympathy with those who exclaim that "Natural Selection originates nothing" because it does not tell the cause of variation. When we contemplate the bewildering complexity of the germplasm and the countless hereditary possibilities in each germ cell, the wonder is not that there is variation, but that it is kept within such reasonable limits. This law is the *qualitative* factor of organic evolution, furnishing differences from which selection may be made.

3rd. *The Law of Geometrical Ratio of Increase,* by which every species tends to over-populate the earth if its natural ratio is not checked. No one doubts that this is a fact. Indeed it seems to have furnished both Darwin and Wallace with the key with which they each solved the problem of the origin of species. This law is the *quantitative* factor, furnishing great numbers from which to select.

Having stated these laws and discussed them at length, Darwin set himself the task of ascertaining how they would act and interact in Nature, and found that the necessary result of such action and interaction would be a *selection* that would result in more and more perfect adaptations to environments and the elimination of the unfit, thus assuring the survival of the fittest or most perfectly adapted forms, and a general advance in complexity and specialization of species. He compared this selection to the artificial selection wrought by man in improving his domestic animals and called it "Natural Selection." It seems to me puerile to object to this comparison, for Darwin pointed out in the most painstaking way the essential differences between the two. They are comparable in a large and true sense.

That a selection of some sort could result from the combined working of these three laws can not be successfully denied, and it was Darwin who proved this to the world. And no name has been proposed for this selection that is more satisfactory to biologists as a whole than "Natural Selection."

The logic of this course of reasoning seems to me and to many of my zoological, botanical and geological colleagues, unanswerable.

I feel very sure that a large majority of those professionally engaged in the study of biological science would answer the question: "Is Darwin completely shorn of his selection doctrines?" by a decided negative. Some of his ideas have been trimmed to suit the prevailing mode of thought and more complete knowledge; but he is not "shorn."

In conclusion I must venture to express the hope that the honored friend of Nature, John Burroughs, will not allow an incursion into the field of tonsorial art to divert his attention from that exquisite art with which he has so often delighted an innumerable host of sincere admirers. There are controversial writers galore, and in every field of thought; but few indeed are they who do the work of observing and depicting the lives and habits of our familiar friends of orchard, field and forest with so keen an insight and so sure and felicitous a touch.

THE BOTANY OF THE NEW ENGLAND POETS

By DR. NEIL E. STEVENS
BUREAU OF PLANT INDUSTRY

MODERN New England poets are necessarily excluded from this discussion. What Amy Lowell writes may be poetry, but her references to plants are certainly not botany. Adequate and appropriate tribute[1] has moreover been paid to her masterly ignorance of things botanical as displayed in a *vers libre* effusion on sugar printed in *The Independent* (December 29, 1917) in which the familiar red table beet is forced to assume the chemical and horticultural rôle of the coarse, whitish, turnip-like root known commercially as the sugar beet. To quote in part:

Wide plains,
With little red balls hidden under them,
Beets like a hidden pavement underneath the plains.
A Roman floor forsooth!
Do mosaics have any color to equal these?
Red as the eyes of cats in firelight,
As carbuncles under a lemon moon,
As the sun swirling out of a foggy sky,
Round as apples,
Footed as tops,
You spin yourself deep into the earth
And swell and fatten,
Sugar in a crimson coat,

. . . .
And there still the blood-skinned beets,
Waiting to be crushed, pulped, and eaten,
Thunder sugar—blood sugar—

In contrast, attention will be confined to the New England poets in the most limited sense, that is to the poets of that little group, the most distinguished in American letters, usually known as the Cambridge School, namely, Longfellow, Whittier, Holmes, and Lowell. It is perhaps more than a coincidence that these men were the contemporaries and most of them the friends of that master mind of New England botany, Asa Gray.[2] Indeed it was of Gray that Lowell wrote:

Just Fate, prolong his life well-spent
  Whose indefatigable hours
Have been as gaily innocent
  And fragrant as his flowers.[3]

[1]Broadhurst, Jean. Botanical Errors of some well-known writers. Torreya, p. 118, 1918.

[2]Gray 1810-1888. Whittier 1807-1893. Lowell 1819-1891. Longfellow 1807-1882. Holmes 1809-1894.

[3]The occasion was Professor Gray's seventy-fifth birthday. A silver memorial vase inscribed with the legend,

Bryant's birth and early life in the Berkshires place him among the New England poets though not in the Cambridge school, and his repute as a nature poet might indicate that he would be entitled to special botanical consideration. In only a few of his poems, however, does one find evidence of accurate botanical knowledge. "The Death of the Flowers," "The Old Man's Council," "The Fountain," and "To the Fringed Gentian," though, show his interest in and love for flowers.

Emerson, although not primarily a poet, belongs of course to the Cambridge school, and there is evidence of considerable botanical knowledge in his poems. In "Nature" for example he names over forty species of plants. If, however, Emerson had been a botanist, and he would have made a very good one, he would not have been a systematist. In 1858 few botanists even took the trouble to record the size of the trees they mentioned, as he does in "The Adirondacs"

> Our patron pine was fifteen feet in girth,
> The maple eight, beneath its shapely tower.

Nor is there to be found in all the good natured abuse showered upon the systematists by physiologists, ecologists and plant breeders during the last ten years anything more caustic, than Emerson's comment in "Blight"

> But these young scholars, who invade our hills,
> . . . .
> Love not the flower they pluck, and know it not,
> And all their botany is Latin names.

In Longfellow's poems there are to be found, of course, fine lines which express realization of the beauty of field and forest, and there is evidence of some botanical knowledge. No careful reader of his poetry will, however, maintain that Longfellow appreciated plants or plant life as he did the ocean, or even inland bodies of water. Some explanation of this may perhaps be found in the surroundings of his youth. Born within sight of the sea and his boyhood spent in a seaport town, it is natural that the ocean should have left an impression on his mind unequaled by other natural objects. Indeed in "My Lost Youth" the first five stanzas deal chiefly with the sea and the harbor including:

> I remember the black wharves and the slips,
>   And the sea-tides tossing free;
> And the Spanish sailors with bearded lips,
>   And the beauty and mystery of the ships,
>   And the magic of the sea.

Whereas the only references to things botanical are to the trees that

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"1810 November eighteenth 1885
Asa Gray
in token of the universal esteem of American botanists"
was presented to Professor Gray accompanied by the lines quoted above and by greetings from 180 American botanists. See Jordan, David Starr, Leading American Men of Science. New York. 1910. Asa Gray, Botanist; by John M. Coulter, p. 211-231.

line the streets, and to Deering's Woods, a grove in the outskirts of Portland.

Whittier, most of whose early life was spent on a farm, knew the names of a good many plants, but even when he mentions them it is usually in their relation to human life or as symbolic of human activity. On receiving a sprig of heather in blossom, he writes a poem for "Burns" and in writing of "The Sycamores" his thoughts are very little with the trees but chiefly of the Irishman, Hugh Tallant, who planted them. The trailing arbutus moves him to two poems; but one "The Mayflowers," deals chiefly with the Pilgrims, and a shorter one "The Trailing Arbutus" ends thus

> As, pausing, o'er the lonely flower I bent,
> I thought of lives thus lowly, clogged and pent,
> Which yet find room,
> Through care and cumber, coldness and decay,
> To lend a sweetness to the ungenial day,
> And make the sad earth happier for their bloom.

It is the labor of the farm, rather than the wild life of the farm, that appeals to Whittier (see his "Songs of Labor"); and one is led to the belief that a very real interest in the man who works with his hands, as well as his creed as a Friend, inspired him in his long fight against slavery.

Even as a boy, however, Whittier apparently showed no special interest in plants. In fact, it would seem that such biological inclinations as he possessed were zoological rather than botanical. If one examines "The Barefoot Boy's" stock of nature lore

> Knowledge never learned of schools,
> Of the wild bee's morning chase,
> Of the wild-flower's time and place,
> Flight of fowl and habitude
> Of the tenants of the wood;
> How the tortoise bears his shell,
> How the woodchuck digs his cell,
> And the ground-mole sinks his well;
> How the robin feeds her young,
> How the oriole's nest is hung;
> Where the whitest lilies blow,
> Where the freshest berries grow,
> Where the groundnut trails its vine,
> Where the wood-grape's clusters shine;
> Of the black wasp's cunning way,
> Mason of his walls of clay,
> And the architectural plans
> Of gray hornet artisans!—

he will come to the conclusion that this particular boy was much more interested in animals than in plants. For against a very creditable list of items of information regarding quadrupeds, birds, and insects are balanced only one generalization about flowers, and three plants regarded as sources of food. Indeed, for a poet, and a life long member of the Society of Friends, Whittier betrays an almost surprising interest in gastronomic pleasures. He exclaims with many another New Englander (The Pumpkin)

> What moistens the lip and what brightens the eye?
> What calls back the past, like the rich Pumpkin pie?

Holmes' medical training gave him a knowledge of drug plants, which he uses to good advantage in a professional poem "Rip Van Winkle, M. D." Holmes seems to have had, moreover, a special interest in and affection for trees, references to them occur again and again in his poems. That this interest dates from his boyhood is evidenced by a poem "The Meeting of the Dryads" written after a general pruning of the trees around Harvard College, some time before he was sixteen. With real feeling the spirit of one of the mutilated trees speaks

> Go on, Fair Science; soon to thee
> Shall Nature yield her idle boast;
> Her vulgar fingers formed a tree,
> But thou hast trained it to a post.

and the poem concludes with the following inclusive curse upon the "tree surgeon" of Harvard

> A curse upon the wretch who dared
> To crop us with his felon saw!
> May every fruit his lip shall taste
> Lie like a bullet in his maw.
>
> . . . .
>
> May nightshade cluster round his path,
> And thistles shoot, and brambles cling;
> May blistering ivy scorch his veins,
> And dogwood burn, and nettles sting.
>
> On him may never shadow fall,
> When fever racks his throbbing brow,
> And his last shilling buy a rope
> To hang him on my highest bough!

Holmes most frequently uses botanical information in figures, and his botanical figures are usually apt. The rose, the lily and the peach have been so much used, and abused by poets in their attempts to do justice to feminine beauty that Holmes' courageous use (in The Autocrat at the Breakfast Table) of the more beautiful but less conspicuous cranberry blossom deserves special mention

> My lady's cheek can boast no more
> The cranberry white and pink it wore.

With a vigor equaled only by the preacher's "of making many books there is no end; and much study is a weariness of the flesh" he sums up the passion for publication, chiefly in botanical figures, in Cacoethes Scribendi

> If all the trees in all the woods were men;
> And each and every blade of grass a pen;
> If every leaf on every shrub and tree
> Turned to a sheet of foolscap; every sea

Were changed to ink, and all earth's living tribes
Had nothing else to do but act as scribes,
And for ten thousand ages, day and night,
The human race should write, and write, and write,
Till all the pens and paper were used up,
And the huge inkstand was an empty cup,
Still would the scribblers clustered round its brink
Call for more pens, more paper, and more ink.

The poet is honest, however, and owns that he is one of the scribblers, when in one of the "Poems of the Class of '29" he sums up the whole matter,

"Why won't he stop writing!" Humanity cries:
The answer is briefly, "He can't if he tries."

Perhaps his best figure, certainly his best known, is a botanical one, "The Last Leaf." It is a curious commentary on the failure of many people to observe the most common natural phenomena that in the latter editions of his poems, Holmes felt obliged to insert in the introduction to the poem bearing the above title an explanation of a relation which should have been obvious to every one who had seen oak trees in New England in early spring. His own fondness for so apt a figure is shown by its repeated use. In 1831 (The Last Leaf) he wrote

And if I should live to be
The last leaf upon the tree
In the spring,
Let them smile, as I do now,
At the old forsaken bough
Where I cling.

Thirty years later he uses the same figure (The Old Player 1861)

Yet there he stood,—the man of other days,
In the clear present's full, unsparing blaze,
As on the oak a faded leaf that clings
While a new April spreads its burnished wings.

And in 1889 in acknowledging the gift of a silver loving cup, he wrote (To The Eleven Ladies)

"For whom this gift?" For one who all too long
Clings to his bough among the groves of song;
Autumn's last leaf, that spreads its faded wing
To greet a second spring.

Lowell was deeply interested in the turbulent political events of his time and The Biglow Papers are the soul of his published work. However, his poems bear evidence of deep interest in and accurate knowledge of natural objects, particularly plants. He does not seem to overstate the case when in "To George William Curtis" he tells of his interest in out of door things and apologizes, almost, for his humanitarian interests:

Dear were my walks, too, gathering fragrant store
Of Mother Nature's simple-minded lore:
I learned all weather-signs of day or night;
No bird but I could name him by his flight,

No distant tree but by his shape was known,
  Or, near at hand, by leaf or bark alone.
This learning won by loving looks I hived
  As sweeter lore than all from books derived.
I know the charm of hillside, field and wood,
  Of lake and stream, and the sky's downy brood,
Of roads sequestered rimmed with sallow sod,
  But friends with hardhack, aster, golden-rod,[4]
Or succory keeping summer long its trust
  Of heaven-blue fleckless from the eddying dust:
These were my earliest friends, and latest too,
  Still unestranged, whatever fate may do.
For years I had these treasures, knew their worth
  Estate most real man can have on earth
I sank too deep in this soft-stuffed repose
  That hears but rumors of earth's wrongs and woes;
Too well these Capuas could my muscles waste,
  Not void of toils, but toils of choice and taste;
These still had kept me could I but have quelled
  The Puritan drop that in my veins rebelled.

But there were times when silent were my books
  As jailers are, and gave me sullen looks,
When verses palled, and even the woodland path,
  By innocent contrast, fed my heart with wrath,
And I must twist my little gift of words
  Into a scourge of rough and knotted cords
Unmusical, that whistle as they swing
  To leave on shameless backs their purple sting.

How slow Time comes! Gone, who so swift as he?
  Add but a year, 'tis half a century
Since the slave's stifled moaning broke my sleep,
  Heard 'gainst my will in that seclusion deep,
Haply heard louder for the silence there,
  And so my fancied safeguard made my snare.

Whatever Lowell's knowledge of botany he certainly understood and appreciated scientists and quite properly places Jonah among them. (The Biglow Papers)

> Men in general may be divided into the inquisitive and the communicative. To the first class belong Peeping Toms, eaves-droppers, navel-contemplating Brahmins, metaphysicians, travellers, Empedocleses, spies, the various societies for promoting Rhinothism, Columbuses, Yankees, discoverers, and men of science, who present themselves to the mind as so many marks of interrogation wandering up and down the world, or sitting in studies and laboratories. . . . . . .
>
> To one or another of these species every human being may safely be referred. I think it beyond a peradventure that Jonah prosecuted some inquiries into the digestive apparatus of whales, and that Noah sealed up a letter in an empty bottle, that news in regard to him might not be wanting in case of the worst. They had else been super or subter human.

[4]For the guidance of those unfamilar with the common names there are included in several places lists of the plants mentioned with their Latin names as given in Gray's Manual, Seventh Edition. Hardhack, *Spiraea tomentosa* L.; Golden-rod, *Solidago sp.;* Succory, *Cichorium Intybus* L.

Horticulture

It is difficult to determine just what should be considered as significant horticultural information. Longfellow, for example, in "Catawba Wine" shows that he knew the names at least of several varieties of wine grapes, but such knowledge could of course be acquired, at least before July 1, 1919, without personal study of the vineyard. On the other hand, in "The Birds of Killingworth" he shows that he understands better than many of his successors the close relation between birds, and insects, and the relation of insects to the destruction of crops. Though the great destruction of crops brought about by the increased abundance of insects comes rather suddenly after the death of the birds.

Here should certainly be included, however, an observation made by Lowell in a note introductory to one of the Biglow Papers

> The two faculties of speech and of speech-making are wholly diverse in their natures. By the first we make ourselves intelligible, by the last unintelligible, to our fellows. It has not seldom occurred to me (noting how in our national legislature everything runs to talk, as lettuces, if the season or the soil be unpropitious, shoot up lankly to seed, instead of forming handsome heads) that Babel was the first Congress, the earliest mill erected for the manufacture of gabble.

The horticultural significance of this quotation lies of course in the parenthetical observation that under conditions unfavorable for vegetative growth, lettuce like many other vegetables runs to seed.

In these days when grades and standards for packing fruit, and the accurate labeling of foods and drugs are an important part of the activity of a Department of Agriculture it may be interesting to note some of the things Holmes considered "essential to a Millennium" (Latter-Day Warnings)

> When legislators keep the law,
> When banks dispense with bolts and locks—
> When berries — whortle, rasp, and straw—
> Grow bigger *downwards* through the box,
>
> . . . .
>
> When preachers tell us all they think,
> And party leaders all they mean,
> When what we pay for, that we drink,
> From real grape and coffee-bean,
>
> . . . .
>
> *Till* then let Cumming blaze away,
> And Miller's saints blow up the globe;
> But when you see that blessed day,
> *Then* order your ascension robe!

We are indebted to Whittier's interest in all that pertained to advocates of the abolition of negro slavery, for a poetic record of seed and plant introduction carried on previous to 1700 by Francis Daniel Pastorius,[5] one of the earliest German immigrants to Pennsylvania. According to Whittier a correspondence and exchange of plants was carried on between Pastorius and his friends and teachers in Germany (The Pennsylvania Pilgrim):

And thus the Old and New World reached their hands
  Across the water, and the friendly lands
Talked with each other from their severed strands.

Pastorius answered all: while seed and root
  Sent from his new home grew to flower and fruit
Along the Rhine and at the Spessart's foot;

And, in return, the flowers his boyhood knew
  Smiled at his door, the same in form and hue,
And on his vines the Rhenish clusters grew.

Mycology and Phytopathology

In view of the scant consideration given fungi by New England botanists before Farlow, it may be worth mentioning that at least two of the New England poets knew that fungi existed. Holmes mentions fungi frequently. One of his early poems is entitled "The Toadstool" and Emerson refers in "Nature" to

Where the fungus broad and red
Lifts its head,
Like poisoned loaf of elfin bread.

Moreover, from two chance references I am convinced that Holmes knew, what some botanists had yet to learn, that a lichen is really a fungus. In Astraea he contrasts the "arctic fungus" and the desert palm; and in "A modest request" he refers to

—the rock where nature flings
Her arctic lichen, last of living things;

Mention of plant diseases are confined chiefly to generalized references to mold, mildew and blight, but in the Biglow Papers there is evidence that Lowell knew Peach Yellows and some of its symptoms.

Take them editors thet's crowin'
Like a cockerel three months old,—
Don't ketch any on 'em goin',
Tho they be so blasted bold;
Aint they a prime lot o' fellers?
'Fore they think on't guess they'l sprout
(Like a peach thet's got the yellers)
With the meanness bustin' out.

Ecology

In these days when ecology has a society, a special journal, and a special language it would be a presumptuous botanist indeed, who, not one of the elect, should attempt to decide what is ecology and what

[5]Jellett, Edwin C., Germantown Gardens and Gardeners, 1914. On pages 5—16 of this work is given an account of Francis Daniel Pastorius, the founder of Germantown, which indicates that Whittier's account is substantially correct.

is not, and it would be even more presumptuous to suppose that in poets of the last generation one would find today's ecology. But in the old fashioned sense of plant relations, the relations of plants to each other and to their environment we find, in Lowell at least, evidence of real comprehension. Any one who has carefully watched the almost unbelievably rapid development of vegetation during the spring of northern New England, and contrasted it with the abject manner in which spring approaches in southern California will appreciate the feeling and the keen observation evidenced in Lowell's description of spring in the Biglow Papers. Beginning on May Day

I, country-born an' bred, know where to find
Some blooms thet make the season suit the mind,
An' seem to metch the doubtin' bluebird's notes,—
Half-ventrin' liverworts[6] in furry coats,
Bloodroots, whose rolled-up leaves ef you oncurl,
Each on' em's cradle to a baby-pearl,—
But these are jes' Spring's pickets; sure ez sin,
The rebble frosts 'll try to drive 'em in;
For half our May's so awfully like May n't,
't would rile a Shaker or an evrige saint;
Though I own up I like our back'ard springs
Thet kind o' haggle with their greens an' things,
An' when you 'most give up, 'uthout more words
Toss the fields full o' blossoms, leaves an' birds:

. . . .

'fore long the trees begin to show belief,
The maple crimsons to a coral-reef,
Then saffern swarms swing off from all the willers
So plump they look like yaller caterpillars,
Then gray hossches' nuts leetle hands unfold
Softer'n a baby's be at three days old:

. . . .

Then seems to come a hitch,—things lag behind,
Till some fine mornin' Spring makes up her mind,
An' ez, when snow-swelled rivers cresh their dams
Heaped-up with ice thet dovetails in an' jams,
A leak comes spirtin' through some pin-hole cleft,
Grows stronger, fercer, tears out right an' left,
Then all the waters bow themselves an' come,
Suddin, in one gret slope o' shedderin' foam,
Jes' so our Spring gits everythin' in tune
An' gives one leap from Aperl into June:
Then all comes crowdin' in; afore you think,
Young oak-leaves mist the side-hill woods with pink;
The catbird in the laylock-bush is loud;
The orchards turn to heaps o' rosy cloud;
Red-cedars blossom tu, though few folks know it,
An' look all dipt in sunshine like a poet;

Not only is the succession of spring flowers correctly observed, and appropriate emphasis given to the rapidity of the development of the vegetation during the latter part of May, but the above quoted poem

[6]Liverwort, *Hepatica triloba* Chaix; Bloodroot, *Sanguinaria canadensis* L.; Maple, Acer, (probably *rubrum* L.); Willers (willow), *Salix sp.;* Hossches' nuts, (Horse-chestnut), *Aesculus Hippocastanum* L.; Oak, *Quercus sp.;* Laylock (lilac), *Syringa vulgaris* L.; Red-cedar, *Juniperus virginiana* L.

is the only record the writer has found of the fact that in New England at least the red-cedar blossoms at the same time as the cultivated apple.

Holmes expressed the idea of the rapid climatic change at this season with equal vigor in an early poem entitled "The Hot Season":

> The folks, that on the first of May
> Wore winter coats and hose,
> Began to say, the first of June,
> "Good Lord! how hot it grows!"

So far as vegetation is concerned, however, Holmes' idea of spring includes, as becomes a townsman, chiefly cultivated plants. In three poems (Poetry, Spring, and Spring Has Come) in which the season is described he mentions the snowdrop, the hyacinth, tulip, crocus, iris, narcissus, and peony; but among wild flowers only the violet.

Not less accurate, nor less vivid than his description of spring is Lowell's record of autumn foliage in An Indian Summer Reverie. During the four years just passed the writer has spent the fall months in eastern Massachusetts and has been unable to note any error either of time, color, or habit in the various species mentioned in the following quotation:

> What visionary tints the year puts on,
> When falling leaves falter through motionless air
> Or numbly cling and shiver to be gone!
>
> . . . .
>
> The sobered robin, hunger-silent now,
> Seeks cedar-berries[7] blue, his autumn cheer;
> The chipmunk, on the shingly shagbark's bough,
>
> . . . .
>
> O'er yon bare knoll the pointed cedar shadows
> Drowse on the crisp gray moss; the ploughman's call
> Creeps faint as smoke from black, fresh-furrowed meadows;
> The single crow a single caw lets fall;
> And all around me every bush and tree
> Say Autumn's here, and Winter soon will be,
> Who snows his soft, white sleep and silence over all.
>
> The birch, most shy and ladylike of trees,
> Her poverty, as best she may, retrieves,
> And hints at her foregone gentilities
> With some saved relics of her wealth of leaves;
> The swamp-oak, with his royal purple on,
> Glares red as blood across the sinking sun,
> As one who proudlier to a falling fortune cleaves.
>
> He looks a sachem, in red blanket wrapt,
> Who, 'mid some council of the sad-garbed whites,
> Erect and stern, in his own memories lapt,
> With distant eye broods over other sights,
> Sees the hushed wood the city's flare replace,
> The wounded turf heal o'er the railway's trace,
> And roams the savage Past of his undwindled rights.

[7]Cedar, *Juniperus virginiana* L.; Shag-bark *Carva ovata* (Mill.) K. Koch; Birch, Betula (probably here *populifolia Marsh.*); Swamp-oak, *Quercus palustris* Muench.; Red-oak, *Quercus rubra* L.; Chestnut, *Castanea dentata* (Marsh) Borkh.; Ash, *Fraxinus americana* L.; Maple (swamp), *Acer rubrum* L.; Scrub-oak, *Quercus ilicifolia Warg.;* Black-alder, *Ilex verticillata* (L.) Gray; Woodbine, *Psedera quinquefolia* (L.) Greene; Elm, *Ulmus americana* L.; Ivy (poison?), *Rhus Toxicodendron* L.

The red-oak, softer-grained, yields all for lost,
And, with his crumpled foliage stiff and dry,
After the first betrayal of the frost,
Rebuffs the kiss of the relenting sky;
The chestnuts, lavish of their long-hid gold,
To the faint Summer, beggared now and old,
Pour back the sunshine hoarded 'neath her favoring eye.

The ash her purple drops forgivingly
And sadly, breaking not the general hush;
The maple-swamps glow like a sunset sea,
Each leaf a ripple with its separate flush;
All round the wood's edge creeps the skirting blaze
Of bushes low, as when, on cloudy days,
Ere the rain falls, the cautious farmer burns his brush.

O'er yon low wall, which guards one unkempt zone,
Where vines, and weeds, and scrub-oaks intertwine
Safe from the plough, whose rough, discordant stone
Is massed to one soft gray by lichens fine,
The tangled blackberry, crossed and recrossed, weaves
A prickly network of ensanguined leaves;
Hard by, with coral beads, the prim black-alders shine,

Pillaring with flame this crumbling boundary,
Whose loose blocks topple 'neath the ploughboy's foot,
Who, with each sense shut fast except the eye,
Creeps close and scares the jay he hoped to shoot,
The woodbine up the elm's straight stem aspires,
Coiling it, harmless, with autumnal fires;
In the ivy's paler blaze the martyr oak stands mute.

The ecology of today includes, I believe, both animals and plants in the same study. Lowell's description of a New England pool is then both up to date and accurate. (Festina Lente):

Once on a time there was a pool
Fringed all about with flag-leaves[8] cool
And spotted with cow-lilies garnish,
Of frogs and pouts the ancient parish.
Alders the creaking redwings sink on,
Tussocks that house blithe Bob o' Lincoln
Hedged round the unassailed seclusion,
Where muskrats piled their cells Carthusian;
And many a moss-embroidered log,
The watering-place of summer frog,
Slept and decayed with patient skill,
As watering-places sometimes will.

No phenomenon more often interests the botanist in rural New York and New England than the persistence of certain plants about the sites of abandoned homesteads. Holmes records the plants he observed about one such in "The Exile's Secret."

Who sees unmoved, a ruin at his feet,
The lowliest home where human hearts have beat?
Its hearthstone, shaded with the bistre stain
A century's showery torrents wash in vain;
Its starving orchard, where the thistle blows
And mossy trunks still mark the broken rows;

[8]Flag (Sweet), *Acorus Calamus* L.; Cow-lilies, *Nymphaea advena,* Ait.; Alder, *Alnus rugosa* (Du Roc) Spreng.

Its chimney-loving poplar, oftenest seen
Next an old roof, or where a roof has been;
Its knot-grass,[9] plantain, —all the social weeds,
Man's mute companions, following where he leads;

. . . .

Its woodbine, creeping where it used to climb;
Its roses, breathing of the olden time;

Whether the original inhabitant of this "Island Ruin" was so unconventional as not to have had a lilac, or the lilac was unable to persist in so exposed a place cannot, of course, be determined. But it is hardly to be supposed that Holmes could have missed what is usually the most conspicuous of the relics. Whittier reports it in a similar situation (The Homestead)

A lilac spray, once blossom clad,
Sways bare before the empty rooms;
Beside the roofless porch a sad
Pathetic red rose blooms.

Wood Technology

Holmes is probably supreme in this field although the landlord in Longfellow's "Tales of A Wayside Inn" knows the fuel value of Oak, Maple and Apple, and in "Hiawatha" the canoe is built from appropriate and serviceable materials. In "Poetry" Holmes shows that he knows some of the penalties for using green wood for construction purposes, and it is no poetic license, but accurate observation of natural phenomena that records the sprouting from the unhewn timbers on the shady, and moister, side.

Scarce steal the winds, that sweep his woodland tracts,
The larch's[10] perfume from the settler's axe,
Ere, like a vision of the morning air,
His slight framed steeple marks the house of prayer;
Its planks all reeking and its paint undried,
Its rafters sprouting on the shady side,

Likewise the Deacon in building his now famous "One-hoss shay" uses, according to Holmes' record, the best of materials and judgment. He

inquired of the village folk[11]
Where he could find the strongest oak,
That couldn't be split nor bent nor broke,—
That was for spokes and floor and sills;
He sent for lancewood to make the thills;

The crossbars were ash, from the straightest trees,
The panels of white-wood, that cuts like cheese,
But lasts like iron for things like these;
The hubs of logs from the "Settler's ellum,"—
Last of its timber,—they couldn't sell 'em,
Never an axe had seen their chips,
And the wedges flew from between their lips,
Their blunt ends frizzled like celery-tips;

[9]Knot-grass (Knotweed), *Polygonum sp.;* Plantain, *Plantago major,* L.

[10]Larch, *Larix laricina* (Du Roi) Koch.

[11]The only mention of the botanical significance of this poem which the

Careful review of the woods used, in the light of the information now available, leads one to believe that when combined with "Steel of the finest, bright and blue" they would go far to make good the Deacon's vow that

He would build one shay to beat the taown
'N' the keounty 'n' all the kentry raoun';
It should be so built that it could n' break daown;
"Fur," said the Deacon, " 't's mighty plain
That the weakes' place mus' stand the strain;
'N' the way t' fix it, uz I maintain,
Is only jest
T' make that place uz strong uz the rest."

Though only by the most extreme care in construction, and a timber inspection even more rigid than that used in the construction of airplanes could one guarantee a result like that reported by Holmes, for

Little of all we value here
Wakes on the morn of its hundredth year
Without both feeling and looking queer,
In fact there is nothing that keeps its youth,
So far as I know, but a tree and truth.

It is, then not surprising that at this age,

There are traces of age in the one-hoss shay,
A general flavor of mild decay,
But nothing local, as one may say.

or that the dramatic conclusion of the experiment occurs on this day.

All at once the horse stood still,
Close by the meet'n'-house on the hill,
First a shiver, and then a thrill,
Then something decidedly like a spill,—
And the parson was sitting upon a rock,
At half past nine by the meet'n'-house clock,—
Just the hour of the Earthquake shock!
What do you think the parson found,
When he got up and stared around?
The poor old chaise in a heap or mound,
As if it had been to the mill and ground!
You see, of course, if you're not a dunce,
How it went to pieces all at once,—
All at once, and nothing first,—
Just as bubbles do when they burst.

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writer has ever seen in print is the "Young People's Arbor" conducted by James Lawler, Canadian Forestry Journal 11:201-202 (1915).

Oak undoubtedly for this use, *Quercus alba* L.

Lancewood, The West Indian *Oxandra virgata*, ("He sent for lancewood.")

Ash, *Fraxinus americana* L.; White-wood, *Liriodendron Tulipifera* L.; Elm, *Ulmus americana* L.

ANTHONY VAN LEEUWENHOEK THE FIRST BACTERIOLOGIST

By DAVID FRASER HARRIS, M. D., B. Sc. (Lond.), D. Sc., F. R. S. E., F. R. Sc.,

PROFESSOR OF PHYSIOLOGY AND HISTOLOGY, DALHOUSIE UNIVERSITY, HALIFAX, N. S.

THERE were two great workers with the microscope in the latter half of the seventeenth century—the Italian, Malpighi, and the Dutchman, Leeuwenhoek. Of these the former was in his own time and still is in our day by far the better known man.

Malpighi was the father of all such as work with the microscope; the creator of histology everywhere, not merely of Italian, the father of both the histologies, vegetable and animal. Much of his life was spent in Bologna, the old-world, arcaded, sun-bathed city, the seat of a university founded more than 800 years ago.

But very different was the place to which my wife and I made a pilgrimage in the Christmas holidays of 1907, the unfrequented little town of Delft in Holland, if known in more than name to the great mass of my countrymen, known as the seat of the manufacture of a certain kind of pottery called "Delf."

Though the place is by no means devoid of interest, all its other interests are for biologists thrown into the shade by the recollection that this was the scene of Leeuwenhoek's life-long labors with the microscope, the place where the first bacteriologist was born, lived, worked, died and was buried. The town is on the line of the canal between Rotterdam and the Hague. Modern it certainly is not, for it was founded at the end of the eleventh century by Duke Geoffrey of Lorraine. In the palace or Prisenhof, William of Orange was assassinated in 1584; in the old church or Oude Kerk as old as the town itself, two of Holland's naval heroes, Van Tromp and Piet Hein, lie buried.

Its New Church, founded in 1381, is the last resting place of a most important person in the history of European theology, Hugo Grotius (Groot). Here, too, is the family tomb of the Princes of Orange. In 1654 there occurred a disastrous gunpowder explosion in which upwards of 1,200 inhabitants perished.

Delft is best known for its pottery, but this industry is almost extinct, the present manufactures being carpet-weaving, distilling and dyeing; there is a polytechnic school, a school of military engineering, a school for the education of colonial civil servants, a school of design, a theater, and a lunatic asylum. The town which is built in the form of a square is rather gloomy, and its narrow streets, flanked by high houses, have stagnant little canals in the middle of them.

Such was the place at which we alighted from the Rotterdam train in the grey light of a January afternoon. Our fellow passengers stared as we left the carriage; they could understand our going on to the Hague, but what was there to detain an Englishman at Delft at that time of year?

Only interest in the history of biology could make one search out the ponderous Oude Kerk to view the tomb of a man whose very name is an unknown sound to all save a few. We knew, however, that in that ungainly old church towering over the crowded houses lay buried an indefatigable worker in Nature's invisible world, one whose greatest honor in life was, as it is the boast in the inscription on his tomb, to have been enrolled a Fellow of the Royal Society of London, or "of England," as it puts it.

The F. R. S. told Leeuwenhoek in his lifetime that he had not lived in vain. We know from the good work he did that, whether he had been made an F. R. S. or not, he belonged to the innermost circle of the scientific immortals. This F. R. S. was, perhaps, the one great event in a life devoid of incident, at any rate empty of anything like the incidents that filled Malpighi's.

Malpighi, for whom a chair was created by a Grand Duke and he a Prince of the Medici, who was invited to teach in the University of Messina, and then entreated to leave it for the chief professorship of medicine at Italy's premier University of Bologna, who was constrained to end his days in the elegant sinecure of physician to the visible head of Christendom, and who was an F. R. S. to boot—even his life has been described as devoid of incident! What, then, must be said of Leeuwenhoek's? Leeuwenhoek probably never left Holland, it is doubtful if he ever quitted Delft. That Leeuwenhoek was a person of reliable character may be incidentally gathered from his having been made curator or trustee for the widow of Jan van der Meer the painter who was born at Delft in 1632 and died in 1675.

Malpighi was a hereditary landowner, Leeuwenhoek began life as assistant or clerk to a linendraper. He worked all his days in the little town where he was born, and seemed content to know that not only his countrymen, but those generous men of science in the greatest city of the world had recognized his worth. Science had equal need of the landowner and the linendraper. According to some accounts Leeuwenhoek was a man of independent means which he had inherited from relatives who were brewers, but he seems for the greater part of his life to have held the post of beadle (bedellus) to some public body in Delft. The document describing his duties which were light and his emoluments which were lighter is still extant.

We were not long in finding the Oude Kerk, nor the venerable guide inside it. He was dressed entirely in black, and wore a black skull cap. He immediately directed us to the tomb of van Tromp; of course, that was what the Englishman had come to see at such a time of year. Casting a passing glance at the elaborate marble sculptures on the gilded monument of the hero, I pushed on saying, "Any light is good enough to see van Tromp's tomb by, let me see Leeuwenhoek's before the dark." To the latter, accordingly, the reverend guide led us, correcting as we went along my pronunciation of the name. At last, then, we stood before the only monument besides his discoveries that keeps the name of the great Dutchman alive on earth; and it was erected, we found, by "his sorrowing daughter," not by any admiring strangers whatsoever. As a monument it is plain and even severe; while its setting in that huge, cold, white-washed, northern church is very cheerless. Not that it was exactly neglected; some hand had placed a wreath upon it not many weeks before. The long inscription is carved on a high, narrow slab of very dark stone--marble or granite —over which is placed a portrait medallion of Leeuwenhoek that thus stands out effectively; it represents the left profile under a full wig. Below the slab is an ornamental pediment of dark stone with another inscription, and above this a marble skull is placed which appears curiously out of place, but is evidently the result of the gruesome conventional taste in mortuary lapidary art prevailing at that time. Perched on the high slab is a marble urn surmounted by a gilded torch; on the white wall behind this a single arch or vaulting springs from two very unpleasing pilasters. From the summit of the arch a female face in white marble looks down on the tomb which is surrounded by a peculiarly ugly black iron railing. The inscription is cut in clear lettering. The sense of the Latin is: "Erected to the pious and everlasting memory of Anthony van Leeuwenhoek, member of the Royal Society of England, who, by the help of microscopes which he had himself made, scrutinized the most hidden things in Nature, and thus by assiduous study learned the secrets of the physical world. These wonders he described in his native language for the instruction and admiration of the whole world. Born at Delft, October 24, 1632, died there August 26, 1723." Another inscription states that "this monument is erected to her very dear father by his sorrowing daughter, Maria a Leeuwenhoek." Her own tomb is marked by a deeply incised stone in the pavement to the left of her father's monument. These deeply cut stones in high relief are a feature of the floors of Dutch churches; they make walking over them difficult and even hazardous to the unobservant.

In the printed account of the monuments in the church we were informed that van Leeuwenhoek's friend the Dutch poet, H. C. Poot, who, in some respects, is to be compared with the famous Scottish bard, Robert Burns, honored his memory with the following epitaph which is carved in the freestone block at the entrance to the grave: "Here lies Anthony van Leeuwenhoek, oldest member of the Royal Society of London; born in the town of Delft on 24th October, 1632, and died on the 26th of August, 1723, at the age of 90 years, 10 months, and 2 days. If, O wanderer, respect for great age and wonderful gifts is universal, then guide thy steps with reverence here, for here hoary science in Leeuwenhoek lies buried."

Once more one could not help comparing the tombs of the two great contemporary microscopists of the seventeenth century. How different their last resting places; here an air of chillness, cheerlessness and massiveness pervades the place, so different from the warmth, the color, the brightness and the tinsel of the southern church of St. Gregory.

Of course we returned to pay our respects to the great van Tromp, for we would not on any account have hurt the feelings of our grave and courteous cicerone who sold us a printed account of the tombs in his church and a faded, amateur photograph of Leeuwenhoek's monument. There being nothing else to detain us, we stepped out into the dark of the winter evening.

Here, then, within a few hundred yards of one another lie three of Holland's great men—van Tromp, Hugo Grotius and van Leeuwenhoek; a hero of Holland's naval wars, a hero in Holland's religious struggles, and a hero in the peaceful, silent conquests of science in the world of the "infinitely little." But whose work remains? What have we of van Tromp's today? We have his memory in naval history, and how it was his guns that made London quake and that turned old Albermarle down to the mouth of the Thames to reply to them; we have this gorgeous mausoleum in Delft, and we have the popular song beginning—

> Van Tromp was an admiral brave and bold,
> And he walked beside the sea.

but it would be difficult to name much else.

And what remains of Grotius, in his lifetime the world-read Arminian theologian? Under the dust of our libraries rest his treatises on Divinity, International Law, Political Liberty and Dutch History. And of Leeuwenhoek?—the whole science of bacteriology, Leeuwenhoek was the first human being to see a protozoan, a bacterium and a micrococcus, and those he first described were scraped from his own teeth. It was to the Royal Society of London that these discoveries fraught with such consequences to the science of medicine were announced. The Royal Society has been at the birth of a good deal that has moulded humanity.

The passage first announcing the discovery of bacteria is in a paper, entitled "Animals in the scurf of teeth," dated September 17, 1683, published in Vol. XIV of the Phil. Trans. (1684), in which we read: "Besides these animals there were a great quantity of streaks or threads of different lengths, but like thickness lying confusedly together, some bent and some straight. These had no motion or life in them" (evidently Leptothrix buccalis). He had just described some motile protistae which he had killed by rinsing his mouth out with vinegar.

Of course Leeuwenhoek was not what we now mean by a bacteriologist; bacteriology began with Pasteur; but scientific microscopy owes a great part of its existence to the Dutchman who ground his own lenses and left a cabinet of twenty-six of them to the Royal Society which has lost them.

Baker in his treatise on the microscope says that Leeuwenhoek's lenses were not spheres or globules, but double convex lenses, with magnifying powers ranging from 40-160 diameters.

According to Professor Stirling, the microscopes used were still of the type of "simple" microscope, high as the magnifying powers were which were reached with them. "Each consisted of a small biconvex lens placed in a socket between two plates of brass which were riveted together and pierced with a small hole opposite the lens. The object to be examined was fixed at a convenient distance and its focal distance adjusted by screws." As no eye-piece was used, the microscope was technically a "simple" microscope.

"His capital discovery was undoubtedly that of the capillary circulation of the blood first announced in 1690," says the late W. B. Carpenter in the Encyclopaedia Britannica. Now, if this means that Leeuwenhoek's discovery of the blood moving in capillaries was the chief thing he saw under the microscope, it is possibly true from a physiological, although not from a morphological, point of view. Leeuwenhoek was not, however, the first to see the flowing blood in capillaries, for in 1660 Malpighi in Bologna had seen the blood flowing in those of the frog's lung. Leeuwenhoek thus discovered the capillary circulation for himself though not for the scientific world which had been informed of it through a letter from Malpighi at Bologna to Alphonso Borelli at Pisa. However the exact date of Leeuwenhoek's seeing it for the first time is 1688, not 1690, or twenty-eight years after Malpighi's discovery.

There is before me an English translation of Leeuwenhoek's classic: "The true circulation of the blood, and also that the arteries and veins are continued blood-vessels clearly set forth, described in a letter written to the Royal Society of London by Antoni van Leeuwenhoek, member of this same Society." The letter is dated September 7, 1688; and as he says that the observations that led to it began with his finding frogs' eggs in May of that year, there is no doubt that it was between May and September, 1688, that he saw living capillaries in the tail of the tadpole, the tail of the fish (stickleback), and in the web of the frog's foot. He verified and extended Malpighi's discovery without apparently knowing anything about Malpighi's work; he does not mention him in this paper; possibly he had not seen any of his writings or even heard of him. Delft was as regards science in a backwater, and for long after 1688 scientific news did not travel very fast.

True, Delft is not far from the university town of Leyden, but it is doubtful if there was one microscope in the whole university at that time. There must have been one in the town, for a student, Ludwig Hamm, discovered spermatozoa in 1674 by the aid of one, a discovery which Leeuwenhoek also made independently of Hamm. But by 1688 the time had not come for the introduction of physical methods into the study of medicine in the class rooms of Leyden, that was left for Boerhaave, whose discourse on "The Use of the Mechanical Method in Medicine" was given at Leyden in 1703 as the inaugural address of the third year of his professorship.

Leeuwenhoek does, however, allude to his countryman, Swammerdam, whom he quotes on the morphology of tadpoles. In this passage we find that Swammerdam mentions the "incomparable Dr. Harvey's anatomical descriptions."

The late Sir Michael Foster, in his truly admirable lectures on "The History of Physiology in the 16th, 17th and 18th centuries," gives the date of Leeuwenhoek's seeing capillaries as "1668" (p. 98); the second "6" may be a misprint for an "8."

Although Delft was not a university town, and Leeuwenhoek not a university man and not in that way brought officially into contact with men of science, yet he happened to have as scientific confrère a young physician of considerable anatomical attainments, Regner de Graaf. This was no other than the discoverer of the ovarian follicles since known as "Graafian," and the author of a treatise on the pancreatic juice. In 1673, the year in which de Graaf died, he introduced Leeuwenhoek to the notice of the Royal Society to the fellowship of which he was elected in 1680. Leeuwenhoek contributed papers to its Transactions which may be seen in Numbers 94 to 380, but his first letter to the Secretary Oldenburg was as early as 1674. He also sent twenty-seven scientific letters to the French Academy.

As regards the red blood corpuscles or erythrocytes, Leeuwenhoek, although not the first to see them, was certainly the first, recognizing what he saw, to describe them correctly as circular in man and oval in the vertebrata below man. As early as 1674 he gave an account of these bodies in the Philosophical Transactions. But Jan Swammerdam (1637-1680) in 1658 had seen erythrocytes in frog's blood and correctly attributed the redness of the blood to these and not to the plasma; this observation was not published until 1738 by Boerhaave in the "Biblia Naturae," a posthumous edition of the works of Swammerdam. Malpighi in 1665 published an account of adipose tissue as he thought he saw it in the omentum. He described what he took to be fat-cells in the capillaries of the membrane, they were really erythrocytes. Thus as Swammerdam's observations were not published, and Malpighi's, although published, erroneous even if accessible to Leeuwenhoek, we may in a certain sense give Leeuwenhoek the credit of the priority of discovery in this matter.

It was, of course, by the presence of these cells in the blood that Leeuwenhoek could see that it moved. It is interesting to note that he is entirely Harveian in his conception of the circulation. He writes: "I could distinctly perceive the whole circuit of the blood in its passage to the extremities of the vessels and in its return to the heart." Quite recently there has been published a reprint of Leeuwenhoek's classical paper; it is one of several such in a work entitled "Opuscula selecta Neerlandicorum de arte medica." It has an English translation on the opposite side of each page and it is illustrated by facsimiles of the original illustrations of the blood-vessels in the tadpole and stickleback. Along with it goes what seems an excellent portrait of Leeuwenhoek representing him in a full wig seated at a table, lens in hand.

As to the circulation of the blood, of course there were unbelievers; each new thing has been doubted. Perhaps one of the most curious paragraphs of Leeuwenhoek's paper on the circulation is the last in which he enumerates for the benefit of the Royal Society three respectable men who had witnessed the capillary circulation. He says that people had remarked: "Must we believe it because Leeuwenhoek tells us?" and so he produces eye-witnesses. "But now that I hear that more credit will be given to my words when I mention the names of those who have partly seen the aforesaid circulation of the blood about which I write to your honorable Society, and which I have discovered, I have no objection to mentioning instead of many, such as I trust will deserve most belief, as, for example, Mr. Cornelius Gravesande, M. D., and ordinary professor of anatomy and surgery, and also councillor and late sheriff of this town; Mr. Cornelius Valensis, also councillor and late sheriff; Mr. Antoni Heinsius, LL. D., councillor and 'pensionaris' of this town, late Envoy Extraordinary to His Majesty the King of France, and not long ago Ambassador of this State to the Court of His Royal Majesty of England. To these gentlemen, to whom I usually communicate many of my discoveries, I have also shown the true circulation of the blood as distinctly as we see the current of the water in a running river with our naked eyes." From this we see that Leeuwenhoek entirely believed himself to be the discoverer of the capillary circulation. Perhaps the best known man who ever looked through a lens of Leeuwenhoek was the Czar, Peter the Great. He passed through Delft in 1698 and asked the man of science to visit him and bring his microscope with him. It is said that the Czar was much impressed by the spectacle of the circulation in the tail of a small eel. The East India Company from time to time supplied Leeuwenhoek with specimens.

In human histology Leeuwenhoek described the dentinal tubules, the fibers of the crystalline lens, the medulla of the hair-shaft, the epidermis, the spermatozoa, and a very great deal else; he also first discovered the striation in skeletal muscle. Leeuwenhoek was undoubtedly the first to give anything like a systematic account of the finer structure of certain insects, he described the scales on the wings, the tracheae, and the claws and appendages of spiders. He noted that the eyes of insects as well as of crustacea are facetted or compound. Besides giving a full account of the anatomy of the flea (Pulex irritans) he studied its development showing that it did not arise from sand, dust or dirt as was variously held in his day, but that it arose from an egg like every other creature he knew and passed through a metamorphosis. He remarks that "This despised creature is endowed with as great perfection in its kind as any large animal."

He observed that the pupa of the flea was attacked and fed upon by a minute parasite. Jonathan Swift having got hold of this fact made use of it in the following clever but now hackneyed lines:

> The vermin only tease and pinch
> Their foes superior by an inch.
> So Naturalists observe, a flea
> Has smaller fleas that on him prey,
> And these have smaller still to bite 'em
> And so proceed ad infinitum:
> Thus every poet in his kind
> Is bit by him that comes behind.

It was Leeuwenhoek who first gave a satisfactory account of the Aphides and the stages of their development. He showed that what had been called "ants' eggs" were the pupae of the Aphides, that the real eggs of Aphides were far smaller and underwent development into larvae. W. B. Carpenter said that Leeuwenhoek was the first to see a Foraminifer, when in the stomach of a shrimp he found what is now called Nonionina. He gave excellent figures of Balanus. He dis-

"Poetry, a Rhapsody," 1733, Vol. XIV., p. 311, Works of Swift, Scott's Edition.

covered Rotifers and gave an account of their surviving desiccation, a condition now known as latent life.

Leeuwenhoek by no means neglected vegetable histology, for he investigated the structure of oak, elm, beech, willow, and fir, noting the "pitting" in conifers and giving an account of medullary rays. He has left accurate descriptions of the embryo in germination and its relation to the cotyledons. He also dealt with the general anatomy of fruits and seeds; he was the first to discover pitted vasa in secondary wood, and the first also to see crystals in plant tissues in the rhizome of the Iris.

The Franklands, in their Life of Pasteur, state that Leeuwenhoek in 1675 discovered yeast-cells in the deposit under a fermenting liquid. He wrote on the forms of crystals, of sugar in particular, on the microscopic appearance of the edge of razors, and he left directions as to how to hone them for shaving.

One feature in Leeuwenhoek's work which does not seem to be as widely known as it ought to be is his battle against the all-prevailing superstitions of his time regarding "spontaneous generation" or Abiogenesis.

It is difficult for us at the present day to realize the depth of darkness and confusion amid which men's minds worked in the seventeenth century with regard to the subject of generation. The Cochineal insect was supposed to be "the fruit of some tree," the putrefaction of the carcase was supposed to engender maggots, the putrefaction of meat to give rise to flies, insects found within galls were supposed to have arisen from the tissues of the tree, even the otherwise enlightened Redi thought this, the flea was believed to be bred of "corruption" in dust or sand, etc., marine molluscs were imagined to be produced from marine mud, and eels were supposed not only by the vulgar but also by learned men to be produced from dew or in a manner wholly inexplicable.

Leeuwenhoek was in no doubt whatever as to these things being prodigious absurdities bred of a priori zoology and Aristotle. "For my part," he says, "I hold it equally impossible for a small shell-fish to be produced without generation as for a whale to have its origin in the mud." He had risen in a manner that a great many people at the present day have not risen, to a grasp of the principle that size has nothing at all to do with the essence of phenomena; that the antecedent of a living thing is a living thing and not non-living matter or dead matter however putrid it may be.

He demonstrated to his daughter and to his engraver the embryo of Unio, the fresh-water mussel. They "watched it for three whole hours." He was particularly delighted with his discovery of the embryo eels in the body of the female, for he had been challenged specifically to show how eels were bred.

The superstitions about spontaneous generation died very hard. Well on into the eighteenth century we have Father Needham (1748), introducing sterilization, and later Spallanzani (1776) bringing fresh proofs against Abiogenesis. Cagnard dela Tour (1837), Schwann (1839) and Helmholtz worked successfully at the same problems. But the coffin of this dead heresy was rapidly approaching completion; Leeuwenhoek had found the wood, the others had put it together, while it was reserved for Pasteur and Tyndall in our own day to hammer in the last two nails with triumphant blows.

In the case of "weevils" of granaries, he showed that they were not produced by wheat, but were grubs from insects' eggs. He suggested that the granaries should from time to time be fumigated with sulphur to destroy the insects before they laid their eggs. This is quite in the modern spirit, he wished to use some sort of chemical to destroy life. In other words, he is not the mere histologist magnifying "the difficulty, looking it full in the face and passing on," but he is a physiologist as well trying to solve it.

He knew that the atmospheric air was necessary to maintain life, even the life of parasites on trees. He writes in 1700 of a free circulation of air as being necessary for insects which he had imprisoned in a glass tube for observation. In fact, he understood ventilation as few in his day did, except Stephen Hales, and had people understood it earlier there would have been less of gaol-fever and typhus fever everywhere, and poisoning of people to death on board ship. Leeuwenhoek was also something of a physiologist for he speculated on the use of the lacteals, of the "slime of the guts," and made an experiment to determine the amount of aqueous vapor daily excreted from the skin. He weighed a glass vessel dry, and, inserting his hand into it and closing up the orifice by a handkerchief packed round the wrist, he found moisture condensed on the inside of it. On weighing the vessel at once before the moisture evaporated, he obtained a distinct increase of weight, and by knowing the area of skin that had produced this, he arrived at the amount of sweat excreted per unit of surface-area. He then estimated the total area of the skin and found that the whole body per 24 hours must eliminate about 28 fluid ounces, which is not very far from the truth.

Leeuwenhoek was evidently possessed of sound commonsense. He could not bring himself to believe that the blood underwent any kind of a "fermentation" analogous to that of beer or wine as was at the time almost universally taught in the medical schools. He said very sensibly that he had never been able to see any bubbles of gas in the blood-vessels such as ought to have been there had the blood been the seat of fermentation as he understood it. However necessary this fermentation of blood was to the theoretical physiology of his day, that Leeuwenhoek could find no evidence of it was a serious objection seeing that he was one of the very few who was in the habit of looking at the living blood. Thus, although not a physician, and not even a professional man of science, he was considerably ahead of the physiology of his day in respect of some of its most important principles.

Leeuwenhoek is not forgotten in his own country, for the Royal Society of Amsterdam gives a medal once in ten years in recognition of the most important work done on microscopic organisms during the previous decade. In 1915 this medal was awarded to Major-General Sir David Bruce, Director of the Royal Society's commission for the investigation of the sleeping sickness.

As a lover of pure science, as a most industrious worker with the microscope, and as a prescient physiologist Leeuwenhoek is interesting to all those who study living nature, but by histologists and bacteriologists in particular his name will ever be regarded with that reverence which a bright example in science must always inspire. The man who first saw and described a micro-organism cannot fail to be interesting to us today seeing of what importance the microscope and its dependent science of bacteriology have become in modern life with their relations to applied medicine, pathology, surgery, public health, the arts, and commerce. The seed of this gigantic tree with its roots in all lands and its flowers culled under every clime was sown by the hand of a solitary worker without reward in a quiet little town on one of the canals of the great plain of Holland.

STONE AGE MAN'S CURE FOR HEADACHE

By Professor ROY L. MOODIE
UNIVERSITY OF ILLINOIS

HEADACHES are bothersome things. People have been annoyed by them for a long time, seven thousand years at least, and probably longer. We are all quite willing, when afflicted with a headache, to agree with the people of the old stone age that a headache is a demon and we would be willing to do most anything to get rid of it. The pain whether due to a blow on the head, indigestion, nervousness or other cause certainly reminds one of a demon and it is readily understood how ancient man should have conceived the idea of releasing this demon which was bothering him. He devised a remedy which certainly was an effective cure for headache whether the pain was due to eye-strain, brain tumor, skull fracture or nervousness, although it must be admitted that his cure was worse than the pain.

Primitive man devised his curative measures as a phase of his religious beliefs, hence the cure adopted for headaches was a religious rite. The operation was performed by a shaman or medicine man in some remote fastness of his region and here the patient remained until completely recovered. This treatment consisted in opening the skull in a variety of ways to relieve the pain, or, as the stone age men thought, to let out the demon. Men in the stone age phase of their culture whether in Peru, Mexico, France, Kabylia or the South Sea Islands practiced this method of relief and it is said to be still employed in the highlands of Peru and Bolivia and in northern Africa.

This ancient surgical art, which forms the very beginnings of prehistoric surgery, seems to have been developed first in the region just north of Paris near the Seine and Oise rivers some seven or eight thousand years ago. In the dolmens, or burial mounds, scientists have found the ancient skulls of people who had suffered headache and who had had their skulls trepanned or opened to release the headache demon. No special class of individuals seems to have been favored since the operation was performed on man, woman and child, apparently without respect to either age or sex. Its frequency is attested by the great number of skulls exhibiting the surgical openings. In one burial mound in France yielding the bones of 120 individuals more than 40 showed the effects of trepannation.

SKULL OF ANCIENT INDIAN WHO SUFFERED HEADACHE. THE RESULT OF THE "CURE" BY THE WITCH-DOCTOR IS SEEN IN THE FOREHEAD, WHERE THE BONE HAD BEEN SCRAPED AWAY BY A SHARP FLAKE OF STONE. SUCH SKULLS ARE COMMONLY FOUND IN PERU.

It isn't very pleasant to picture the torture undergone by the ancient sufferer at the hands of the priest who either cut, scraped or bored the bone of the skull away with a sharp piece of stone. Some relief from pain may have been had by the application of a quid of coca, a plant yielding anesthetic substances which grows in Peru. But the worst thing about headaches is that they recur, so the ancient people not deterred by one failure submitted themselves to the operation again and again. A few ancient skulls reveal five cruel openings, which had all healed. The patient had survived them all.

The equipment of the primitive surgeon was meager. His knowledge of cleanliness was not keen. If he possessed a rough flint knife, a scraper, a few leaves of the coca plant and a piece of coarse cloth to bind the wound he was content. A mossy bank out in the woods served him for an operating table.

CAN THE ALASKA SALMON FISHERIES BE SAVED?

By BARTON WARREN EVERMANN
DIRECTOR, MUSEUM CALIFORNIA ACADEMY OF SCIENCES

THERE are, in Alaskan waters, five species of salmon, all belonging to the genus *Oncorhynchus*. They are (1) the King, Chinook, Quinnat, or Spring Salmon (*Oncorhynchus tschawytscha*); (2) the Sockeye, Red, or Blueback Salmon (*O. nerka*); (3) the Coho, Silver, or White Salmon (*O. kisutch*); (4) the Humpback, or Pink Salmon (*O. gorbuscha*); and (5) the Dog, or Keta Salmon (*O. keta*). The Steelhead Trout (*Salmo gairdneri*) also occurs in Alaska where it is usually classed as a salmon by the commercial fishermen.

Each of these six species is more or less abundant in Alaska and all are the objects of important commercial fisheries.

Habits of the Pacific Salmon

The habits of all the different species of Pacific salmon are essentially the same. They are all anadromous; that is, they live most of their life in the sea and enter fresh water only to deposit their eggs. After having spawned once they all die, both males and females alike; none lives to return to salt water. The eggs are deposited in the gravel or on other suitable bottom, usually in the fall of the year, and usually well toward the headwaters of freshwater streams. They hatch in the winter and following spring, but not until some time after the fish that produced them have died. There is a period of a few weeks each year during which each particular salmon family is represented only by a number of eggs. Both parents are dead and none of the children has yet been born; there are only eggs to tide the family over. It is, therefore, evident that no Pacific Coast salmon ever saw either of its parents or any of its children.

After the eggs have hatched the young migrate to the sea, some going down as fry while others remain in freshwater at least one year. In the sea they live and grow rapidly and, when mature, return to freshwater where they spawn and die, thus completing the life-cycle.

The Sockeye or Red Salmon

In the present paper, consideration is given to the Sockeye Salmon only. In order that the recommendations that will be presented may have a proper background of fact, and that they may the more readily be understood and appreciated, it will be well to give in somewhat greater detail some of the more important facts in the life-history of

CASCADES IN LITNIK STREAM, AFOGNAK ISLAND, SHOWING SALMON STRUGGLING IN THE FALLS AND IN THE POOL BELOW. NEAR HERE THE BUREAU OF FISHERIES HAS OPERATED A RED SALMON HATCHERY FOR MANY YEARS WITH UNCERTAIN RESULTS this very important fish, particularly those wherein it differs from the other species.

The Sockeye enters Only Those Streams that have Lakes in their headwaters

Unlike the other species of salmon, the Sockeye enters only those streams which have one or more lakes somewhere in their course. It ascends such streams to the lakes and spawns either in the shallow water near the shores of the lakes themselves or, more commonly, in the small streams that flow into the lakes. So far as is known, there is no exception to this rule.

Upon reaching the spawning beds, the sockeyes deposit their eggs in the gravel bed of the stream or lake where, more or less deeply covered by the gravel, they remain for several weeks before they hatch. Then the young go down to sea, as fry the first spring after hatching, or they may remain in the lake until the second spring and then go down as yearlings or fingerlings.

The run of adult sockeyes into freshwater varies considerably in different streams. It may occur at any time from spring until fall. The actual spawning takes place in the late summer or fall. The eggs hatch in the fall, winter, or early spring following.

Age at which the Young Sockeyes Migrate to Salt Water

Chamberlain showed (1903-1905) that Sockeye Salmon fry hatched at the Fortmann hatchery linger a short time on the nursery grounds where liberated, then move down into the lake where they remain a year before going on down to salt water. Gilbert's observations have confirmed those made by Chamberlain, especially as applied to the smaller streams. In the larger rivers, many go down to sea the first spring after hatching, while others remain in the lake until the second spring.

Parent Stream Theory

It has long been maintained by salmon fishermen and others that salmon, when mature, usually, if not invariably, return to the particular stream in which they were hatched. It was generally believed that a great majority of the fish hatched in any particular stream would return to that identical stream when mature and ready to spawn, but that a good many would, or might, go to other streams. Some thought that the salmon return to their own stream because they possess a marvelous geographic or homing instinct, while others maintained that the salmon, after going down to sea as fry or fingerlings, do not wander far from the mouth of the stream in which they were hatched, and that, when they reach maturity they seek freshwater; and the fresh-

A REALLY REMARKABLE PHOTOGRAPH OF A HUMPBACK SALMON ASCENDING THE FALLS IN LITNIK STREAM, AFOGNAK ISLAND water most easily found is that nearest at hand, which is the water of the stream in which they were hatched; they therefore ascend that particular stream.

While this theory, known as the "Parent Stream Theory," has long been held by many, it was not until recently that its truth was demonstrated. As early as 1906, Chamberlain announced, as one of the conclusions reached from his study of the Sockeye at Naha Stream, Yes Bay and elsewhere in Alaska, that "at least the greater part of the supply of any stream must be derived from the fry produced in that stream."[1]

As one of the results of a long series of investigations and observations requiring infinite patience, as well as the greatest care and skill, Dr. Gilbert has demonstrated the validity of the theory not only in its essential features but even in its minutest details. Gilbert says:[2] "The validity of this important theory has been conclusively demonstrated in the case of the larger rivers of the Province. * * * Examination of the scales has removed any possibility of doubt that the progeny of the Fraser River fish return to the Fraser at their maturity, and that this is true also of the fish of each of the large river-basins. It has now been shown * * * that this same principle holds in the case of all the rivers and creeks, however small these may be, and however near together they may enter the sea."

Gilbert's study of the scales has shown that the salmon of each particular stream possess scale characters in common which enable them to be distinguished from the salmon of any other stream, however near the streams may be to each other. He calls attention to the fact that it is only during their life in freshwater that the salmon are subject to obviously diverse conditions. He further says:[3] "It frequently happens that two lakes belonging to different river systems are separated by a few miles only across a low divide. Their physical conditions, it can not be doubted, in so far as these depend on climate, are practically identical. Yet the sockeyes they produce grow each after its own kind while still in freshwater, and exhibit characteristics of growth and habit which distinguish them from their near neighbors across the divide, and ally them closely with all the other like-colonies of their river-basins, however distant these may be."

Life-History of Sockeye Salmon as Recorded in Their Scales

The study of the life-history of a salmon, as recorded in its scales, presents one of the most fascinating of stories. There is none more marvelous in all animate nature. Suppose you should take a trip to

[1]Some Observations on Salmon and Trout of Alaska, Bureau Fisheries Doc. 627, 1906 (1907), p. 25.

[2]Contributions to the Life-history of the Sockeye Salmon (Paper No. 3), B. C. Fisheries Department, 1915, p. 527.

[3]Loc. cit., p. 3.

HUMPBACK SALMON ASCENDING LITNIK FALLS, AFOGNAK ISLAND

British Columbia and Alaska this summer, and while there you should visit some of the great salmon canneries. You have heard somewhere that the age of a salmon can be told from its scales. But you are skeptical. To try the thing out, you cut off a piece of skin with a few scales on it from the side of each of three or four salmon at three or four different canneries. You ask the cannery superintendents from what streams those particular fish came. They tell you and you make a note of it. Numbering the samples for identification, you send them to some expert, Dr. Gilbert, let us say, and ask him to examine them and tell you how old each of the fish was and where it came from. When you get Dr. Gilbert's report you will be surprised. He will tell you not only how old each fish was, but he will tell also the particular stream from which it came, if, perchance, it came from a stream whose salmon he has studied. And he will tell you how long it remained in fresh water before it migrated to the ocean—whether it went down to sea while yet in the fry stage the first spring after hatching, or remained in freshwater a year longer and then went down to sea as a yearling or fingerling. If it remained in the lake one summer and one winter, he will tell you whether the summer was a favorable one as to food supply and other conditions which enabled it to grow rapidly. He will tell you how long it lived in the sea—how many summers and how many winters, and this, of course, added to the time it spent in freshwater before going to sea, will give its age. And, finally, he will tell you what stream this particular salmon was bound for when it was caught. He will be able to learn all these facts regarding each of the specimens you submit to him from an examination of the scales.

Age at which Sockeye Salmon mature

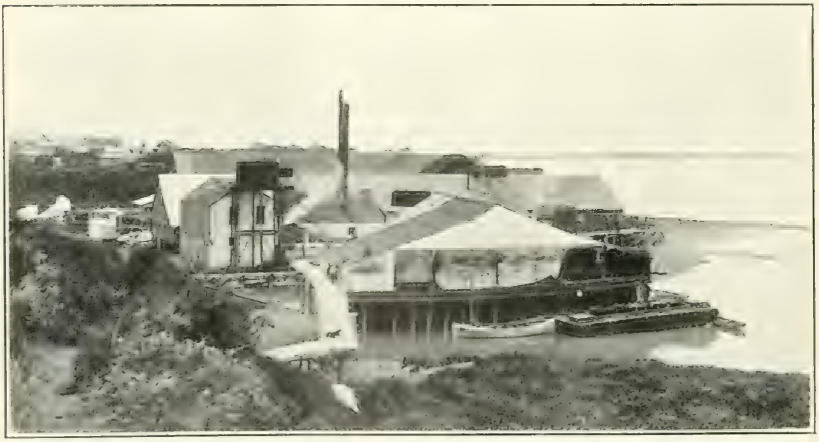
It has been shown by Gilbert that the Alaska and British Columbia sockeyes, as a rule, mature and return to their home streams to deposit their eggs when four years old. A considerable proportion, however, in certain streams, do not return until five years old, and still smaller numbers return at three, six, or even seven years of age. This varies with different streams. For example, it was found that the great majority of the Fraser River sockeyes mature at four years of age, but that, in average years, 10 to 15 per cent. of the run consists of five-year fish. As a result of his study of the sockeyes of Naha Stream, Chamberlain concluded that they are chiefly four-year fish. The Nushagak Bay salmon are either four-year or five-year fish, chiefly the latter.

Attention should here be called to the fact that the salmon return to the stream in which they were liberated when young and in which they were reared through the fry stage or longer. Under natural conditions this, of course, will be the stream in which were laid the eggs

KARLUK HATCHERY, SHOWING RETAINING CORRALS

which produced them. But when eggs taken in one stream, as, for example, the Yes Bay Stream, are hatched and liberated as fry or fingerlings in another, as the Columbia, for example, they will return not to Yes Bay but to the Columbia.

As the adult salmon return to the stream in which they as young were liberated and reared, regardless of whether the eggs from which they were hatched came from fish of that stream or not, it is evident that there is no inherited "homing instinct." They return to the stream in which they, as fry, fed, and not to the stream in which their parents fed when fry, unless it be the same stream. The name "Parent Stream Theory" is not well chosen. "Home Stream Theory" is suggested as a better name.



A TYPICAL WELL-EQUIPPED SALMON CANNERY ON NUSHAGAK BAY. A CANNERY OF THIS TYPE MEANS AN INVESTMENT OF MANY THOUSAND DOLLARS

In view of this important fact, a hatchery which liberates all its output in the stream on which it is located will have no effect upon the run of salmon in any other stream. As Gilbert has said: "In order to maintain the supply of salmon in a given district, it will not be adequate to install a hatchery on any convenient stream into which the entire output of the hatchery will be turned. On the contrary, each stream must be given separate consideration, and must receive its own quota of fry to grow within its boundaries. The original source of the eggs is seemingly a matter of no importance. The destination of the adult salmon is determined by the locality in which the young were reared."[1]

Importance of the Alaska Sockeye Salmon Fisheries

The importance of the Alaska Sockeye Salmon fishery has been very great, as every one knows. As Professor Cobb has said: "Alaska is the most favored salmon-fishing region in the world." The first cannery was erected in 1878 and the first pack was made that year. Other canneries were established from time to time until the number operated in 1918 was 135. The annual pack has varied from 8,159 cases in 1878 to 2,201,643 cases in 1914, when the zenith seems to have been reached. Since 1914 the pack has suffered a great decrease, the pack in 1919 being only 1,204,343 cases. The total pack from 1878 to 1919 reached the enormous total of about forty million cases, as shown by years in tables which have been compiled by Professor Cobb.[1]

Artificial Propagation of the Sockeye Salmon in Alaska

The artificial hatching of salmon in Alaska was begun about thirty years ago. Private hatcheries have been operated at several different places, as at Etolin Island, Karluk, Hetta, Quadra, Freshwater Bay, Kell Bay and Naha. Federal hatcheries are maintained at Yes Bay and at Afognak.

The Callbreath Hatchery

One of the most interesting of these hatcheries was that maintained by Captain Callbreath on Jadjeska Stream, Etolin Island. Captain Callbreath had full faith in the parent stream theory. He believed that, through artificial propagation, he could build up a large annual run of salmon in this small stream. He began in 1893 and continued the experiment until 1905. His method was to catch all the sockeyes ascending this stream, take their eggs and, after hatching, release the fry in the stream.

The experiment was continued for a period of thirteen years. Captain Callbreath, always hopeful, abandoned it only when total

[1]Gilbert, 1915, No. 3, p. s 327.
[1]Report U. S. Fish Commission for 1916, pp. 156-181.

ETOLIN ISLAND RED SALMON HATCHERY WHICH CAPTAIN CALLBREATH OPERATED FOR MANY YEARS IN AN UNSUCCESSFUL ATTEMPT TO ESTABLISH A LARGE RUN OF SALMON IN A STREAM IN WHICH BUT FEW SALMON NATURALLY RAN blindness and the infirmities of age made it impossible for him to continue longer. He liberated a total of more than 52,000,000 fry. He at first believed the results would show in four years. But there was no increase in the fourth year. Then he expected them in the fifth year, but was again disappointed. Always optimistic, he never lost faith as to the final result. He extended the time to six years, then to seven, then to eight, nine, ten and even longer. The increased run for which he had labored and of which he had dreamed for so many years, never came, and Captain Callbreath died still believing the big runs would begin "next year." Not only did the run in Jadjeska Stream fail to show any increase, it actually diminished. A more pathetic story is not known in all the history of the Alaska salmon fisheries.

The Fortmann Hatchery

The Fortmann hatchery on Naha Stream near Loring, Southeast Alaska, was established by the Alaska Packers Association in 1901, and has been operated each year since. It is the best equipped and largest salmon hatchery in the world, its capacity being over 110,000,000 eggs.

Since the establishment of this hatchery no fishing has been permitted off Naha Stream. The entire run has been permitted to enter the stream and all the fish have been utilized by the hatchery. The fry have been liberated in the lakes of the Naha system. It is assumed that all the eggs that could be obtained were taken; yet, instead of there being an increase in the run, as was expected, there has been a marked decrease. There has been a decided progressive decrease in the number of eggs taken in each of the last three five-year periods, the figures being:

1905-1909	245,674,000
1911-1915	197,580,000
1916-1920	133,980,000

These figures show that the number of eggs taken in the last 5-year period (1916-1920) were less than 56 per cent. of the number taken in the first full 5-year period (1905-1909). Or estimating the egg take of the present year (1920) at the average for the preceding four years, we then have four 5-year periods to compare, and find that the take in the last period is 64 per cent. of that in the first, 51 per cent. of the second, and 70 per cent. of that of the third.

The number of red salmon eggs taken by the various hatcheries totals nearly three billions. If the fish that supplied this enormous number of eggs had been permitted to spawn naturally, the number of eggs they would have produced would doubtless have been much greater, for, in artificial spawning, there is always considerable loss. It is a fair question to ask what would have been the result if these fish had been permitted to spawn naturally?

Statistical tables and other available data, when examined in their relation to each other, ought to throw some light upon the question of the actual value of artificial propagation of the Sockeye Salmon and its relative value as compared with natural reproduction. Unfortunately the records have not been kept with the fullness and accuracy essential to unquestioned conclusions on all phases of the problem, but it would seem that the experiment has been conducted sufficiently long and in a sufficient number of places to warrant the raising of the question as to whether artificial propagation of salmon in Alaska, as conducted, has been more effective in conserving the salmon fisheries than natural reproduction would have been. In answer to the question as to the effect of the Yes Bay hatchery upon the salmon fisheries of Alaska, the U. S. Commissioner of Fisheries replied: "It is difficult to furnish direct evidence of the effects of the [Yes Bay] hatchery operations other than what may be indicated by the statistical figures." Essentially the same reply was given regarding the Afognak hatchery.

In reply to questions as to what increase, if any, has been noted in the catch of salmon in the region with which the Fortmann hatchery is concerned, the Alaska Packers Association replied that no data are available. "We have no data * * * therefore can form no judgment what effect the output of the Fortmann hatchery and the near-by United States Government Yes Bay hatchery may have had upon the supply of salmon of that district."

As to the Karluk hatchery, it is quite certain that none of the millions of fry liberated at that station ever survived to maturity. Although the Karluk run continued large for many years, it was doubtless able to do so because of a considerable annual escape of fish to the spawning beds in and about Karluk Lake where they spawned naturally.

Sockeye Salmon Streams on which Hatcheries have not been operated

There are many Red Salmon streams in Alaska which have not had hatcheries located on them and which, therefore, have not been influenced one way or the other by artificial propagation. Among important streams of this kind that may be mentioned are the Alitak, the Chignik, and the *Nushagak* region. Each of these has supported a great fishery for many years. Although enormous catches were made year after year and although it was felt that the supply must fail sooner or later, there was little decrease for many years. The enormous run in each of these streams depended entirely upon natural reproduction; there was no hatchery on any of them. I have not at hand the figures, but it seems that these streams were able to hold up under natural spawning longer than those streams where artificial propagation was resorted to. It is not claimed that a direct comparison of the value of natural reproduction as compared with artificial propagation as exhibited by these streams is by any means conclusive, but it is believed such comparison as can be made fails to demonstrate any marked advantage of artificial salmon culture, *as conducted*, over natural methods.

I do not claim for a moment that the artificial propagation of salmon in Alaska must necessarily be less effective than natural reproduction, but I do say that its superiority has not been demonstrated. Indeed, the available evidence would seem to justify the statement that, up to the present, the salmon hatcheries in Alaska have done more harm than good. It would surely be unwise to establish additional hatcheries in Alaska until investigation has shown wherein lies the defect in present methods. The whole question of method in hatchery work and fry planting needs the most careful scientific study by the very best men that can be induced to undertake the solution of this vital problem.

How can the Alaska Salmon Fisheries be saved?

That the Alaska salmon fisheries, as well as those of Puget Sound and Fraser River, are doomed unless something is done and done soon can not be doubted. They have already in some streams reached a condition of depletion so complete that commercial rehabilitation will be possible only with the complete stopping of all fishing for a long period of years. But that this great industry can be saved I have not the slightest doubt.

The knowledge we now have of the life-history of the Sockeye salmon, acquired chiefly through the painstaking investigations and study made by Dr. Gilbert, is adequate for the formulation of a definite plan of investigation which will supply the data which will point the way to a method of conducting the salmon fishery so that we shall not only be able to rehabilitate it but to continue it indefinitely as a going industry with a maximum annual output. Indeed, we can even now say with confidence what the essential features of the plan must be. They are five in number:

1. *Determine the ratio between the number of salmon spawning naturally and the run four (or five) years later.* In other words, determine the number of adult fish which may be expected to return at the end of the four—or five-year—cycle as the result of the natural spawning of a certain number of fish.

There has been much discussion as to the number of salmon eggs required to produce one adult salmon; in other words, for every salmon that spawns naturally on the spawning beds, how many adult salmon may be expected to return four or five years later?

HEAD OF NORTH OLGA STREAM, ALITAK, KODIAK ISLAND; A TYPICAL RED SALMON STREAM

In 1908, the Bureau of Fisheries began a series of observations on a certain stream in Alaska. The observations were known as *The Wood River Investigations.* The present writer had for some years been disposed to believe that, if the run of salmon in a suitable stream could be studied in the proper way for the requisite number of years, the problem could be solved. Wood River in the *Nushagak* region was selected as the stream on which to make the study, and the investigation was begun in the summer of 1908.

A rack was placed across Wood River at the outlet of *Lake Aleknagik* in such a manner as to prevent any salmon from entering the lake except as they were permitted to pass through gates so constructed that they could be opened or closed as desired. A suitable platform or observation station was constructed above the gates from which the observer was able to open or close the gates at will and count the salmon as they passed through. It was found that the fish passed through freely and in an orderly manner, so that an intelligent, conscientious attendant, after a little experience, had no difficulty in keeping an accurate tally. The method was very simple. An actual count was made of the fish passing through in one minute in each fifteen minutes. The number counted in the one minute was assumed to be the average for 15 minutes.

This investigation was carried on every year from 1908 to 1919, both inclusive, except in 1914, when the Secretary of Commerce in his wisdom refused to continue it. He had little or no sympathy with scientific investigation or appreciation of its value. The

A TYPICAL SALMON TRAP NEAR GRAVEYARD POINT, KIRCHAK BAY, SHOWING THE NORTHERN AND INSHORE POT, AS SEEN FROM THE BEACH AT LOW TIDE, THE TUNNEL BEING DOWN

NATIVE METHOD OF USING GILL NETS BETWEEN TIDES ON THE BEACH IN NUSHAGAK BAY continuity of the investigation was thus broken and the whole experiment rendered of little value.

If an investigation of this kind is carried on for a sufficient number of years on a stream which does not present any complicating conditions which would render the results inconclusive, and, if, during the same years, an accurate record is kept of the fish taken by the canneries from the run of that stream, there would be acquired all the data necessary to answer the question as to how many fish must be permitted to spawn each year in order to provide a certain catch year after year.

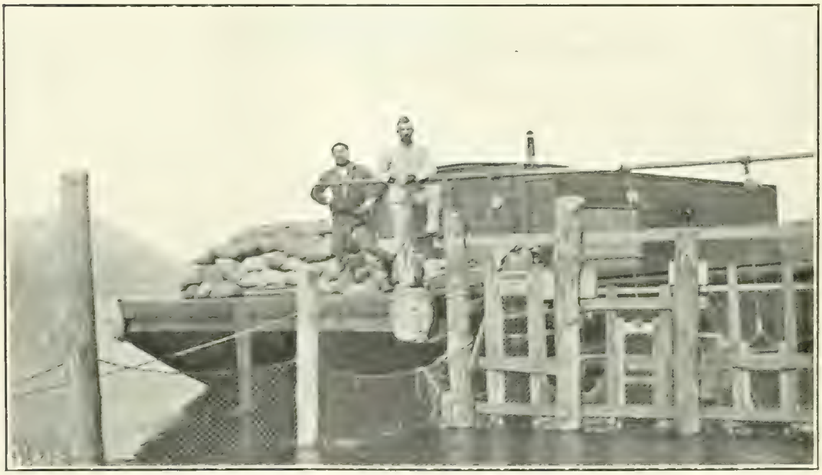
When Wood River was selected for the purpose of this experiment, certain difficulties were recognized as existing. Wood River is only one of four streams that enter Nushagak Bay. The other three are the Nushagak, the Egushik, and the Snake. The mouths of these four streams are not far from each other. Each of them receives a part of the Nushagak Bay run. What proportion of the entire run goes to Wood River, and what to each of the other streams no one knows, but it is certain that the Wood River contingent is vastly greater than that of the three other streams combined; indeed, it was thought the run in the Nushagak, Egushik and Snake was relatively so small as to be negliable for the purpose in view. It was believed that a census of the escape in Wood River taken for a series of eight or ten years, compared with the commercial catch for the same series of years, would enable us to arrive at an approximate ratio of escape to catch that would be fairly reliable; in other words, we would know how many fish must spawn in Wood River each year to permit a certain catch four and five years later.

The safety of this assumption may well be questioned. But we know more about the Red Salmon now than was known then. We now know that it is quite practicable to determine the proportional run in each of the four rivers without racking any but Wood River. Dr. Gilbert has shown that salmon return to the particular stream in which they were hatched and that the salmon of any stream are readily distinguished from those of any other stream however close together may be the mouths of the two streams. This being so, it is only necessary to determine what are the distinguishing characters of the salmon of each of the four streams—the Wood, the *Nushagak*, the Egushik and the Snake, then an examination of a considerable number of salmon at each Nushagak Bay cannery for a series of years would enable one to arrive at the percentage of fish of each river in the entire run. The actual escape of Wood River fish is learned by the census, and the percentages obtained at the canneries would enable one to arrive at the escape to each of the other streams.

THE RACK AT LAKE ALEKNAGIK (WOOD RIVER) JULY, 1912

In view of these facts, it seems that Wood River offers an entirely practicable field in which to solve this vitally important problem.

It is realized that the ratio determined for Wood River may not be the proper ratio for any other salmon stream. It will in all probability be necessary to determine the ratio for each particular stream. A census should be made on every red salmon



THE RACK AT LAKE ALEKMAGIK (WOOD RIVER) JULY, 1912

stream possible. There are doubtless some streams on which this investigation can not easily be made, but the great majority of Alaska red salmon streams present no insuperable difficulties, and probably the ratio for all can be determined if the rack is put further up the stream. In any event, the data which can be gotten on the other streams will suggest what to do with those few where it is impracticable to determine the ratio.

COUNTING RED SALMON AS THEY PASS THROUGH THE RACK AT WOOD RIVER, JULY, 1912

2. *Study of the spawning beds.*—The spawning beds in every red salmon stream in Alaska should be carefully studied for the purpose of determining just what conditions are favorable and what unfavorable; what percentage of the eggs are fertilized; what percentage hatches; what percentage of the fry escape all enemies and go down to sea; what the natural enemies are and how destructive each is; whether there is over-crowding of spawning fish, and the result; depth to which the eggs are buried and what the best depth is; food supply for the fry, qualitative and quantitative; and any and all other questions which throw any light on the essential habits of the adults and young when in fresh water. We know practically nothing about the efficiency of natural reproduction of the Sockeye. Fish culturists declare unhesitatingly that a large percentage of the eggs fail of fertilization; that a large percentage of the eggs that do succeed in getting fertilized are lost by being washed away, by being crushed, by being eaten by fishes or other enemies, or by disease of one kind or another; and that of those that do hatch only a small percentage

escape the various enemies that beset them in their fry or fingerling stage, and grow to maturity. All of this in a sense seems reasonable and may be true, but nobody knows; and certainly no convincing proof has been presented. Indeed, the question has never been seriously investigated. The asseverations of the fish-culturists are merely their opinions, supported by scarcely any known facts.

But we should know. We should determine through repeated observation and investigation, what the normal or average loss is from failure in fertilization, from mechanical injuries, from fish and other enemies, from disease, and from all other causes. Else we shall never be able to compare natural with artificial propagation.

3. *Improvement of spawning beds.*—Much can doubtless be done toward improving the spawning beds by removing obstructions, by bettering the character of the gravel, and by increasing the area. It is believed that improvements can be made in many places which will permit the spawning of a much greater number of salmon than now find room or suitable bottom. To know the capacity of any stream it is necessary to know the extent of bottom suitable for spawning beds, whether the beds are utilized to their full capacity, and whether the beds can be improved by enlargement or otherwise. It may well be that, in some streams, the spawning fish are too crowded on parts of the bed while other parts are only partially utilized. It may well be that, by a little work the character of some beds can be improved and that, through removal of obstructions the area of suitable bottom can be greatly increased. It is directly in the interest of the salmon fisheries that every Sockeye salmon stream in Alaska be physically improved to its maximum area of suitable spawning bottom and that, within a margin of safety, spawning fish be permitted to reach those beds to their full capacity.

4. *The life of the young while yet in fresh water.*—As already stated elsewhere in this paper Dr. Gilbert and Mr. Chamberlain discovered that some of the young migrate to salt water in their first spring, others in their second, the proportion varying with different streams and different seasons. While in freshwater the fry may encounter conditions more or less adverse. The food supply may be inadequate, and living enemies such as salmon trout, bullheads, terns, and other birds, and other kinds of fishes, may make serious inroads on their numbers. All these factors should be carefully studied and the conditions improved wherever possible.

5. *Statistics of the run of salmon.*—During the years that the studies outlined above are being made on the streams, statistics of the run of salmon of each stream should be made. The primary object of these studies would be to determine the total number of fish of each particular stream for each of a series of years. If the investigation is properly made, the total run of each stream would be the number of fish headed for that stream taken by the fishermen, plus the escapement as determined by the census at the rack, plus a negligible few that escaped observation. These data, for a series of years would, it is believed, supply a ratio between the number of fish in the escape and the total run which will show the number of fish that must be permitted to escape to the spawning beds to maintain the fishery at a maximum annual pack.

Summary

The essential features of the plan here proposed for the rehabilitation and conservation of the Alaska salmon fisheries may then be summarized as follows:

1. Rack every stream that can be racked and make an accurate count of the salmon ascending it. The census or count must be made often enough to cover at least two returns of each annual run of the first two or three years.

2. In each of the years in which a census of the spawning fish is made, secure statistics showing the number of fish taken by the fisheries from the run of that river. This number plus the escape let through the rack will be the total run of that year. From these data the proper ratio of *escape* to *catch* can be determined.

3. Study each spawning bed and determine its maximum capacity, giving attention at the same time to the possibility of increasing its area and improving the physical and biological conditions thereon.

4. When all has been done in these respects that can be done or need be done, the capacity of the stream and the maximum catch and escape determined—then rack the stream, let through the rack the number of fish which have been found to be necessary to keep up the catch from year to year at the maximum capacity of that stream, close the rack, and then let the commercial fishermen catch in the easiest way they can all the fish that are left.[1] This will probably be by means of haul seines which would most likely be operated immediately below the rack where the fish

[1] Whether all the spawning reserve be passed through the gates before any fishing is permitted, or whether the gates be closed at intervals and "escape" and "catch" alternate through the season, is a matter of detail which, with many others, may properly be left for experimental determination.

would be bunched. All other kinds of gear can then be abandoned—gillnets (fixed and floating), purse-seines, and expensive traps and pounds—all these can be discontinued except in exceptional places.

This would mean a very decided change in the methods of the fisheries and an enormous reduction in the cost. A licensing system similar to that employed in the oyster fisheries of the Atlantic and Gulf coasts, or that of the Federal Government regulating timber-cutting or grazing in national parks and reservations, can be devised and put in operation, satisfactory to the fishery interests.

During the progress of these investigations fishing off the mouths of a good many of the streams will have to be limited; the run in some streams has already been so seriously depleted that it may be wise to prohibit for a number of years all fishing that draws from their run.

The plan here proposed will doubtless meet with strong opposition from the actual fishermen; they will, of course, object to any system which will result in a reduction of the number of fishermen needed to catch the fish. This need not disturb us; the object in view is to maintain the salmon industry as a going concern, not the employment of the greatest possible number of fishermen.

It will also be urged that the investigations required to give us the body of facts essential to the development and application of the method here outlined must necessarily extend through a long series of years and are bound to cost enormously.

This is perfectly true. It will require several years to determine the details of the methods in accordance with which this great fishery must be conducted if it is to live. The cost will be great indeed; perhaps a million dollars, may be more; but what is that in comparison with the untold billions that will in the years to come be the return from the great fishery which the expenditure of a million dollars during the next decade will insure for all time, but which, unless this or something like it is done and done soon, will very soon cease to exist?

THE PROGRESS OF SCIENCE

THE CHICAGO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The seventy-third meeting of the American Association for the Advancement of Science was held in Chicago, from December 27 to January 1. From the account of the meeting printed in *Science,* the official organ of the association, some data of general scientific interest may be quoted. It was the second of the greater convocation week meetings of the association and of the national scientific societies associated with it, convened once in four years successively in New York, Chicago and Washington. The remarkable scientific activity of the central west and of the reconstruction period following the war were adequately reflected by the attendance and programs at Chicago, which have probably not been surpassed by any previous gathering of scientific men in this or any other country. In addition to fourteen sections of the association, forty-one national scientific societies met in Chicago and the official program of 112 pages exhibited the scientific productivity of the nation in the whole range of the natural and exact sciences.

At the opening session on the evening of December 27, after the introduction of the president of the meeting, Dr. L. O. Howard, and greetings by the president of the University of Chicago, Dr. H. P. Judson, the retiring president, Dr. Simon Flexner, gave his address on "Twenty-five Years of Bacteriology," which was listened to by a crowded audience with absorbed attention.

Two other general evening sessions of popular interest were held. At one of these was given an illustrated lecture by Dr. R. F. Griggs, on the region of Mt. Katmai, Alaska, and the "Valley of Ten Thousand Smokes." The other general interest lecture was by Professor R. W. Wood, on high power fluorescence and phosphorescence, in connection with which he performed numerous ingenious experiments and demonstrations dealing with the study of these phenomena and of ultra-violet light. The sessions were held mainly in buildings of the University of Chicago, which furnished excellent facilities. The total registration was 2,412, which is the largest registration ever recorded for the association, and it must be remembered that many persons in attendance at the meeting failed to register, so that the correct number was much larger.

The increase in scientific knowledge and interest among the general public is one of the most important functions of the association and the one which it has been most difficult to accomplish. The reports in the press vary from year to year, and at Chicago represented a fair average. Several of the more important papers, such as that of Professor Michelson on the application of interference methods to astronomical measurements, were fully reported, not only in Chicago but also in New York and other cities. The Science Service, definitely organized at Chicago for the wide-spread diffusion of current scientific information, will hereafter make possible adequate reports of scientific meetings.

It was decided that the next meeting of the American Association will be at Toronto, on Tuesday, Decem-

DR. L. O. HOWARD, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE CHICAGO MEETING

DR. SIMON FLEXNER, RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE CHICAGO MEETING

DR. ELIAKIM HASTINGS MOORE, PRESIDENT-ELECT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MACDOUGAL — CATTELL — FAIRCHILD — HUMPHREYS — OSBORN

HOWARD — FLEXNER — LIVINGSTON

MEMBERS OF THE EXECUTIVE COMMITTEE OF THE COUNCIL AT CHICAGO ber 27, to Saturday, December 31, 1921, inclusive. The meeting for 1922-1923 will be held in Boston, and that for 1923-1924 will be held in Cincinnati. Then will follow the stated convocation meeting in Washington.

THE OFFICERS OF THE ASSOCIATION

The American Association has been fortunate in its presidents. The address of the retiring president, Dr. Simon Flexner, director of the laboratories of the Rockefeller Institute for Medical Research, on the history of bacteriology during the past twenty-five years, printed in the issue of *Science* for December 31, was an admirably clear presentation of a subject unsurpassed in its importance to human welfare, described by one who has led in the work.

Dr. L. O. Howard, chief of the Bureau of Entomology, presided with dignity, skill and tact. He has played a large part in a subject in which science has demonstrated its service in the economic development of the nation and has been the chief executive officer of the association during the twenty-two years which have witnessed such an extraordinary development of the scientific work of the country, paralleled by the growth of the association from some 1,200 to over 10,000 members.

Professor E. H. Moore, of the University of Chicago, who will preside at Toronto and give his address at Boston, is the acknowledged leader of American mathematicians. It is now many years since that science which is fundamental to all others has supplied a president to the association, and it is fortunate that a representative could be selected with the unanimous approval of all mathematicians.

Dr. D. T. MacDougal, director of the department of Botanical Research of the Carnegie Institution, who has been active in the organization of the work of the association, more especially in the Pacific and Southwestern Division, was elected general secretary to succeed Professor E. L. Nichols, of Cornell University. By the constitution the general secretary is entrusted with the important task of promoting the organization of the association, especially in its relation to the affiliated societies. Another step that will promote the efficiency of the work of the association was the authorization of the appointment of an assistant secretary who will assist the permanent secretary in the scientific work of the association, as he is now assisted in the work of the office by the efficient executive assistant, Mr. Sam Woodley.

Dr. Burton E. Livingston, of the Johns Hopkins University, whose admirable conduct of the affairs of the association during the past year has won general recognition, was re-elected for the stated term of four years. Dr. R. S. Woodward, though retiring from the presidency of the Carnegie Institution on reaching the age of seventy years, consented to continue as treasurer, in which office he has served the association for twenty-six years.

Vice-presidents of the association and chairmen of the sections were elected as follows: *Mathematics,* Oswald Veblen, Princeton University; *Physics,* G. W. Stewart, State University of Iowa; *Chemistry,* W. D. Harkins, University of Chicago; *Astronomy,* S. A. Mitchell, University of Virginia; *Geology and Geography,* Willet G. Miller, Toronto; *Zoological Sciences,* Charles A. Kofoid, University of California; *Botanical Sciences,* Mel T. Cook, Rutgers College; *Anthropology,* Albert Ernest Jenks, University of Minnesota; *Psychology,* C. A. Bott, University of Toronto; *Agriculture,* J. G. Lipman, Rutgers College; *Education,* Guy M. Whipple, University of Michigan.

SIR J. J. THOMSON, LATELY CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS AT THE UNIVERSITY OF CAMBRIDGE, RETIRING PRESIDENT OF THE ROYAL SOCIETY OF LONDON

RESOLUTIONS PASSED AT THE CHICAGO MEETING

Among the resolutions adopted by the Council of the American Association are the following:

Be it resolved: That the American Association for the Advancement of Science would welcome the organization of Mexican men of science, and their affiliation with this Association.

Resolved: That a committee of seven be appointed to cooperate with such organization as Mexican men of science may form.

The following were appointed on this committee: L. O. Howard, *Chairman,* A. E. Douglas, E. L. Hewitt, D. S. Hill, W. J. Humphreys, D. T. MacDougal and W. Lindgren.

Whereas the American Association for the Advancement of Science includes sections on Physiology, Experimental Medicine and Zoology, and

Whereas advancement of knowledge in these sciences, which is dependent upon intensive study of living tissue, is inevitably followed not only by amelioration of human suffering, but also by a lessening of animal disease and by substantial economic gain and by conservation of the food supply, and

Whereas this association is convinced that the rights of animals are adequately safeguarded by existing laws, by the general character of the institutions which authorize animal experimentation and by the general character of the individuals engaged therein.

Therefore be it resolvd, that this association agrees fully with the fundamental aim of those whose efforts are devoted to the safeguarding of the rights of animals but deprecates unwise attempts to limit or prevent the conduct of animal experimentation such as have recently been defeated in California and Oregon, for the reason that such efforts retard advance in methods of prevention, control and treatment of disease and injury of both man and animals and threatens serious economic loss, and be it further

Resolved, that a copy of these resolutions be included in the official records of this Association, and that copies be sent to the national congress, to the legislature of each state in the union and to each member of the Association.

Whereas, clean [illegible] road-sides and the drainage of marshes in the United States is imperiling the existence of the wild-life of our country not now included in special preserves, and

Whereas, the preservation of this wild-life not in preserves is felt to be of great national importance not only to students and lovers of nature, but to human welfare in general, therefore,

Be it resolved, by the council of the American Association for the Advancement of Science, that it appreciates the importance of preserving this wild-life not in preserves, and that it lends its moral support to the effort to combine all interested organizations in a cooperative investigation and conservation program for the preservation of our unprotected wild-life.

Whereas, in recognition of the unique character and value of our National Parks and Monuments to present and future generations, twenty-four successive Congresses have wisely resisted attempts to commercialize them and have preserved them inviolate for nearly half a century,

Whereas, certain private interests are now seeking to secure special privileges in these areas, which if granted will seriously interfere with their true purpose and undoubtedly result in the entire commercialization of these unique national museums,

Therefore, be it resolved, that the American Association for the Advancement of Science request members of Congress first to amend the Water Power Act so that it shall not apply to National Parks and Monuments and that their full control be restored to Congress, and second, to reject all present and future measures which propose to surrender any part of these National Parks and Monuments to private control or to divert them in any way from their original and exclusive purpose, the preservation for all future generations of unique representations of natural conditions such as exist in no other part of the world.

SCIENTIFIC ITEMS

We record with regret the death of Henry Andrews Bumstead, professor of physics at Yale University and director of the Sloan Physical Laboratory; of Sir William Abney, eminent for his contributions to photography and color vision, and of Dr. Yves Delage, professor of zoology in University of Paris, distinguished for his work on protoplasm, heredity and general biology.

Dr. Henry Norris Russell, professor of astronomy at Princeton University, has been awarded the Gold Medal of the Royal Astronomical Society. The medal will be presented at the annual meeting of the society and Professor Russell will sail for London on January 29.

The Perkin medal of the American Section of the Society of Chemical Industry has been awarded to Dr. Willis R. Whitney, research director of the General Electric Company.

Professor Edward S. Morse of Peabody Academy and Boston Museum of Fine Arts, has been elected an honorary member of the East Asiatic Society.

Dr. E. E. Slosson, associate editor of *The Independent* and formerly professor of chemistry in the University of Wyoming, has been elected editor of the *Science Service*, the temporary headquarters of which are at 1701 Massachusetts Avenue, Washington, D. C.

Dr. Edgar Fahs Smith, former provost of the University of Pennsylvania, has been elected president of the American Chemical Society.

Plans have been completed by the trustees of the Johns Hopkins Hospital for the reconstruction of the hospital group, which will involve an investment of approximately $11,500,000, including $6,750,000 as a permanent endowment fund. The first unit will be started next summer by the erection of a new pathologic building, costing $600,000, to replace the structure destroyed by fire last winter.

THE SCIENTIFIC MONTHLY

MARCH, 1921

THE BIOLOGY OF DEATH: I—THE PROBLEM[1]

By Professor RAYMOND PEARL

THE JOHNS HOPKINS UNIVERSITY

1. Introduction

PROBABLY no subject so deeply interests human beings as that of the duration of human life. Presumably just because the business of living was such a wonderfully interesting and important one from the viewpoint of the individual, man has endeavored, in every way he could think of, to prolong it as much as possible. He has had recourse to both natural and supernatural schemes for attaining this objective. On the mundane plane he has developed the sciences and arts of biology, medicine and hygiene, with the fundamental purpose of stretching the length of each individual's life on earth to the greatest attainable degree. Recognizing pragmatically, however, that at best the limitations in this direction were distinctly narrow, when conceived in any historical sense, he has with singularly wide-spread unanimity, deemed it wise to lay a hedging bet upon a horse of another color. Man's body plainly and palpably returns to dust, after the briefest of intervals, measured in terms of cosmic evolution. But there is nothing in this fact which precludes the postulation of an infinite continuation of that impalpable portion of man's being which is called the soul. With the field thus open we see some sort of notion of immortality incorporated in an integral part of almost all folk philosophies of which any record exists.

Now, perhaps unfortunately, perhaps fortunately, it has up to the present time proved impossible absolutely to demonstrate, for reasons which will presently appear, by any scientifically valid method of experimentation or reasoning, that any real portion of that totality of being which is an individual living man persists after he dies. Equally, for the same reasons, science can not absolutely demonstrate that such per-

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 28.

This, and the papers which will follow it under the same general title are based upon a series of lectures recently given at the Lowell Institute in Boston.

sistence does not occur. The latter fact has had two important consequences. In the first place, it has permitted many millions of people to derive a real comfort of soul in sorrow, and a fairly abiding tranquility of mind in general from the *belief* that immortality is a reality. Even the most cynical of scoffers can find little fault with such a result, the world and human nature being constituted as they are. The other consequence of science's present inability to lay bare, in final and irrefragable terms, the truth about the course, if any, of events subsequent to death is more serious. It opens the way for recurring mental epidemics of that intimate mixture of hyper-credulity, hyper-knavery, and unsatisfied Freudian urges, which used to be called spiritualism, but now usually prefers more seductive titles. We are at the moment in the midst of perhaps the most violent and destructive epidemic of this sort which has ever occurred. Its evil lies in the fact that in exact proportion to its virulence it destroys the confidence of the collective mind of humanity in the enduring efficacy of the only thing which the history of mankind has demonstrated to contribute to the real advancement of his intellectual, physical, spiritual and moral well being, namely that orderly progression of ascertained knowledge which we now call *science.*

The reason why science finds itself helpless to prevent spiritualism's insidious sapping of the intellectual fiber of the race is because it is asked to prove a negative, upon the basis of unreal data. How difficult such a task is is obvious as it is proverbial. Until science has demonstrated that there is *not* a continuation of individual supernatural existence after natural death, the spiritualist can, and will, come forward with supposed demonstrations that there is such a continuation. But the most characteristic feature of science is its actuality, its reality, its naturality. Pearson has pointed out, in characteristically clear and vigorous language, the reason why, in the minds of uninformed persons, science appears helpless in this situation. He says:

> Scientific ignorance may either arise from an insufficient classification of facts, or be due to the unreality of the facts with which science has been called upon to deal. Let us take, for example, fields of thought which were very prominent in medieval times, such as alchemy, astrology, witchcraft. In the fifteenth century nobody doubted the "facts" of astrology and witchcraft. Men were ignorant as to how the stars exerted their influence for good or ill; they did not know the exact mechanical process by which all the milk in a village was turned blue by a witch. But for them it was nevertheless a fact that the stars did influence human lives, and a fact that the witch had the power of turning the milk blue. Have we solved the problems of astrology and witchcraft today?
>
> Do we now know how the stars influence human lives, or how witches turn milk blue? Not in the least. We have learnt to look upon the facts themselves as unreal, as vain imaginings of the untrained human mind; we have learnt that they could not be described scientifically because they involved notions which were in themselves contradictory and absurd. With alchemy the case was somewhat different. Here a false classification of real facts was combined with inconsistent sequences—that is, sequences not deduced by a rational method. So soon as science entered the field of alchemy with a true classification and a true method, alchemy was converted into

chemistry and became an important branch of human knowledge. Now it will, I think, be found that the fields of inquiry, where science has not yet penetrated and where the scientist still confesses ignorance, are very like alchemy, astrology, and witchcraft of the Middle Ages. Either they involve facts which are in themselves unreal—conceptions which are self-contradictory and absurd, and therefore incapable of analysis by the scientific or any other method—or, on the other hand, our ignorance arises from an inadequate classification and a neglect of scientific method.

This is the actual state of the case with those mental and spiritual phenomena which are said to lie outside the proper scope of science, or which appear to be disregarded by scientific men. No better example can be taken than the range of phenomena which are entitled Spiritualism. Here science is asked to analyse a series of facts which are to a great extent unreal, which arise from the vain imaginings of untrained minds and from atavistic tendencies to superstition. So far as the facts are of this character, no account can be given of them, because, like the witch's supernatural capacity, their unreality will be found at bottom to make them self-contradictory. Combined, however, with the unreal series of facts are probably others, connected with hypnotic and other conditions, which are real and only incomprehensible because there is as yet scarcely any intelligent classification or true application of scientific method. The former class of facts will, like astrology, never be reduced to law, but will one day be recognized as absurd; the other, like alchemy, may grow step by step into an important branch of science. Whenever, therefore, we are tempted to desert the scientific method of seeking truth, whenever the silence of science suggests that some other gateway must be sought to knowledge, let us inquire first whether the elements of the problem, of whose solution we are ignorant, may not after all, like the facts of witchcraft, arise from a superstition, and be self-contradictory and incomprehensible because they are unreal.

Let us recapitulate briefly our discussion to this point. Mankind has endeavored to prolong the individual life by natural and by supernatural means. This latter plan falls outside the present purview of the scientific method. The former is, in last analysis, responsible for the development of the science of biology, pure and applied, and the arts which found their operations upon it. Biology can and has contributed much to our knowledge of natural death and the causes which determine the duration of life. It is the purpose of this series of lectures to review this phase of biological science, and endeavor to set forth in an orderly and consistent manner the present state of knowledge of the subject.

2. The Problem

The problem of natural death has two aspects, one general, the other special. These may be stated in this way:

1. Why do living things die? What is the meaning of death in the general philosophy of biology?

2. Why do living things die *when* they do? What factors determine the duration of life in general and in particular, and what is the relative influence of each of these factors in producing the observed result?

Both of these problems have been the subject of much speculation and discussion. There has accumulated, especially in recent years, a considerable amount of new experimental and statistical data bearing upon them. I hope to be able in what follows to show that this new material, together with that which has for a long time been a part of the common store of biological knowledge, makes possible a clearer and more logically consistent picture than we have had of the meaning of death and the determination of longevity. Let us first examine in brief review the broad generalizations about death which have grown up in the course of the development of biology, and which may now be regarded as agreed to by practically all biologists.

3. Biological Generalizations About Natural Death

The significant general facts which are known about natural death are these:

(a). *There is an enormous variation in the duration of life, both intra and inter-racially.* Table 1, which is adapted from various authorities, is to be read with the understanding that the figures are estimates frequently based upon somewhat general and inexact evidence, and record extreme, though it is believed authentic instances. While the figures, on the accounts which have been mentioned, are subject to large probable errors, the table does give a sufficiently reliable general picture of the truth to indicate the enormous differences which exist among different forms of animal life in respect of longevity.

TABLE 1
Longevity of Animals

Animal	Approximate limits of maximum duration of life in different species
Lower invertebrates	24 hours to?
Insects	24 hours to 17 years
Fish	? to 267 years
Amphibia	? to 36 years
Reptiles	? to 175 years
Birds	9 years to 118 years
Mammals	1½ years to over 100 years

We see from this table that life may endure in different forms from only the briefest period, measured in hours as in the case of *Ephemeridae*, to somewhere in the hundreds of years. The extremely long durations are of course to be looked upon with caution and reservation, but if we accept only extreme cases of known duration of life in man, the range of variation in this characteristic of living things is sufficiently wide.

It is probable that man, in exceptional instances, is nearly the longest lived of all mammals. The common idea that whales and elephants attain great longevity appears not to be well founded. The absolutely authentic instances of human survival beyond a century are, contrary to the prevalent view and customary statistics, extremely rare. The most painstaking and accurate investigation of the frequency of occurrence of centenarians which has ever been made is that of T. E.

Young. Because of the considerable intrinsic interest of the matter, and the popular misconceptions which generally prevail about it, it will be worth while to take a little time to examine Young's methods and results. He points out in the beginning that the evidence of great age which is usually accepted by census officials, by registrars of death, by newspaper reporters, and by the general public, is, generally speaking, of no validity or trustworthiness whatever. Statements of the person concerned, or of that person's relatives or friends, as to extreme longevity, can almost invariably be shown by even a little investigation to be extremely unreliable. To be acceptable as scientific evidence, any statement of great age must be supported by unimpeachable *documentary* proof of at least the following points:

a. The date of *birth,* or of baptism.
b. The date of *death.*
c. The *identity* of the person dying at a supposed very advanced age with the person for whom the birth or baptismal record, upon which the claim of great age is based, was made out.
d. In the case particularly of married women the date of *marriage,* the person to whom married, and any other data which will help to establish proof of identity.

In presumptive cases of great longevity, which on other grounds are worthy of serious consideration, it is usually in respect of item c—the proof of identity—that the evidence is weakest. Every student of genealogical data knows how easy it is for the following sort of thing to happen. John Smith was born in the latter half of the eighteenth century. His baptism was duly and properly registered. He unfortunately died at the age of say 15. By an oversight his death was not registered. In the same year that he died another male child was born to the same parents, and given the name John Smith, in commemoration perhaps of his deceased brother. This second John Smith was never baptized. He attained the age of 85 years, and then because of the appearance of extreme senility which he presented, his stated age increased by leaps and bounds. A study of the baptismal records of the town disclosed the apparent fact that he was just 100 years old. The case goes out to the public as an unusually well authenticated case of centenarianism, when of course it is nothing of the sort.

Young applies rigidly the criteria above enumerated first, to the historically recorded cases of great longevity such as Thomas Parr, *et id genus omne,* and rejects them all; and second to the total mortality experience of all the Life Assurance and Annuity Societies of Great Britain and the annuity experience of the National Debt Office. The number of persons included in the experience was close upon a million. He found in this material, and from other outside evidence, exactly 30 persons who lived 100 or more years. In Table 2 the detailed results of his inquiry are shown in condensed form.

TABLE 2

Authentic Instances of Centenarianism (from Young)

Sex	Social status (single or married)	Age at death (or living)		
		Years	Months	Days
♀	M	110	..	321
♀	M	108	..	144
♀	M	105	8	...
♀	S	104	9	16
♀	M	103	9	28
♀	?	103	..	269
♀	M	103	3	7
♂	?	103	1	8
♂	?	102	9	2
♀	?	102	..	218
♀	S	102	2	10
♀	S	102	1	8
♀	S	102	..	21
♀ *	S	102	..	19
♂	?	102	..	2
♀ **	S	101	10	4
♀	S	101	8	25
♂	?	101	..	263
♂	?	101	4	...
♀	S	101	1	16
♀	S	101	1	4
♂	?	101	..	32
♀	S	101	..	1
♂	?	100	9	4
♀	S	100	7	6
♀	S	100	6	9
♀	M	100	..	133
♂	M	100	2	24
♀	S	100	1	10
♂	?	100	..	20

*Living 30 September, 1905.
**Living 31 July, 1898.

It will be noted from this table that the most extreme case of longevity which Young was able to authenticate was about a month and a half short of 111 years. Of the 30 centenarians recorded 21 were women and 9 were men. The superiority of women in expectation of life is strikingly apparent at the very high age of 100 years. We shall later see that this is merely a particularly noteworthy instance of a phenomenon which is common to a great portion of the life span.

The contrast between these proved findings of Young exceedingly modest both in respect of numbers and extremity of longevity, and the loose data on centenarianism which one can find in any year's mortarity statistics, is striking. In an examination of the matter recently I found that in the Registration area of the United States there were recorded in the year 1916, out of a total of 1,001,921 deaths at all ages the following as of ages 100 or over.

White males	137
Colored males	116
White females	180
Colored females	216
Total	649

In this large total 4 persons were recorded as having died at age 120, and one, a colored female, at the preposterous age of 134!

B. *There is no generally valid, orderly relationship between the average duration of life of the individuals composing a species and any other broad fact now known in their life history, or their structure, or their physiology.* Many attempts have been made to set up generalizations establishing connections of this sort. Weismann particularly has endeavored to establish such relations only to have them overthrown sometimes by facts which he himself presents. It has, for example, been contended that the larger an animal the longer its life. This is obviously no general law. Again it has been held that no animal lives after reproducing, except such as care for their young, but almost numberless instances can be adduced where no such relationship holds. It will not pay us to examine all the hypotheses of this general type which have, at one time or another, been put forward. With one exception, to which we shall advert immediately, they all suffer from too many important exceptions to be considered valid generalizations.

C. *Natural death as distinguished from accidental death is preceded by definite structural and functional changes in the body.* These changes in the structure of different organs and parts of the body, and in their manner of functioning constitute the material basis of what is called *senescence* or growing old. Some of the morphological and physiological changes which characterize extreme senescence are apparent and known to all. Such are in case of man the bent posture which means a bending and fusion of the elements of the vertebral column, the wrinkled visage, which denotes a profound alteration of tissue elements, and the shuffling and uncertain gait, which bespeaks a failing motor coordination. In Figure 1 these senescent changes are all well indicated in the case of an old man who has received much newspaper notice during the past year, "Uncle" John Snell of Kentucky, who is here shown with his last wife and supposed son. This poor old man has been exhibited about that part of the country as "The oldest living human being," at a claimed age of 131 years. As a matter of fact, Nascher, who has made a careful investigation of the case, finds him to be "about one hundred years old, possibly a year younger or older." The paternity of the 4½ year old boy, though claimed by Shell, is in considerable doubt.

Besides these obvious senescent changes there are going on even more significent changes in the cellular elements which compose the body. Certain of these cellular changes of age were fully described, in a brilliant series of Lowell lectures given a little more than a decade ago by a great master of morphological research, the late Dr. Charles Sedgwick Minot. Over a quarter of a century ago Hodge made a careful study of senile changes in nerve cells. In a man dying naturally at 92 years of age he found marked changes in the cells of the spinal ganglia as compared with those of a new born babe. The chief differences are exhibited in Table 3.

FIG. 1. PHOTOGRAPH OF JOHN SHELL, CLAIMED TO BE 131 YEARS OLD, BUT ACTUALLY ABOUT 100, WITH HIS WIFE AND PUTATIVE SON. (From Nascher).

TABLE 3

Showing the Principal Differences Observed on Comparing the Spinal Ganglion Cells (First Cervical Ganglion) from a Child at Birth With Those from a Man Dying of Old Age at Ninety-two Years.
(From Hodge's data)

	Baby at birth. Male	Old Man
Volume of nucleus	100 per cent.	64.2 per cent.
Nucleoli visible	53 per cent.	5 per cent.
Deep pigmentation	0 per cent.	67 per cent.
Slight pigmentation	0 per cent.	33 per cent.

Hodge found still more marked changes in the antennary lobe of the nervous system of the honey bee. The nature of the changes is shown in Figure 2.

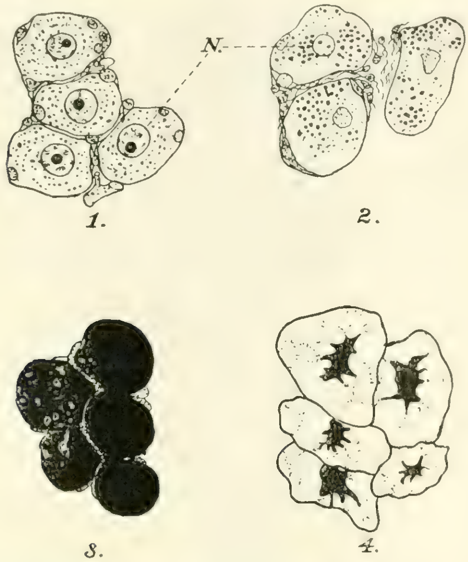


FIG 2. SHOWING THE CHANGES IN NERVE CELLS DUE TO AGE. 1, spinal ganglion cells of a still-born male child; 2, spinal ganglion cells of a man dying at ninety-two years; N. nuclei. In the old man the cells are not large, the cytoplasm is pigmented, the nucleus is small, and the nucleolus much shrunken or absent. Both sections taken from the first cervical ganglion, X 250 diameters; 3, nerve cells from the antennary ganglion of a honey-bee, just emerged in the perfect form; 4, cells from the same locality of an aged honey-bee. In 3, the large nucleus (black) is surrounded by a thin layer of cytoplasm. In 4, the nucleus is stellate, and the cell substance contains large vacuoles with shreds of cytoplasm. (From Donaldson after Hodge).

In the ganglion cells of both man and the honey bee, the volume of the nucleus in proportion to that of the rest of the cell body becomes reduced with advancing age. Dr. Minot showed that this was a very general phenomenon in senescence, and was a continuous process from birth to death. He gave to it and related and associated cellular changes the name "cytomorphosis," and attributed to it the greatest significance in bringing about senescence and death. As we shall presently see, cytomorphosis may perhaps more justly be regarded as one of the morphological results of senescence rather than its cause.

Recently Mrs. Pixell-Goodrich, an English worker, has re-studied the senescent changes in the cells of the honey bee. Her work shows in a striking way the loss of protoplasm in the aged cell. In the young bee immediately after hatching, the cells are large and plump, only separated from each other by narrow strands of connective tissue. In the same region of the same ganglion in an old bee which came from a hive on a fine day in March, but was too weak to effect a cleansing flight and soon became moribund, the nerve cells were quite worn out. There was left only a framework of connecting tissue, with an occasional nucleus of a nerve cell in a more or less necrotic condition, with only a little cytoplasm around it.

There are other, and perhaps even more general and striking morphological changes in senescence than the changed relation between cytoplasm and nucleus. Conklin says:

> By all odds the most important structural peculiarity of senescence is the increase of metaplasm or differentiation products at the expense of the general protoplasm. This change of general protoplasm into products of differentiation and of metabolism is an essential feature of embryonic differentiation and it continues in many types of cells until the entire cell is almost filled with such products. Since nuclei depend upon the general protoplasm for their growth, they also become small in such cells. If this process of the transformation of protoplasm into differentiation products continues long enough it necessarily leads to the death of the cell, since the continued life of the cell depends upon the interaction between the general protoplasm and the nucleus. In cells laden with the products of differentiation, the power of regulation is first lost, then the power of division, and finally the power of assimilation; and this is normally followed by the senescence and death of the cells.

D. *Natural death (as distinguished from accidents) occurs normally and necessarily only in animals composed of many cells.* Unicellular organisms are finally known, chiefly as the result of the brilliant and painstaking researches of Woodruff and his students, to be immortal *in esse* as well as *in posse.* Since the discovery by Woodruff and Erdmann of the process of nuclear reorganization, which they call endomixis, this conclusion is as solidly grounded if we regard a cycle of protozoan divisions as the homologue of the metazoan body, as it is if we consider each individual protozoan as such homologue. Woodruff has been cultivating the common unicellular form *Paramecium*, shown in Figure 3, for over 13 years.

During all this time no conjugation or pairing of individuals has occurred. In a recent letter Dr. Woodruff says: "After we had discovered and worked out endomixis there seemed no particular use of carefully recording the number of generations each day. But the culture is still going on as well as ever and is at approximately the 8500th generation—13½ years old! On May 1st, 1915, (just 8 years old) it was at the 5071st generation." If in 8,500 generations—a duration of healthy reproductive existence which, if the generation were of the same length as in man would represent roughly a quarter of a million years in absolute time,—natural death has not occurred, we may with reasonable assurance conclude that this animal is immortal.

The distinction between Protozoa and Metazoa in respect of the incidence of natural death is so important that it requires a somewhat detailed explanation, together with the reasons for it. Protozoa reproduce by a process of simple division or fission. A particular individual after growing to a certain size simply divides transversely into two like individuals, at first smaller in size, but rapidly growing to full adult magnitude. The essential gross features of this process are illustrated in Figure 4. One can not say which is parent and which is offspring. One individual simply becomes two. Upon occasion another process known as *conjugation* may intervene.

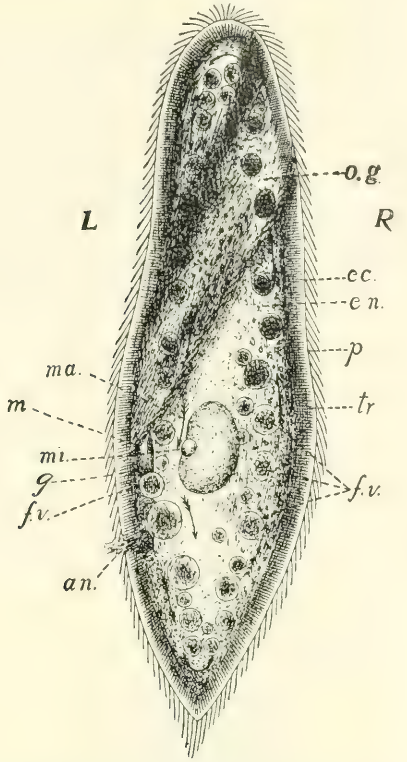


FIG. 3. PARAMECIUM, VIEWED FROM THE ORAL SURFACE. *L*, left side; *R*, right side; *an.*, anus; *ec.*, ectosarc; *en.*, endosarc; *f. v.*, food vacuoles; *g*, gullet; *m*, mouth; *ma.*, macronucleus; *mi.*, micronucleus; *o. g.*, oral groove; *P.*, pellicle; *tr.*, trichocyst layer. The arrows show the direction of movement of the food vacuoles. (From Jennings).

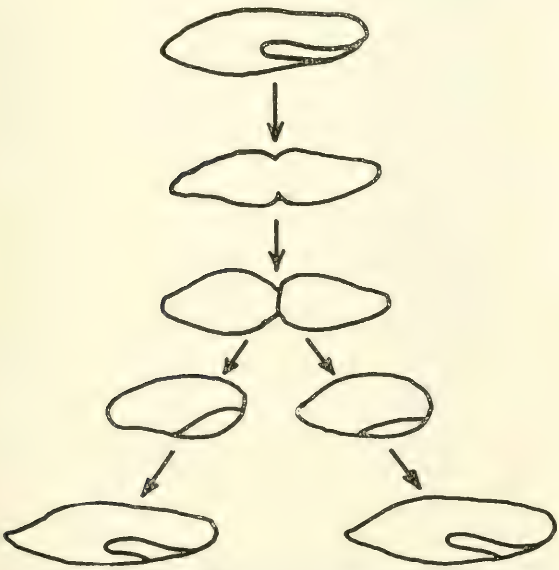


FIG. 4. DIAGRAM SHOWING THE PROCESS OF REPRODUCTION BY FISSION IN THE UNICELLULAR ORGANISM *Paramecium*.

FIG. 5. CONJUGATION IN PARAMECIUM

In this process two individuals mate together. By a process of assortative mating like sizes pair together, as was first shown by the writer and later confirmed by Jennings. After pairing has occurred an interchange of nuclear substance occurs by a complicated mechanism described and figured in many elementary textbooks of zoology. This process of conjugation need not further concern us here, for the reason that Woodruff in the work already referred to has shown that this phenomenon is not essential to the continued life of the race. Its place may be, and normally very frequently is, taken by the process called

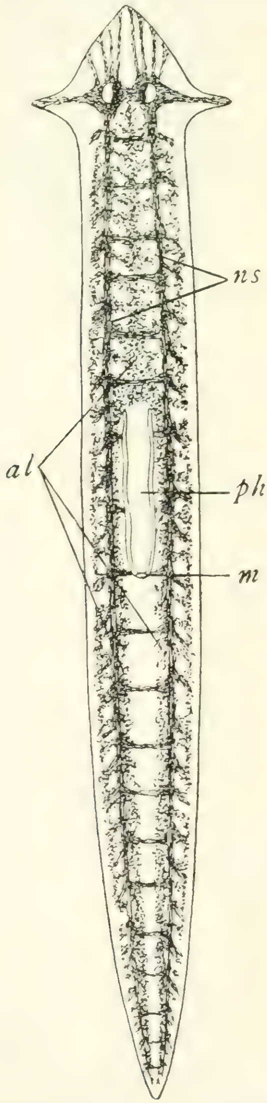


FIG. 6. PLANARIA DOROTOCEPHALA: *m*, mouth; *ph*, pharynx; *al*, alimentary tract; *ns*, nervous system. (From Child).

endomixis. In this process there occurs a nuclear breakdown and reorganization which appears to be the equivalent, functionally at least, of that which takes place during conjugation.

Now it is apparent that there is no place for death in a scheme of reproduction by simple fission such as is illustrated in Figure 4. Nothing is left at any stage to fulfill the proverbial scheme of "dust to dust and ashes to ashes." When an individual is through its single individual existence it simply becomes two individuals, who go merrily on playing the fascinating game of living here and now. There is, in short, no hope that messages will be received from Paramecia in the spirit world, for the simple reason that there is no chance for the soul of a Paramecium—assuming for the argument that he has one—to get there.

In a few of the simplest and most lowly organized groups of many-celled animals or Metazoa this power of multiplication by simple fission, or budding off a portion of the body which reproduces the whole, is retained as a facultative asset. This process of reproduction in which the somatic or body cells of one generation produce the

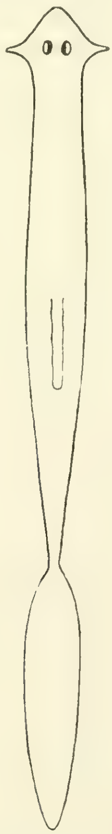


FIG. 7. BEGINNING OF PROCESS OF AGAMIC REPRODUCTION BY FISSION IN PLANARIA (From Child).

somatic cells of the next generation has been called agamic reproduction. It occurs as the more usual but not exclusive mode of reproduction, in some or all forms of the three lowest groups of multicellular organisms, the sponges, flatworms, and coelenterates. More rarely it may occur in other of the lower invertebrate groups. It may occur in the form of budding or of fission comparable to that of the *Protozoa*. The agamic reproduction of one of the flatworms, *Planaria dorotocephala*, studied by the writer many years ago, shown in Figure 6, may serve as an illustration.

This simply organized worm, which lives under stones in sluggish streams and ponds, after attaining a certain size, will under the appropriate environmental conditions exhibit a constriction towards the posterior end of the body, as shown in Figure 7.

For a time the animal moves about as a rather ungainly double individual. It finally separates into two. The larger anterior part forms a new tail, and the smaller posterior fission product forms a new head and rapidly grows to full size. The process is in principle exactly the same as the multiplication of Paramecium by fission. In another member of the same general group of animals as *Planaria*, named *Stenostomum*, several fission planes may form and the process start anew before the products delimited by the first plane have separated. As a result we get frequently in this form chains of individuals attached in a long string to each other, as shown in Figure 8.

It is obvious that so long as reproduction goes on in this manner in these multicellular forms there is no place for death. In the passage from one generation to the next no residue is left behind. Agamic reproduction, and its associated absence of death occurs very commonly in plants. Budding and propagation by cuttings are the common forms in which it is seen. The somatic cells have the capacity of continuing multiplication and life for an indefinite duration of time, so long as they are not accidentally caught in the breakdown and death of the whole individual in which they are at the moment located. Thus virtually every apple tree in every orchard in this country is simply a developed branch or bud of some original apple tree from which it was cut, in many cases centuries ago. Apple trees can not of their own unaided efforts propagate either buds or cuttings. So until the intervention of man apple trees died natural deaths, somatically speaking, just as do the higher animals of which we shall speak presently. But their cells were inherently capable of better things, as was demonstrated when man first cut off a shoot from an old apple tree and provided it with a root by grafting.[2] Then it went on and made a new tree. From it in turn cuttings were taken, and so the process has continued to the present day. A part of the soma of one generation produces the soma of the next generation and goes on living indefinitely.

A different mode of reproduction is characteristic of higher multicellular animals, and in all but the lowest groups is the exclusive method. A new individual is started by the union of two peculiar cells of extraordinary potentialities, called germ cells. These germ cells are of two sorts, ova and spermatozoa. In bisexual organisms the former are borne in the female, and the latter in the male body. Both sorts undergo a complicated preparation for union, the result of which is that when union does occur each party to it contributes either an exactly equal or an approximately equal amount of hereditary material. After union has taken place the fertilized ovum or zygote

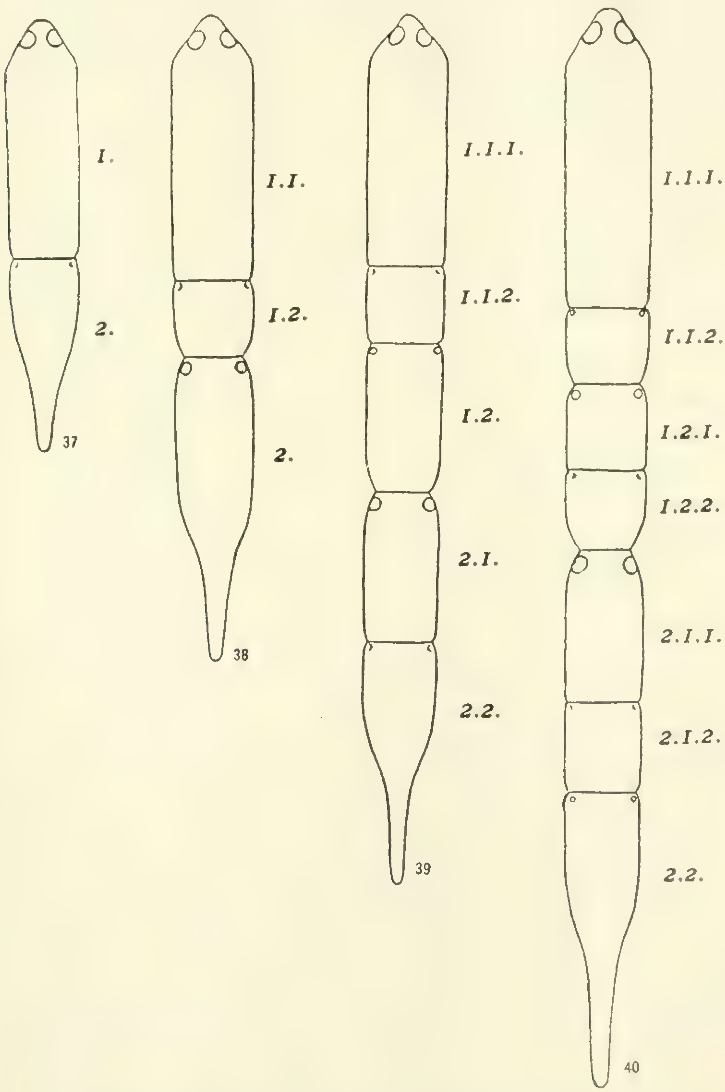


FIG. 8. PROGRESS OF AGAMIC REPRODUCTION IN STENOSTOMUM: the sequence in the formation of new zooids is indicated by the numerals. (From Child).

presently begins to divide, first into two cells, these again to four, and so on until by a continuation of this process of division with concomitant differentiation the whole body is formed. As the animal develops by repeated cell division and differentiation it is frequently found that at a very early stage the cells which are to be the germ cells of the next generation are clearly recognizable by their structure, and often are set aside in a definite location in the developing embryo. Thus, to take out a single example of phenomenon of wide generality, at a very early stage in the development of the dog-fish, when the only bodily organs of which even the rudiments are recognizable are the beginnings of what will presently become the spinal cord and the backbone, it was shown by Woods many years ago that the germ cells are definitely localized and recognizable, as shown in Figure 9.

In some forms, notably the round-worm *Ascaris*, various crustacea and insects, the cells which are to become germ cells are visibly set apart from the very first or one of the first three or four cleavages of the fertilized ovum. For example, in the case of the crustacean *Cyclops* Amma has shown that the granules visible at one pole in the very first division mark the prospective germ path, as shown in Figure 10.

In the gnat *Chironomus* the same thing is visible at a very early cleavage, according to the observations of Harper. For the most comprehensive and critical review in existence of the extensive literature on the *Keimbahn* one should consult the recent contributions of Hegner on the subject.

To condense a long and complicated matter we may state the situation regarding reproduction and death in the *Metazoa* in this way. A higher, multicellular individual may be conceived, from the viewpoint of the present discussion, as composed of two essentially independent portions, the germ cells on the one hand, which are immortal in the same sense that the Protozoa are immortal, and the rest of the body, which it is convenient to call technically the soma, on the other hand. The soma undergoes natural death after an interval of time which as we have seen varies from species to species. The germ cells which the individual bears in its body at the time of its death of course die also. But this is purely accidental death so far as concerns the germ cells. Such of them as were, prior to the death of the soma, enabled to unite with other germ cells went on living just as does the dividing *Paramecium*. Reduced to a formula we may say that the fertilized ovum (united germ cells) produces a soma, and more germ cells. The soma eventually dies. Some of the germ cells, prior to that event produce somata and more germ cells, which in turn produce somata and germ cells, and so on in a continuous cycle which has never yet ended since the appearance of multicellular organisms on the earth.

[2]This provision of roots was not essential, only practically convenient. The cutting would, if enough pains were taken, grow its own roots.

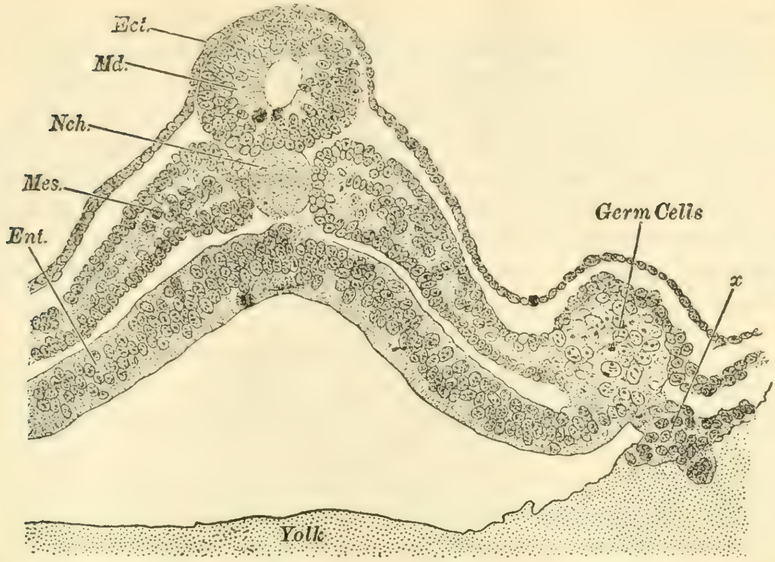


FIG. 9. SECTION ACROSS THE POSTERIOR PART OF AN EMBRYO DOG-FISH (ACANTHIAS) OF 3.5 MM., to show the compact cluster of germ cells on one side. The germ cells in later stages migrate from this primitive position, moving singly or in small groups. *Ect*, ectoderm; *Md*, medullary canal or primitive spinal cord; *Nch*, notochord; *Mes*, mesoderm; *Ent*, entoderm; *X*, cellular strand connecting the germ cell cluster with the yolk. (From Minot after Woods, with permission of the publishers, G. P. Putnam's Sons).

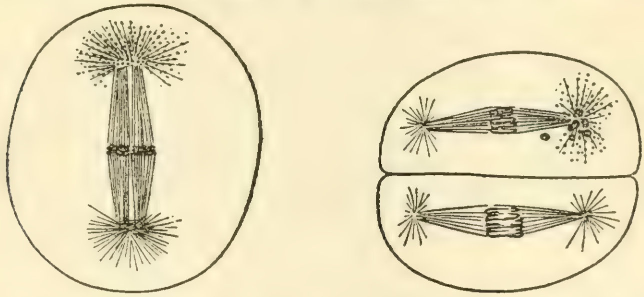


FIG. 10. FIRST AND SECOND DIVISION IN EGG OF CYCLOPS, showing at one pole of spindle the granules which mark the germ path. (From Child, after Amma, by permission of University of Chicago Press).

The contrast between the protozoan and the metazoan method of descent is shown in Figure 11, which is a modification of a similar diagram originally due to my colleague, Dr. H. S. Jennings.

The diagram represents the descent of generations. The upper portion of the diagram shows the mode of descent in forms reproducing from organisms reproducing from a single parent. The lower, or B portion of the diagram shows the mode of descent in form reproducing from two parents. The lines represent the lives of individuals (as in A diagram) or of germ cells (in the B diagram) beginning at the left and passing to the right. In the A diagram which represents uniparental reproduction by fission the line of ancestry traced back from any individual at the right is always single, and there is no corpse to be found anywhere, each present body transforming directly into the two bodies of the next generation. In the B diagram where we have biparental reproduction by the union of germ cells, as in man, the solid black triangles represent the bodies, or somata, and the lines the germ cells. A line of ancestry traced back from any individual towards the right end of the diagram forks at each generation, and in comparatively few generations one has a multitude of ancestors. The *bodies* of one generation have no continuity with the bodies of the previous or the following generation. In each generation the soma dies while new somata are produced by the union of germ cells from diverse lines.

E. *Life itself is a continuum.* A break or discontinuity in its progression has never occurred since its first appearance. Discontinuity of existence appertains not to life, but only to one part of the makeup of a portion of one large class of living things. This is certain, from the facts already presented. Natural death is a new thing which has appeared in the course of evolution, and its appearance is concomitant with, and evidently in a broad sense, caused by that relatively early evolutionary specialization which set apart and differentiated certain

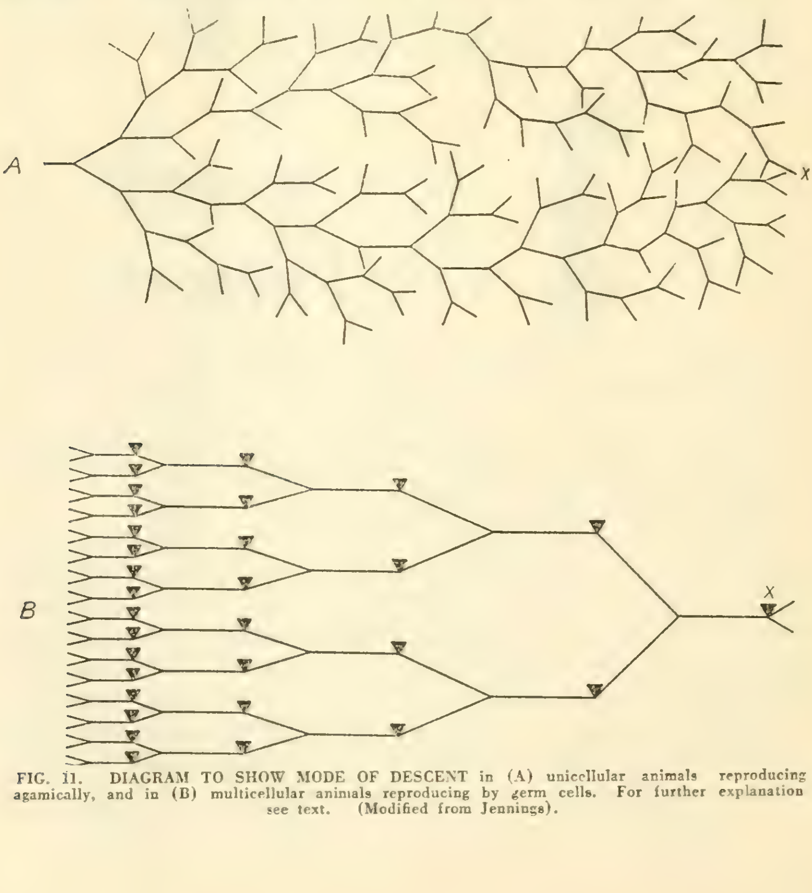


FIG. 11. DIAGRAM TO SHOW MODE OF DESCENT in (A) unicellular animals reproducing agamically, and in (B) multicellular animals reproducing by germ cells. For further explanation see text. (Modified from Jennings).

cells of the organism for the exclusive business of carrying on all functions of the body other than reproduction. We are able to free ourselves, once and for all, of the notion that death is a necessary attribute or inevitable consequence of life. It is nothing of the sort. Life can and does all the time go on without death. The somatic death of higher multicellular organisms is simply the price we pay for the privilege of enjoying those higher differentiations of structure and function which have been added on as a side line to the main business of living things, which is to pass on in unbroken continuity the never-dimmed fire of life itself.

4. Theories of Death

On the basis of these five general classes of facts which have been briefly reviewed a whole series of speculations as to the meaning of death have been reared. Of course, theologians have not failed to assay the ore of so valuable a lode. The one interesting thing to note in passing is that the traditional view which the Christian religion takes of death, is in one important respect in complete accord with the results of modern biology. I refer to the recognition that death is not a *necessary* adjunct or "grand characteristic of life itself." In the view of the Church death is a consequence of sin, and prior to the advent of sin living things were in order to continue indefinitely in the enjoyment of life. Now in this statement what the theologian calls sin the biologist calls differentiation. A wonderful sermon could be preached on this identity of sin and differentiation. It has, of course, always been recognized that the sinful was different. Consideration of the matter convinces one immediately that all too frequently in man's sad history here below the different has been regarded as sinful. But as the object of this discussion is not theological I refrain from pursuing further so alluring a theme.

The first attempt at a biological evaluation[3] of the meaning of death which attracted the serious attention of scientific men was that of Weismann. In his famous address of 1881 on the duration of life, Weismann propounded the thesis that death was an adaptation, advantageous to the race, and had arisen and was preserved by natural selection. Probably no more ridicuously absurd and perverse extension of the theory of natural selection than this was ever made. It appeared, however, just at the time when the post-Darwinian attempt to settle the problems of evolution by sheer dialectic was at the zenith of its popularity. Now-a-day such a doctrine as Weismann's would not receive so respectful a hearing.

Metchnikoff, whose views excited so much popular interest some years ago, held that death was the result of intoxication, arising from the absorption of putrefactive products of the activity of intestinal bacteria. For obvious reasons such a view has no general validity and does not touch the philosophical problem of the biological meaning of death. More philosophic developments of the same basic idea have been presented by Jickeli and Montgomery. Both held that because of the mechanical incompleteness of the processes of cellular metabolism injurious and toxic substances tend to accumulate in the cells of the body and that senescence and death are the results of such accumulations.

A much broader, and in the light of all the facts sounder view, is that the determination of degrees of longevity and of the fact of death itself, is inherent in the biological constitution of the individual and the species. This view was expressed by Johannes Müller a quarter of a century ago in his *Physiologie*, by Cohnheim forty years later, and has had many later adherents. I shall return to a discussion of it later.

There have been a number of theories of senescence and death, differing widely in details, but having the one point in common of attributing these phenomena to orderly changes with advancing age in the relative proportion of nucleus to cytoplasm in the cells of the body. Here may be mentioned, without pausing to go into detailed consideration of their different views Verworn, Mühlmann, Richard Hertwig, and Minot.

Another group of hypotheses, all advanced in comparatively recent times and associated with the names of Kassowitz, Conklin, and Child, are developed about the metabolic aspects of age changes. There is observed a decrease in assimilatory capacities of cells with differentiation and age. These metabolic changes are regarded as fundamentally causal of the phenomena of senescence and death. In this general group of hypotheses would belong the views of my colleague, Dr. W. T. Howard.

Benedict in a detailed investigation of senility in plants reaches the conclusion

"that the duration of life is directly linked with the degree of permeability in that part of the living cell which places it in contact with the universe about it, and that as the activities of life proceed the cell is being gradually entombed by an inevitable decrease in the permeability of its protoplasm.

While decreasing permeability furnishes a possible explanation of the more obvious symptoms of senility, it cannot be the only degeneration of first rank. All protoplasmic functions must be involved. Underlying these primary causes of senile degeneration there must be some general fundamental cause from which they spring. This fundamental cause may well be the colloidal nature of protoplasm."

Delage and Jennings have considered that death is the result of differentiation. Unicellular organisms, as we have seen, do not nor-

[3]The following brief review of the various biological hypotheses which have been advanced as to the meaning of death is largely based upon and follows the excellent discussion of the matter given by Child in his "Senescence and Rejuvenescence."

mally experience natural death. In the higher organisms there has been a progressive setting apart of cells and tissues to perform *particular* vital functions with a consequent loss of the ability to perform *all* vital functions independently. As soon as any one of these cells or tissues begins for any cause whatever to fail to perform its special function properly it upsets the delicate balance of the whole associated community of cells and tissues. Because of the differentiation and specialization of function the parts are mutually dependent upon each other to keep themselves and the whole going. Consequently any disturbance in the balance which is not promptly righted by some regulatory process must eventually end in death. Essentially this view of the matter has been well set forth by Loeb in his most recent paper on the subject. He says: "All this points to the idea that death is not inherent in the individual cell, but is only the fate of more complicated organisms in which different types of cells or tissues are dependent upon each other. In this case it seems to happen that one or certain types of cells produce a substance or substances which gradually become harmful to a vital organ like the respiratory center of the medulla, or that certain tissues consume or destroy substances which are needed for the life of some vital organ. The mischief of death of complex organisms may then be traced to the activity of a black sheep in the society of tissues and organs which constitute a complicated multicellular organism."

At this point I shall not stay to discuss critically each of the hypotheses so summarily reviewed. Instead I shall make bold to state somewhat categorically my own views on the origin and meaning of death and the determination of longevity, and in what follows shall endeavor to set forth in orderly array the evidence which seems to me to support these views. In this process the relations to the conclusions of earlier investigators of what I shall suggest will, I think, sufficiently appear.

Let us consider, then, the following picture of life and death.

1. Life itself is inherently continuous.

2. Living things, whether single-celled or many-celled organisms, are essentially only physico-chemical machines of extraordinary complexity, but regardless of their degree of complexity only amenable to, and activated in accordance with, physical and chemical laws and principles.

3 The discontinuity of death is not a necessary or inherent adjunct or consequence of life, but is a relative new phenomenon, which appeared only when and because differentiation of structure and function appeared in the course of evolution.

4. Death necessarily occurs only in such somata of multicellular organisms as have lost through differentiation the power of reproducing the whole soma from a part of it, or still possessing such power in their cells, have lost the necessary mechanism for separating a part of the soma from the rest for purposes of agamic reproduction.

5. Somatic death results from an organic disharmony of the whole organism, initiated by the failure of some organ or part to continue in its normal harmonious functioning in the entire differentiated and mutually dependent system. This functional breakdown of a part may be caused in a multitude of ways from external or internal sources. It may manifest itself in a great variety of ways both structurally and functionally. Many of these manifestations which have been regarded as causes of senescence, may more truly be considered concomitant attributes of senescence.

6. As a consequence of our second thesis which postulated life to be a mechanism, death, whether of a single somatic cell or of a whole soma, is a result of physico-chemical changes in the cell or organism and these changes are in accordance with ordinary physico-chemical laws and principles

7. The time at which natural death of the soma occurs is determined by the combined action of heredity and environment. For each organism there is a specific longevity determined by its inherited physico-chemical constitution. This specific longevity is capable of modification, within relatively narrow limits, as a result of the impact of environmental forces, the chief mode of action of the environment being in the direction of determining the rate at which the inherited endowment is used up.

For no one of the separate elements of this picture can I claim any particular originality. Most of them would probably be agreed to at once, at least by some biologists. The need is for a synthesizing into a consistent whole of a wide range of data which have accumulated in various fields of biology about death and the duration of life. Such a synthesis will be attempted in what follows. Generally those who have speculated about the biology of death have drawn their evidence from, or at least had their thinking largely colored by the facts in a relatively small part of the whole field. In particular few biologists have any detailed knowledge of the most impressive mass of material, both in respect of quality and quantity, which exists regarding the duration of life of any organism. I refer, of course, to the enormous volume of rather exact data regarding human mortality. Much of this material, to be sure, wants proper analysis, not only mathematical but biological. But that it is a rich material admits of no doubt.

HAIR COLORATION IN ANIMALS

By Dr. LEON AUGUSTUS HAUSMAN
CORNELL UNIVERSITY

IN some recent papers[1] the writer has endeavored to point out that an accurate knowledge of the histology of mammalian hair may be applicable not alone in the field of pure zoological science, but also in the standardization of furs and fabrics in the industries. The need of some sure means for the identification of textile and fur materials, and for their standardization, is increasingly recognized. The methods of identification which will prove most useful will be those which can be applied, with results of unimpeachable certainty, to any textiles, furs, or fur products, no matter how great a degree of modification away from their original color or texture they may have undergone. In the papers already referred to, attention is called to certain microscopic elements in the structure of the hair shaft which are of value in determining the species of mammal from which the hair was taken. These structural elements are the medulla, or central column of "pith" cells, and the cuticular scales, forming the outermost investiture of the hair shaft. (Fig. 1). The writer has suggested[2] that the pigment granules in the hair shaft, to which the color of the hair is primarily due, may also be used as determinative criteria for identification, when considered either alone or in conjunction with the other compositional units of the hair shaft structure. This paper will strive to show how the nature of the pigment granules in the hair shaft can be used in aiding in the identification of hairs. Detailed criteria of this sort may be useful in making determinations of very small fragments.

The various colors of animal hairs are due either to pigment materials within the shaft, or coloring matter deposited on the outside of the cuticle, and may be modified by the way in which light is reflected from the surfaces of the various structures of the hair shaft itself. Hair which owes its hue to the latter cause is comparatively rare, being found, for example, on the flanks and base of the tail in members of the weasel tribe, and appearing as a yellow tint, from deposits from skin glands. In the great majority of cases, however, it is the presence of pigment *within* the hair shaft which gives color to the hair.

[1]Hausman, L. A., The Microscopic Identification of Commercial Fur Hairs, Sci. Mon., Vol. 10, Jan., 1920, p. 70; Hairs That Make Fabrics, Sci. Am., Feb. 21, 1920, p. 184; Structural Characteristics of the Hair of Mammals, Am. Nat., Vol. 44, Nov.-Dec. 1920, p. 496.

[2]Hausman, L. A., Mammal Fur Under the Microscope, Nat. Hist. (Jour. of Am. Mus. Nat. Hist.) Vol. 20, No. 4, 1920, p. 434.

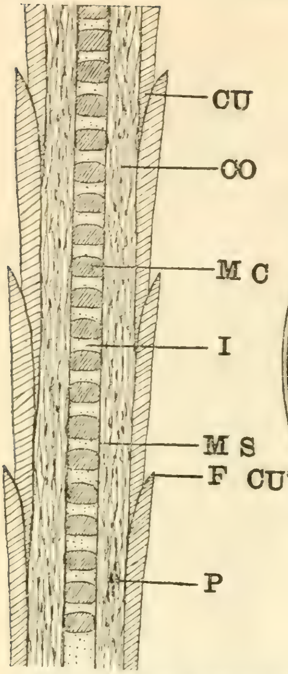


FIG. 1.—Ideal longitudinal section through a generalized mammal hair, CU. cuticular scale, CO. cortex, MC. medullary cells, I. interspaces between medullary cells, MS. medullary shaft, or column, F. CU. free edge of cuticular scale, P. pigment granules in cortex.

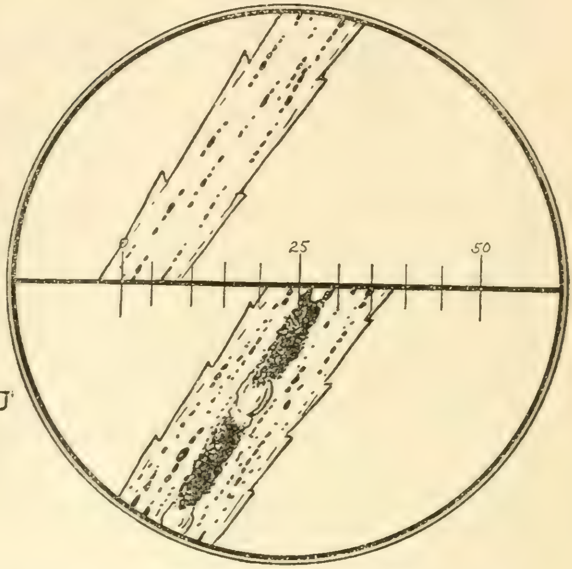


FIG. 2.—Fur hairs from the American otter (above), and the coypu, or "nutria" (below), seen in the comparison ocular. The scale in the center is that of the micrometer eyepiece. Each division equals 5 microns. One micron equals about 1/125,000 of an inch.

The pigment material within the hair shaft may be diffuse *i. e.*, not present in the form of distinct masses, and, if such is the case, the whole shaft is homogeneously stained, and the hair appears, even under the highest powers of the microscope, as a uniformly colored structure. Yellow, or amber hairs are usually pigmented in this way.

The most common cause of color in hair, however, is not external deposit, or internal diffuse stain, but the presence of pigment masses, occurring (1) in the cortex as separate granules, or (2) in the medulla, usually as amorphous masses, though sometimes as discrete granules. Fig. 1 shows a generalized mammal hair, to make clear the relationship of the structures, medulla, cortex, and cuticle.

The hair of the polar bear (Fig. 3) may be taken as typical of a pure white, i. e., colorless, hair. It will be seen that no pigment is present in the cortex of such a hair, which appears under the microscope as a transparent, glassy shaft. The medulla appears to be dark in color. This is due, possibly, to a slight amount of black pigment in the fused medullary cells, but more largely to the dispersion of light from the microscope mirror.

The addition of black pigment in the medulla, very commonly in the form of lenticular masses between the medullary cells, produces hairs of varying shades of gray, a common fur color among mammals. Fig. 5 illustrates the nature of the pigmentation in a hair of typical gray color, the drawing being made from near the middle of the fur hair[3] of the large blarina. An increase in the size of these medullary pigment masses gives to the hair a darker gray color, as illustrated in the hair of the Sewellel, Fig. 6. The size, mode of placentation and especially the form of the medullary pigment masses are in most cases characteristic of the species possessing them, and can be used as valuable aids in identifying hair samples. Gray hair, produced by these lenticular medullary pigment masses, is extremely common among the moles, shrews, voles and soft-fur bearing animals.

Brown pigment masses, composed of granules more or less perfectly fused, are also found between the medullary cells of certain hairs, imparting brown colors, as, for example, in the hair of the cottontail rabbit, Fig. 12. The intensity of the color varies according to the size of the medullary masses, and the depth of color of the component granules. Hairs colored in this way may vary from a light yellowish to a deep reddish brown. Hairs are occasionally found possessing granules in the medulla separate, and not fused. When such is the case the granules are grouped into aggregations of characteristic form and size. Such a condition is illustrated near the base of the fur-or underhair of the muskrat. (Fig. 18).

In a few cases the medullary pigments are also present in the form of separate granules, which are scattered about among the cells of the medulla in a rather uniform way. This gives a pigmentation character quite different from those already mentioned. These granules seem to be largely black, or of various shades of brown. Typical examples of such very distinctive pigmentation characters may be seen in the gray fur hairs of the Sennett kangaroo rat (Fig. 7), in the yellowish-brown hairs of the prairie dog (Fig. 11), and in the yellow hairs of the domestic guinea pig (Fig. 14).

The pigment materials found in the cortex of the hair are usually present in the form of disjunct granules, and are less often coalesced into masses than in the medulla. Furthermore, their patterns of arrangement are all built up along an axis parallel to the hair shaft. This is because the granules are deposited in and among the elongate, fusiform cells, or hair spindles, that go to make up the cortex. (See Fig. 1, CO.). The colors caused by the presence of cortical granules are the various shades of yellows, browns, reds, etc., to black, depending on the depth of color of the granules, and their numbers. The hair

[3]Two varieties of hair occur commonly in mammals: the *fur,* or *under*-hair, usually soft and thick; and the *protective,* or *over*-hair, longer, and stiffer. In the make-up of many furs the protective hair is removed.

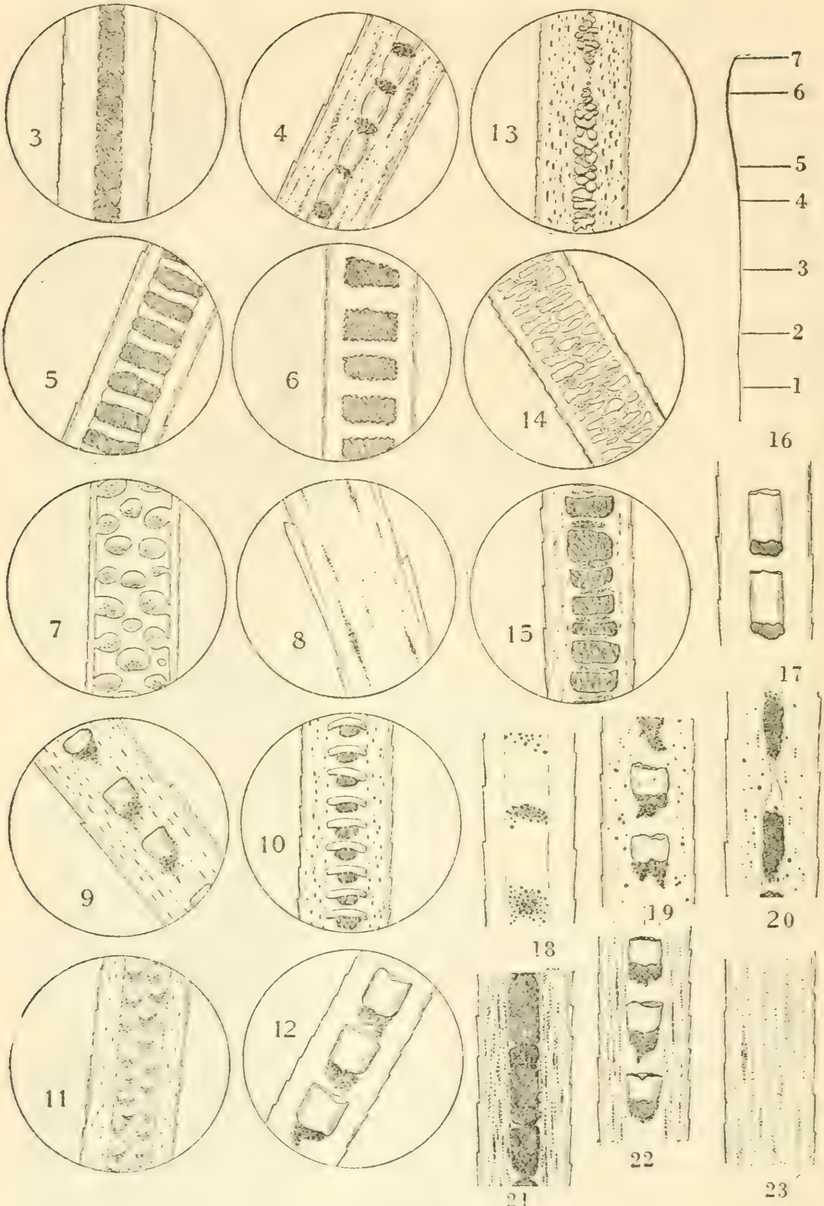


PLATE I

Explanation of Figures 3 to 23

Figs. 3 to 15 represent the conditions in the fur hair of the species, midway from the tip to the base, in each case, unless otherwise noted. For comparison, the diameter of each hair is given in micra.

Fig. 3. Polar bear (Thalarctos maratimus), 52 μ, color white

Fig. 4. Black bear (Ursus americanus), 46 μ., color, dark brown, almost black.

Fig. 5. Blarina (Blarina brevicauda), 38 μ, color, gray.

Fig. 6. Sewellel (Aplodontia californica), 25 μ., color, dark gray.

of the big brown bat (Fig. 8) is a typical example of a pure brown hair which owes its color solely to cortical granules. Fig. 23, from the tip of the fur hair of the muskrat, and Fig. 29, from the tip of the protective hair[3] of the same species, illustrate the same conditions of cortical pigmentation.

In most instances, however, the colors in hair are produced by a combination of cortical and medullary pigmentation, sometimes with the addition of diffuse color as well. In the hair of the black bear (Fig. 4), for example, the color is due to very dark brown cortical granules, plus black medullary masses. Light brownish or yellowish cortical granules, plus dark brown medullary masses, produces dark brown fur, as in the New York weasel (summer pelage), Fig. 9. Fig. 10, taken from near the tip of the fur hair of the large blarina, shows the usual pigmentation conditions in a dark grayish brown hair *i e.*, black medullary masses, and some few light brown cortical granules. Figs. 13 and 15, hair from the squirrel monkey and marmoset, respectively, illustrate the typical conditions found in yellow or yellowish hairs, *i. e.*, yellow granules both in medulla and cortex, or yellow granules in cortex, and yellow masses in the medulla.

These descriptions of pigmentation characters have been adduced thus in detail to show that the significant thing from the standpoint of fur identification is not the structural cause of the different colors, but that pigmentation characters can be used as aids in identification.

The pigmentation in the fur hair of a species often differs from that in the protective hair. There is likewise a change in the character if the pigmentation from the base to the tip of both varieties. The nature of these pigmentation differences in the hairs of the same animal can be well illustrated from the hair of the muskrat. Fig. 16 shows an entire muskrat fur hair, from base to tip. The numbers 1 to 7 refer

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Fig. 7. Sennett Kangaroo Rat (Perodipus sennetti), 40 μ., color, gray.
Fig. 8. Brown Bat (Vespertilio fuscus), 8 μ., color, brown.
Fig. 9. New York Weasel (Putorius noveboracensis), 10 μ., color, brown.
Fig. 10. Blarina (Blarina brevicauda), tip of fur hair, 30 μ., color, grayish brown.
Fig. 11. Prairie dog (Cynomys ludovicianus), 50 μ., color, yellow-brown.
Fig. 12. Cottontail rabbit (Lepus sylvaticus), 10 μ., color, brown.
Fig. 13. Squirrel monkey (Chrysothrix sciurea), 47 μ., hair from wrists, color, deep yellow.
Fig. 14. Guinea pig (Cavia porcellus), 76 μ., color, yellowish.
Fig. 15. Marmoset (Hapale jacchus), median band of yellow in the fur hair, 25 μ., color, yellow.
Fig. 16. Muskrat (Fiber zibethecus) the entire fur hair, to serve as a guide figure. The numbers, 1, 2, 3, etc., refer to points represented by Figs. 17, 18, 19, etc.
Fig. 17. Muskrat-Character of pigmentation at point 1, Fig. 16.
Fig. 18. Muskrat-Character of pigmentation at point 2, Fig. 16.
Fig. 19. Muskrat-Character of pigmentation at point 3, Fig. 16.
Fig. 20. Muskrat-Character of pigmentation at point 4, Fig. 16.
Fig. 21. Muskrat-Character of pigmentation at point 5, Fig. 16.
Fig. 22. Muskrat-Character of pigmentation at point 6, Fig. 16.
Fig. 23. Muskrat-Character of pigmentation at point 7, Fig. 16.

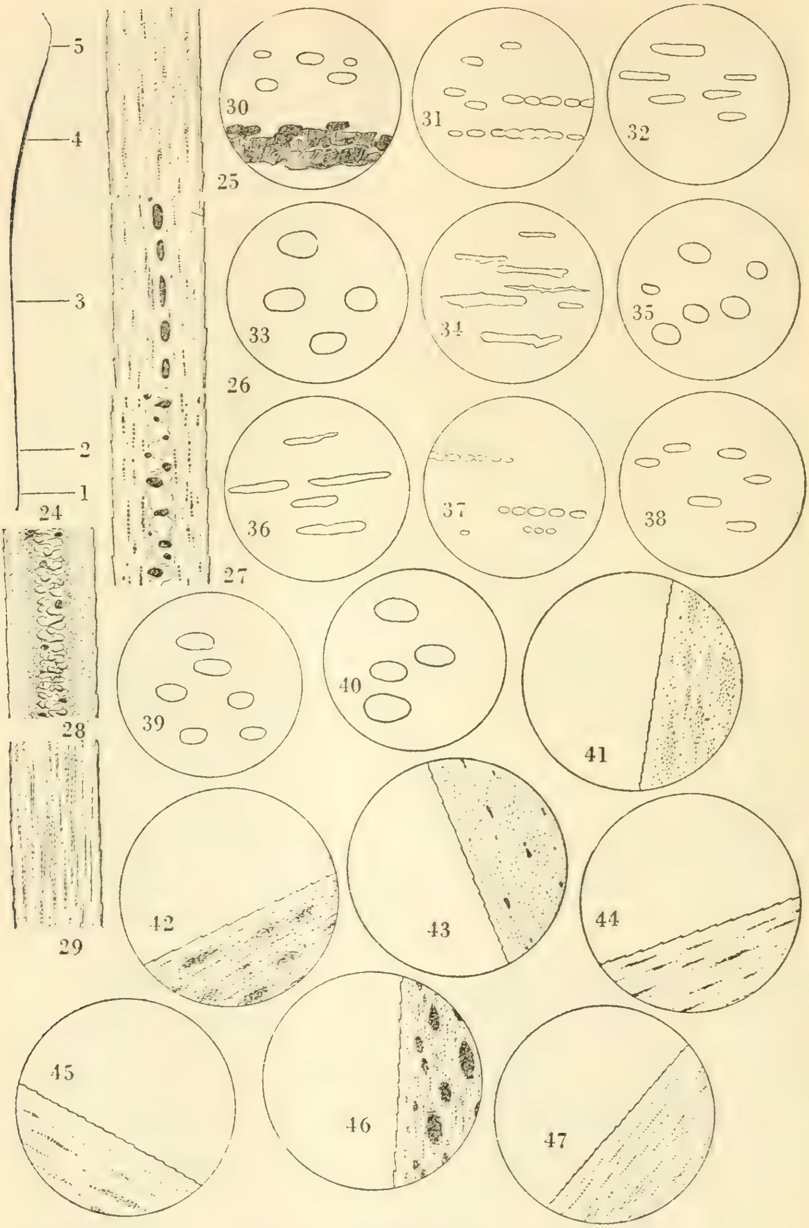

PLATE II

Explanation of Figures 24 to 47.

Fig. 24. Muskrat (Fiber zibethecus), the entire protective hair, to serve as a guide figure. The numbers 1, 2, 3, etc., refer to points represented by Figures 25, 26, 27, etc.

Fig. 25. Muskrat-Character of pigmentation at point 1, Fig. 24.

Fig. 26. Muskrat-Character of pigmentation at point 2, Fig. 24.

Fig. 27. Muskrat-Character of pigmentation at point 3, Fig. 24.

Fig. 28. Muskrat-Character of pigmentation at point 4, Fig. 24.

Fig. 29. Muskrat-Character of pigmentation at point 5, Fig. 24.

to localities illustrated by Figs. 17 to 23, respectively. It will be noted that there is a progressive increase in the density of the pigmentation from base to tip, as well as a change in the nature of the relationships between the black medullary pigment masses (Fig. 17), the brown medullary masses (Fig. 18 to 22), and the brown cortical granules (Figs. 19 to 22). A somewhat similar color change can be followed along the length of the protective hair of the muskrat, (Figs. 24 to 29).

The pigment granules themselves, particularly those present in the cortex, also show variations. These are variations in form, size, color value and color depth, and are susceptible of accurate comparison, as an aid in determining to species-source of the hair, or part of the body from which the hair was taken. As has been pointed out in the case of the muskrat, the character of these granules bears a relationship to their position in the hair shaft.

The value of the prosecution of the detailed study of pigmentation of mammal hairs may be looked for in the application it may have to problems connected with the artificial coloring of furs; in its value for the additional data which it yields for the identification of the species-source of hair samples, and especially in the possibility which

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Fig. 30. Coypu rat (Myocastor coypus), pigment granules, midway from tip to base in fur hair. Length, 0.775 μ.

Fig. 31. Sea Otter (Latax lutris), pigment granules, midway from tip to base in fur hair, Length, 0.46 μ.

Fig. 32. American Otter (Lutra canadensis), pigment granules, midway from tip to base in fur hair. Length, 1.18 μ.

Fig. 33. Muskrat (Fiber zibethecus) pigment granules in tip of fur hair, Length, 0.91 μ.

Fig. 34. Squirrel monkey (Chrysothrix sciurea), pigment granules, midway from tip to base in yellow hair of wrists. Length, 1.80 μ.

Fig. 35. Fur Seal (Callorhinus alascensis), pigment granules near base of protective hair. Length, 0.76 μ.

Fig. 36. Black bear (Ursus americanus), pigment granules midway from tip to base in fur hair. Length, 1.20 to 1.85 μ.

Fig. 37. Brown Bat (Vespertilio fuscus), pigment granules midway from tip to base in fur hair. Length, 0.20 to 0.53 μ.

Fig. 38. Chinese (Manchu), pigment granules in head hair, midway from tip to base. Length, 0.74 μ.

Fig. 39. Eskimo (St. Lawrence Id.), pigment granules in head hair midway from tip to base. Length, 0.91 μ.

Fig. 40. Fingo (Bantu), pigment granules in head hair, midway from tip to base. Length, 1.06 μ.

Fig. 41. Papuan of New Guinea, pigment granule patterns in head hair, midway from tip to base.

Fig. 42. Fingo (Bantu), pigment granule patterns in head hair, midway from tip to base.

Fig. 43. English girl (hair, golden red), pigment granule patterns in head hair, midway from tipe to base.

Fig. 44. English girl (dark brunette), pigment granule patterns in head hair, midway from tip to base.

Fig. 45. Early Egyptian (floruit, 4,000 B. C.), pigment granule patterns in head hair, midway from tipe to base.

Fig. 46. South African Bushman, pigment granule patterns in head hair, midway from tip to base.

Fig. 47. Chinese (Manchu), pigment granule patterns in head hair midway from tip to base.

it affords of identifying minute fragments of hair, when these may be the only ones available in an investigation, as is sometimes the case in legal work.

It was the possibilities of the forensic application of the study of mammal hairs, which has induced the author to make a cursory survey of samples of the head hair of different races of man, to determine whether the pigmentation characters, so marked among the mammals, might not be equally well-defined in human hair. While the results of this tentative survey have not been conclusive, they are most suggestive.

The coloration of human hair appears to be due, in large measure, to either diffuse pigment (as is the case in "red" hair), or to granules in the cortex. The cortical granules are arranged in patterns, of distinctive size and form, for several of the chief races which were examined. Figs. 41 to 47 illustrate various forms of cortical granule patterns from the head hair of members of different races, and Figs. 38 to 40 depict separate pigment granules. The further study of pigmentation in human hair, may bring to light relationships of forensic significance.

For the study of their pigmentation, mammal hairs need to be prepared in the same way as for the study of the medulla, i. e., cleared and mounted in oils of various sorts, or Canada balsam.[4] They should be examined under the highest powers of the microscope, obtainable with oil-immersion objectives of greatest amplification in combination with 18, 20, and 25-power oculars.

An indispensable piece of apparatus for those who wish to make careful identifications is the comparison ocular. This is fitted to two microscopes, and each microscope exhibits half of its field in the comparison ocular, in such a way that two samples of hairs or other fibers, mounted separately on two slides, can be enlarged to equal magnitudes and brought close together for comparison within the same microscopic field. The utility of such a device will be at once apparent. Figure 2 shows a drawing, made from a photomicrograph, of one of the common fur hairs of commerce, and its imitator. The differences in the pigmentation of the two hairs becomes at once apparent when the hairs are thus brought together for comparison. A micrometer scale in the eyepiece aids in making measurements.

The development of micro-analysis has, during the past several years, been very great, and its utility in industrial fields, as well as in pure science, has been firmly established.

[4]For the technique of hair examination, see Hausman, L. A., Structural Characteristics of the Hair of Mammals, footnote 1.

Papers Presented Before the Section of Social and Economic Science of The American Association for the Advancement of Science

SOME PRELIMINARIES OF PEACE[1]

By the Honorable DAVID JAYNE HILL
WASHINGTON, D. C.

A YEAR ago, at St. Louis, we were discussing the merits of the League of Nations as a mechanism for securing the world's peace. It was then pointed out that the Covenant of the League undertakes to accomplish two separate and different purposes—the execution of the Treaty of Versailles and the establishment of permanent peace in the future. It was then made evident not only that these two purposes are disparate, but that the means to be employed for the realization of them must be different.

Before we can discuss intelligently the problem of permanent peace, it is necessary to distinguish between the termination of an actual state of war and the establishment of the conditions of permanent peace in the future.

An actual war is normally terminated by the exercise of superior force; for war is, by its very nature, a contest of opposing forces, each seeking the mastery of its opponent. The war with Germany, for example, could be terminated in no other way than by overpowering the enemy's forces and compelling the vanquished to accept terms of peace imposed by the conqueror. Such terms were embodied in the Treaty of Versailles and accepted by Germany. Whether they are just or unjust is not in this place a question to be considered. The important point to emphasize is that they were *terms imposed by force*, and that the Covenant of the League of Nations was designed as an instrument to carry them into execution. It creates an armed military and political alliance for the enforcement of the Peace of Versailles.

Considered from this point of view, the League of Nations has a legitimate reason for existence; but why neutral nations, or any nations not associated in the war and directly responsible for the particular peace imposed, should be incorporated in the League, is a question that requires an answer. The obvious answer is, that it is intended to maintain the future peace of Europe *by an armed coalition.*

That this is really the purpose of the existing League of Nations

[1]Address of the President and Chairman of the Social and Economic Science Section of the American Association for the Advancement of Science, Chicago, December 28, 1920.

is evident from the pledge contained in Article X to preserve, unconditionally, the territorial integrity and political independence of every Member of the League; and from the provisions of Article XVI, which declares that a state of war with all the Members of the League will arise, *ipso facto*, whenever a Member fails to comply with the obligations of the Covenant. In express terms, therefore, it is a *war* league, not a *peace* league; since peace is to be preserved, not by voluntary agreement to observe certain principles, but by the threat of war. The conclusion is inescapable that the league is a compact for the exercise of economic and military force, to be brought into operation automatically whenever a provision of the treaty is violated.

It would seem superfluous to insist that this attempt to base the peace of the world on an exercise of economic and military force is a preparation for permanent peace. The settlement of a past war on the terms of the victors, whatever they may be, and the prevention of future wars, are clearly undertakings so fundamentally different, and in truth so incompatible, that they are not to be accomplished by the same means or in the same manner. We rightly use force to subdue an enemy who challenges our rights; but we can not base permanent peace upon the pretension of any group of nations that a nation wronged may not defend its rights by force of arms, except by the permission of that group.

And here it is important to note the fact, that there are in Europe, including the United Kingdom, according to the latest statistics, 247,848,168 inhabitants, occupying a territory of 1,410,219 square miles, who are represented by their governments in the League of Nations; and 271,701,401 inhabitants, occupying 2,721,118 square miles, who are not represented in the League of Nations—that is, the non-members in Europe *exceed* the members of the League of Nations in Europe by 23,653,233, occupying territory of *twice* the extent of that occupied by the inhabitants of Europe, including the United Kingdom, represented in the league.

At present, it is true, the league contains the nations possessing the greater military strength; but it does not follow that this will always be the case, especially if there should be dissensions among the members of the league. At most, the league represents only a small preponderance of military efficiency, consisting chiefly in the possession of superior armament, and not at all in numbers. The retention of this preponderance will require the enforcement of the policy of preventing the non-members from arming, while the members continue to maintain their armed forces. But this is, in effect, a continuation of a latent state of war.

It can not, therefore, be said that, even if the terms of the treaties made at Versailles, St. Germain and Sèvres can be enforced, they insure the permanent peace of Europe. This is not to affirm that the victory of the Allies was not an essential step toward permanent peace. On the contrary, it was absolutely necessary. The lesson it has taught is, that, however formidable an aggressor may appear at the momment of aggression, the world can not be permanently ruled by military force. The appeal to force is in itself a challenge to all that is highest and best in human nature. The resort to military force as a means of maintaining the right to control the action of other nations is in its very nature a menace of despotism, and there never has been, and never will be, any permanent despotism in human history.

Herein lies the fallacy of the whole theory of enforcing peace universally by military power. There never was, and there never can be, any permanent exclusive monopoly in the power to enforce the conditions of peace. The mere pretense of possessing it is a declaration of war. The reason is that this pretension strikes a fatal blow at the whole theory of self-government, for it implies a superiority of right and of judgment in the possessors of power which no nation can rightly claim to possess alone, and which no self-constituted council of nations can vindicate the right to exercise.

When civilization is attacked, it will always find means to defend itself; but civilization can never be more plainly or more fundamentally attacked then when a self-constituted combination of powers assumes the authority to say that a nation shall not vindicate its rights by force of arms when there is no other available means of redress.

What then is the true foundation of peace? It is the provision of means of redress without a resort to arms. It is the recognition of a right to those conditions of life that are essential to the satisfaction of a people's needs, and the establishment of a tribunal before which a nation's wrongs may obtain the judgment of a just judge.

I have spoken of the rights and wrongs of nations, because the existence of organized nations is not only a historic fact but a human necessity. There cannot be a world government that is not supported by national governments; for government, aside from futile dreams of universal empire, is of necessity local in its bases. It is a process of development by which families and communities establish the conditions of life with their neighbors. History is largely made up of the efforts of men to impose upon others submission to their control, but it has never anywhere been permanently successful except by the consent of the governed. The whole foundation of peace must be sought through the recognition of that consent.

The basis of human life is material subsistence. The standard of peaceful living is accepted law. These are the essential prerequisites of permanent peace. Without them it is illusory to try to enforce it anywhere.

What is needed at this time is a reorganization of the Society of Nations *as a whole,* including *all peoples* that maintain a responsible government; and the test of responsible government is acceptance of International Law, which is based on the inherent rights of sovereign States, and obedience to that law. What International Law *is* can only be determined by a properly constituted international tribunal. It should be a tribunal to which all responsible governments may appeal, *of right,* for the redress of their wrongs. What International Law is to *become* will depend upon the willingness of the nations to accept freely and support faithfully the principles of jurisprudence which are held to be governing in civilized states, and these are not difficult to determine.

Can it be claimed that it is the prerogative of any minority league to make the Law of Nations, and to apply it through a tribunal created exclusively by itself? If not, is it not evident that the league can not by its superior force, make itself a substitute for the Society of Nations? Does it not then become clear that the reorganization of the Society of Nations must be accomplished by the cooperation of nations outside of the league with those inside of it?

To this it may be answered, that the Society of Nations could be completed by eventually admitting *all* responsible nations into the league.

This would be so if the league were not a military alliance, and were open to all responsible nations, without other conditions than their voluntary consent to enter it and their free participation in amending it; but the nature of the existing league does not admit of this choice and this freedom. It is a predetermined compact, designed not to meet the necessities of a free association of equals, but to carry out the purposes of the victors in rendering the vanquished powerless now and hereafter. It would be illogical, for example, to admit Germany into this league, which has been organized expressly to impose penalties upon that nation; and admission would never be sought for any other purpose than defeating the object of the league in this respect. And yet, why has not Germany, if able to maintain a responsible government, having accepted the terms of peace imposed, a perfect right to a place in the Society of Nations, and to appeal to a neutral tribunal capable of deciding whether or not she fulfills her treaty obligations? If a nation, though conquered, has not that right does it not continue to be at the complete mercy of its conquerors?

It will perhaps be said, that, until a conquered nation has fully paid all the penalties imposed upon it, there can be no certainty that it possesses a responsible government, and should, therefore, be excluded from the Society of States.

If this position be accepted, what hope is there of ever arriving at peace? Can peace really be made with a nation whose government is not responsible? Can a nation ever form and maintain a responsible government, unless it entertains the hope that through it peace can be made? Is there any prospect of ever executing a peace, unless it is assumed that it is made with a responsible government? In brief, what motive is there to accept, and attempt to fulfill, the terms of peace imposed, if a nation is to be wholly excluded from the Society of Nations, is not accorded equal rights under the Law of Nations, and has not the right to appeal to a neutral tribunal to determine whether or not it has fulfilled its obligations? If those obligations may be arbitrarily interpreted, and especially if they may, from time to time, be arbitrarily increased, with no opportunity of redress, what becomes of the pretension that peace has been made?

Would not a full conference of responsible states—the standard of responsibility being full acceptance of International Law and actual conformity to it—where the members of the Society of Nations might meet as juristic equals, furnish an occasion for reorganizing that Society in its true sense? Could not the nations, both victors and vanquished, meet there upon the assumption that a formal peace having been made, a friendly disposition might make that peace effective between the peoples that have been at war? Obviously, no such meeting as this could be held under the auspices of the League of Nations, while organized as a military and political alliance.

Would such a meeting of the Society of Nations, confined to specific peaceful purposes, furnish new occasions for collision?

The answer lies in the will of the peoples of Europe. If there is a sincere general desire for peace, a real peace is possible. If there is not such a desire, the League of Nations certainly can not long preserve the peace by force of arms.

We need not enter here into any discussion of American policies. These are now under consideration by responsible and competent authorities, and it is to be hoped that they will be framed in a sense to unite every party and every faction of the American people upon a course that will give us peace and at the same time enable us to fulfill every obligation of national duty. But here, in this gathering of men and women devoted to truth for its own sake, and to the recognition of those facts which form the material of social and economic science, it is not beyond our province to consider, as we have attempted to do, the grounds on which permanent peace may be established. We are not indulging in theory, but are merely interpreting human experience, when we say, that among the necessary preliminaries of lasting peace are the conditions of life which meet the essential needs of men and of nations, and a bar of justice before which the wrongs of nations may be presented for at least that measure of redress which the unselfish opinion of civilized mankind can give.

WAR RISK INSURANCE

By RICHARD G. CHOLMELEY-JONES, ESQ.

DIRECTOR OF THE BUREAU OF WAR RISK INSURANCE, WASHINGTON, D. C.

THE stage has been reached when we may carefully consider the failures and accomplishments of the Bureau of War Risk Insurance and thereby arrive in our own minds at a conclusion as to whether or not the legislation creating the Bureau was short of vision, whether or not such legislation was intended for a war emergency only, and when we may discuss the social and economic place of the function and activity of the Bureau of War Risk Insurance as it affects the life of our nation.

Before going into these phases of the question, it may possibly serve to clarify our thought if we consider the history of the legislation bringing forth the Bureau of War Risk Insurance. To begin with, the Congress of the United States felt it should provide something in the way of protection against war hazards. What contingencies, would in the opinion of the War Congress be considered as the main hazards to be provided against? There was—first, the marine hazard of war, second, the economic and social hazards of the dependent relatives of the fighting forces, and third, the physical hazards resulting in complete or partial disability, or terminating fatally with the decedent leaving behind a dependent family.

In providing for these main war hazards there has developed, as of June 30, 1920, what might be regarded as five of the largest businesses of their kind in the world:

1.	Marine insurance (war risk) total amount written.....$	2,390,074,384.82
	Premiums received on above less claims paid representing a profit of.....$	17,500,897.92
2.	Allotments and family allowances paid.....$	554,691,626.25
3.	Compensation for death or disability as a result of service (total expenditure to June 30, 1920).....$	114,765,422.84
4.	Insurance on military and naval forces (Total volume war risk term insurance written to June 30, 1920).....$	40,284,892,500.00
5.	The largest medical practice in the world with the total number of patients admitted to hospitals.....	54,779
	And patients given treatment and examination.....	452,609

We will first trace the exigencies of the war period as it called forth the enlarged scope and activity of the bureau.

What can be termed as the original War Risk Insurance Act was passed by Congress on September 2, 1914. Immediately on the outbreak of the European War, Congress, in order that the commerce of the United States might be adequately protected, created in the Treasury Department a bureau charged with the duty of insuring American vessels, their freight and cargoes, against loss or damage from risk of war.

It is to be remembered that the initial legislation did not cover marine insurance, but covered solely war hazards. Such war risk insurance was brought forth by necessity. If the commerce of the world was to be safeguarded, national legislation should be passed. No private insurance company could assume the risk except by charging the almost prohibitive rates, which, because of the peril resulting from modern warfare, it would be called upon to charge.

The original War Risk Insurance Act of September 2, 1914, was further amended to insure the crews of vessels against death or disability resulting from war.

By the legislation creating marine and seamen's insurance, the government embarked upon what proved to be the most stupendous and successful marine insurance business which the world has ever known, and which resulted in stabilizing the commerce of the entire country, as well as causing renewed confidence in the government. The vastness of the business undertaken can be easily grasped when it is known that the total amount of insurance written was $2,390,074,384, and the success with which the bureau administered this function given by Congress, and the united support which the bureau received from our own navy as well as those of allied governments, can be appreciated when it is known that the premiums received, less claims paid, represented a profit of $17,500,897.

With the cessation of active hostilities on November 11, 1918, the activity relating to the marine and seamen's feature of the War Risk Insurance Act was brought practically to a close.

The most widely known functions of the bureau, however, are found in the administration of the War Risk Insurance Act as it relates to soldiers or sailors allotments and government allowances, insurance, and compensation, which were provided for by the Act approved October 6, 1917.

Let us first consider the social and economic reasons that called forth this last classified legislation. Congress had passed the Selective Service Act, believing it to be the best means by which the army of this great democracy should be formed, to the end that the armed forces should be assembled and trained without discrimination to class, caste, or creed. Congress increased the pay of the enlisted man by about 100 per cent. and yet felt that the drafting into military or naval service of a person would not withdraw the legal and moral obligation of each man, wherein the necessity existed, to contribute to the support of his family. The breadwinner had been taken from the home, and it was evident that some method should be devised to alleviate the attendant financial distress that would inevitably follow.

Congress further appreciated that no army, however strong in numbers, could wage a successful warfare if the morale of the country supporting such army were at a low ebb. By Article II of the War Risk Insurance Act of October 6, 1917, provision is made for the granting of allowances by the government to families and dependents of enlisted men in the military or naval service. The law required the soldier or sailor to allot a certain amount of his pay to certain classes of dependents such as a wife or child, and also to brothers, sisters or grandchildren, he might allot, if he wished, a part of his pay. To this allotment the government would add an allowance to be determined by the number of members in his family and the amount of the man's habitual contribution to their support, previous to entering military or naval service.

Successfully to carry out the terms of this legislation presented a multitude of economic and social problems. The legislation was both liberal and fair, recognizing the legal and moral responsibility of the man to meet the burden which rests upon him in supporting his family and at the same time recognizing his inability while absent from home on military duty to discharge that responsibility.

The government, therefore, agreed to contribute its share, which might amount to a contribution of more than three times the sum which the enlisted man was required to allot for the support of his family. The Bureau of War Risk Insurance was the agency through which this aid was to be rendered. Its doors were formally opened for this purpose on October 6, 1917, with approximately twenty employees.

It was stated at the time of the passage of the legislation that the degree of dependency in the army would approximate forty-five per cent. of the total enlistment. Hence about 900,000 applications for allotment and allowance would be received as soon as the bureau began to function. No force had been recruited to cope with the volume of work; no facilities were available; army and navy contact necessary for obtaining the information upon which to base allotment and allowance had not been established and the clientèle of this great organization was scattered throughout the various military and naval organizations. These were some of the almost insurmountable problems immediately confronting the bureau. I can not infringe upon your time other than to point out some of the difficulties which in the beginning faced the bureau.

The bureau undoubtedly failed in many instances to render prompt aid and thereby relieve many cases of dire distress, but I believe when the accomplishments are measured by the failures, the bureau will receive favorable commendation.

As a result of the administration of the allotment and allowance feature of the War Risk Insurance Act, the bureau became one of the largest financial institutions the world has ever known. Requests for allotment and allowance from October 6, 1917, to the close of this fiscal year, June 30, 1920, totaled 1,666,607. There were in addition 2,807,093 application blanks returned on which no allotment and allowance was requested. It was necessary, however, to go over all of these forms received, in order that a proper index might be made. The total expenditure to June 30, 1920, totaled $554,691,626.25. Certainly from an economic and social standpoint no one will question the vision of the legislation providing for allotment and allowance, nor the family economic stability that resulted.

Congress felt that, inasmuch as relief had been afforded for the period of war by providing for the dependents left behind, and inasmuch as insurance had been and still is a great factor in the family life of the American people, some provision should be made whereby the men whose insurability in a private company had been destroyed by going into the war, or, if not destroyed, would persist only upon the payment of premiums signally higher than those of peace-time, should not individually suffer this economic loss at the hands of the government; instead, that the government should itself grant insurance to soldiers and sailors at a premium rate which took account only of peace-time risk, leaving the cost of administration to be borne as a part of the cost of war.

Congress, therefore, wrote into the War Risk Insurance Act of October 6, 1917, Article IV concerning insurance, by the terms of which insurance might be applied for by men and women in the military or naval service in amounts ranging from $1,000 to $10,000, payable in the event of death or total and permanent disability, no matter from what cause resultant, and irrespective of whether or not such death or disability was incident to military or naval service. Provision was also made whereby insurance applied for during the war period could be converted into government life insurance along the same lines as insurance policies issued by private insurance companies.

By this legislation the government embarked upon an entirely new enterprise, an enterprise without parallel in the history of mankind, the stupendousness of which can be fully appreciated when it is known that in this connection 4,631,993 applications for insurance were received, which totaled a liability of $40,284,892,500, a sum far in excess of the total amount of insurance in force with all commercial companies in the United States.

There has been a great economic question in the minds of some people since the signing of the armistice as to whether or not the government should continue in the insurance business. Should it seemingly compete with private insurance companies? Would the government in this field of enterprise promote the economic stability of the country or would it bring attendant economic distress? Should all war risk insurance be cancelled and a cash bonus substituted therefor?

These are some of the many questions that have confronted Congress and the people at large.

While the Bureau of War Risk Insurance has labored under tremendous handicaps, I believe that the time which has elapsed since the signing of the armistice has proved the stability and value of government insurance.

The government is now paying insurance, as of December 1, 1920, to 131,824 beneficiaries under war risk term insurance, which represents a total liability of $1,169,597,021.63 to the government. This does not mean, however, that this last named amount of money will be immediately disbursed because war risk term insurance is payable in monthly installments extending over a period of twenty years.

There has been one great difficulty in the administration of the insurance feature of the War Risk Insurance Act and that has been because the work of the bureau is by legislation centralized. Legislation and appropriations do not permit of the bureau's establishing satisfactory contact in the field. Could a large private insurance company hope to maintain a high degree of efficiency were it possible to have only one central office through which all correspondence, the writing of insurance, and the settlement of claims should be handled, and should not the bureau be allowed the opportunity of taking this great economic relief provided by insurance to the homes of all ex-service men and women? If knowledge of this opportunity could be taken to the home of every ex-service man and woman would it not react favorably upon the social and economic life of the nation as a whole? But in spite of this difficulty the approximate data as of December 1, 1920, discloses that 347,664 men and women have continued their war risk insurance amounting to $2,882,736,500.00, and 228,615 men and women have converted their war term insurance into government life insurance, the converted insurance amounting to $775,717,000.

Can you visualize the tremendous and far-reaching economic stability to our nation should there be more than four and one-half million men and women in the prime of life who had fortified themselves and provided for their dependents by carrying insurance in the amount of $10,000?

I must hasten to the last great feature of the War Risk Insurance Act and that is the provision for the payment of compensation. Congress desiring to be free from the pension complications following previous wars provided compensation payments in case of death or disability connected with military service, not merely a gratuity, but compensation based somewhat upon the compensation laws of the different states and computed according to the family status or the degree of disability suffered.

It should be pointed out that compensation benefits are completely distinct from those of insurance. An insurance award has no influence or bearing whatever on a compensation award for the same death or disability, and *vice versa.* Insurance is a government contract with a soldier or sailor, whereas compensation is a government grant which is discontinued upon the termination of the contingency necessitating it. Payments of the benefits of insurance are payable without regard to a line of duty status, while compensation payments are dependent upon a line of duty status.

The bureau had adjudicated, as of December 1, 1920, 437,588 claims for death and disability compensation. The last monthly payment for compensation being paid to disabled soldiers amounts to $10,164,493.09 and the last monthly payment of the bureau to the dependents of deceased soldiers amounted to $1,345,617.42. The total amount disbursed to December 1, 1920 by the bureau for compensation purposes amounting to $163,979,175.25.

In providing for the payment of compensation the bureau can justly be termed the largest employees liability company the world has ever known.

The bureau is also charged with the responsibility of providing medical care and treatment for disabled soldiers and sailors where such disability is traceable to military or naval service, and in this respect, has given medical care and treatment as of the close of the present fiscal year, June 30, 1920, to 452,609 patients with 54,779 having received hospital treatment. There are now in hospitals scattered over the entire United States approximately 23,000 ex-service men and women.

The medical activities of the Bureau of War Risk Insurance throughout the country is a function of the United States Public Health Service acting under the joint authority of the director of the Bureau of War Risk Insurance and the Surgeon General of the United States Public Health Service. In order better to administer the vast number of physical examinations and the hospital relief incident to the proper execution of the War Risk Insurance Act, the Surgeon General of the United States Public Health Service, acting for and in behalf of the Bureau of War Risk Insurance, has divided the continental United States into fourteen districts and detailed a medical officer to take charge of the organization of each such district.

In June, 1920, the Congress of the United States, realizing the imperative need of additional hospital facilities, approved the utilization, where feasible, of government hospital facilities of the United States Army and Navy, and the National Homes for Disabled Volunteer Soldiers. This act on the part of Congress greatly relieved the acute hospital situation. The director of the bureau also entered into negotiations, with the State of New York, and as a result of such negotiations, that state passed legislation authorizing the construction of a $3,000,000 hospital for the care of disabled soldiers and sailors suffering from mental disorders, such hospital to be leased to the government with the option of purchase at the expiration of a ten-year period. The authority of the government thus to contract with a state is now before Congress.

In discharging the functions required by law of granting marine and seamen's insurance, allotment and allowance, insurance, and compensation, the present director divided the work of the bureau into several major administrative divisions, having an assistant director or chief in charge, who is held responsible for the work of such division. The director through intensive study of the flow of work throughout the various divisions of the bureau has lessened duplication, and by the installation of many labor-saving devices improved the character of the work performed as well as made possible a material reduction in the total personnel of the bureau. At one time the bureau's personnel totaled over 17,000 while now the entire personnel of the bureau numbers 5,775. This reduction has taken place in spite of the fact that the work of the bureau has increased, and still further reductions in personnel are contemplated.

The present director of the bureau has also installed a central record control for the entire bureau in order that he may get daily reports of the work of each particular division, and in order that he may have knowledge at all times of the exact flow of work. A carefully planned budget system has also been put into effect.

There are many legislative relief bills pending. The Wason Bill which has passed the House of Representatives and is now before the Senate for action, provides for the decentralization of the activities of the bureau and for many other advantageous adminstrative steps. There is also before Congress an adequate program for the construction of government hospitals.

The most radically re-constructive bill now before Congress is for the consolidation of all agencies having to do with ex-service men and women and their dependents. Certainly to establish and co-ordinate the work of the United States Public Health Service, the Federal Board for Vocational Education, and the Bureau of War Risk Insurance, by bringing all agencies under one directing head, will be a great step forward in meeting the immediate needs of ex-service men and women and in relieving much duplication of work with relief from that attendant delay that inevitably follows such duplication.

I am thoroughly in accord with this plan to have all of these agencies co-ordinated under a sole directing head.

Early in my administrative effort as director of the Bureau of War

Risk Insurance I became conscious of the fact that while the responsibility of conducting the affairs of the bureau rested upon the director, subject, of course, to the general supervision of the Secretary of the Treasury, that the work of the bureau was no one man's job, that the full counsel and cooperation should be secured of all who were equally interested and concerned in order to make the bureau's work most effective and so that the provisions of the War Risk Insurance Act could serve effectively all those whom Congress intended should be benefited thereby.

The influence and cooperation of you, gentlemen, whose sphere is unlimited, is not only desirable, but is essential to the proper carrying out of the government's program in meeting adequately the needs of ex-service men and women.

PRESENT NEEDS OF THE UNITED STATES PATENT OFFICE

By ROBERT F. WHITEHEAD

COMMISSIONER OF PATENTS

UNDER Article 1 of Section 8 of the Constitution, Congress was granted power to promote the progress of Science and Useful Arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.

Under this power Congress has passed laws authorizing the issuance to any one who has made a new and useful invention in an art, machine, manufacture, or composition of matter, of a patent for a term of seventeen years, granting to the patentee the exclusive right to make, use and sell his invention or discovery.

To the Patent Office, Congress has given the duty of examining all applications for patent and determining whether the applicant is justly entitled to the patent which he seeks.

While many people are more or less familiar with patents, few realize to what extent all classes of citizens are affected by the work of the inventor who is largely stimulated to do his work by the hope of a reward from the granting of a patent.

The Patent Office deals with all the efforts of the world in every field of industry to advance the useful arts. In his report for 1916 the Commissioner of Patents, as illustrating the various interests both public and private which are involved and the extent of such interest, said:

> What great interests are involved, not merely of private but of public concern, may be illustrated by a few examples relating to the field of conservation of fuel.
>
> The Commonwealth Edison Company of Chicago reports that it has

effected a reduction in coal consumption from nearly seven pounds per kilowatt-hour to 2.7 pounds per kilowatt-hour within the last 10 years. With this and other economies the cost to the consumer per kilowatt-hour was reduced in 1915 to one-sixth the cost of 1905, and the company in 1912, with a consumption of 1,103,230 tons of coal, produced an amount of electricity which on the basis of the apparatus of 1902 would have required the consumption of 2,650,000 tons.

The Seventy-fourth Street Station of the Interborough Rapid Transit Company of New York City has recently introduced improvements which, it is reported, have caused a drop of coal consumption from 2½ pounds per kilowatt-hour to 1½ pounds per kilowatt-hour.

It is estimated that the new steam plant of the Buffalo General Electric Company at Tonawanda, N. Y., will generate electricity from coal more cheaply than can be done from the waters of Niagara Falls.

The great economies are due, in large measure, to the modern automatic stoker and regulator, to furnace construction, to forced draft, to coal-handling machinery, and other inventions.

What has gone on in this particular field has been going on in almost all of the fields of industry known in 1890 and in many which have been discovered since that date.

New arts have been discovered such as wireless telegraphy, telephony, and control of torpedoes, searchlights and gun pointing, vacuum cleaning, X-ray apparatus, liquefaction of air to produce oxygen and nitrogen for commercial use, flying machines, the moving picture and mercury-vapor lamps.

Advances have been made, of enormous importance, in chemical methods and materials, such as catalytic materials used in the manufacture of sulphuric acid and ammonia, and in the hydrogenation of organic substances; hydrogenization of oils whereby new products are obtained from cotton-seed oil; the discovery of cellulose esters; almost innumerable coal-tar products useful in pharmacy, dyeing, and photography; gas manufacture, such as acetylene gas; evaporation and drying of milk; gasoline manufacture; fixation of atmospheric nitrogen with resultant production of synthetic ammonia and nitric acid; rapid vulcanizing; glass making; manufacture of synthetic resins; recovery of potash from silicates for the manufacture of fertilizers.

By way of illustration, I will cite certain facts relating to bread making reported to me by the Mellon Institute. For a period of some five years an industrial fellowship has been maintained there, in which trained scientists have devoted their time to the study of methods of bread making, with the object of producing better bread. Certain of the processes developed have been patented and put into operation on a large scale and it is found that they not only produce better bread, but effect great economies. Better nourishment of the yeast has reduced the amount required in raising the bread and maturing the dough, with consequent lessening of the amount of flour and sugar which is used up by the yeast and converted into carbon dioxide and alcohol. The saving of these and other economies to those employing the novel processes are estimated to amount to over $1,000,000 per annum. This estimate is based upon the present high scale of prices, but on any scale of prices would be enormous.

The economy is illustrated in another way, as follows: The average flour production for the State of Kansas is about 20,000,000 barrels, or roughly, 4,000,000,000 pounds. The saving of flour effected is about 2 per cent., which would amount to 80,000,000 pounds, or 400,000 barrels annually on the production of this one State.

In the field of electrical engineering there has come the electric heater, the electric elevator, the supplanting of cable street railways by electric street railways, the electrification of long steam railway lines, train control, storage-battery developments, polyphase and high voltage systems of electric transmission, electro-dynamic phase transformers, long-distance transmission in telephones, and the development of the automatic switchboard.

I personally know of two patents, in the electrical field, both about to expire, each of which shortly after it was granted was sold for a large sum. Neither has been the subject of litigation, yet neither could at any time since the purchase have been bought for many times the sum paid for it.

In the field of farming implements there have come the tractor engines, apparatus for digging irrigation and drainage canals, beet harvesters, corn and cotton planters, deep-soil disk plows, cleaning and manipulation of cotton and wool fiber and other great advances.

But what is true of these arts is true of innumerable others, such as spinning, weaving, manufacture of steel, reinforced concrete for bridges and the like, the steel frame building, stone-working machinery, coal-mining machinery, and oil-drilling machinery.

The automobile has been almost wholly developed since 1890, and there have been vast advances in the construction of internal combustion engines; water purification methods and filters; fire extinguishers; match making, basket and barrel making machines; electrical welding; calcium carbide making; sound reproducing machines; flotation processes of concentrating ores; flour making and refining; shoemaking machinery.

In fact, the list might be extended almost indefinitely; and the prospect is that as great, or greater, advances and discoveries will be made in the immediate future.

Prior to 1836 the system both in this country and abroad was to grant patents on application therefor without any search to determine whether the alleged invention was really new. The system of granting patents on examination, which was established in 1836, was primarily in order to safeguard the public interest by the avoidance of unwarrantable grants.

It is obvious that the more thorough the examination and the more accurate the determination of the scope of a given invention, the more valuable the patent is to the patentee and the less likelihood there is of the improper grant of a patent or the grant of one with claims which are too broad. It is also obvious that in order that such an examination may be made it is necessary that the examining corps be composed of men qualified for such work both by education and experience and that they shall have time not only to examine applications but to study and keep abreast of what is being done in their several arts.

It takes time for an examiner to learn his art and how to handle it efficiently. An excessive loss of trained men is very uneconomical as new men can not for a long time efficiently do the work of those whom they replace.

The salaries paid at the present time to the members of the examining corps are not such as to hold the men or to attract properly trained men to stand the entrance examinations. During the year 1919 there were seventy-seven resignations from the examining corps of slightly over four hundred, and during the first ten months of 1920 there were seventy-eight resignations. The Civil Service Commission has not been able for a long time to furnish sufficient eligibles to fill these vacancies and many of the Fourth Assistant Examiners positions have been filled by making appointments of persons who had not passed the required test.

The greatest need of the Patent Office at the present time is, therefore, such a reorganization of the salaries as will attract graduates of the technical schools and justify them in making this work their life work. In other words, to change the Patent Office from what it largely is at the present time, a mere training school, to an institution offering a real career to its employees.

A bill (H. R. 11,984) for this purpose was passed by the House of Representatives last year and is now in conference, having been passed by the Senate in a somewhat different form. If this bill becomes a law it is believed that the desired results will largely be obtained.

If the examining corps could be stabilized not only would examinations for ascertaining the novelty of inventions be better made but the work could be kept much more nearly up to date. At the present time, due to the overturn in the examining corps and to a very large increase in the number of applications being filed, the work is far in arrears. In many instances this delay works a hardship on inventors and their assignees.

Another need of the Patent Office is the completion of the work of reclassification of existing patents. This work was begun some twenty years ago, but from time to time has been slowed down owing to the inability of the force to keep up with the examining work and also carry on reclassification work. At the present time it is not being pushed as vigorously as it should be for the same reason. With the increased force provided for by the pending bill above referred to this work can be proceeded with more rapidly. When all the patents have been classified the question can then be taken up of the desirability of publishing briefs of the inventions and abridgments such as published by the British Patent Office.

The Patent Office needs now more room and that need is becoming greater each year Not only are some of the examining divisions overcrowded and many of the clerks working under undesirable conditions, but there is not room available for the needed expansion of the public search room, the Scientific Library, and the storage of the rapidly accumulating records. This relief will have to come either by the erection of a new building or by allowing the Patent Office to occupy a portion of the building across F Street, which is connected to the Patent Office by a tunnel. Plans had been worked out for transferring certain divisions of the Patent Office to this building but at the outbreak of the war it was found necessary to assign this space to the War Department and the plans could not be carried out.

The work of the Patent Office has increased immensely in the last two years. While statistics are not usually very interesting it may be well to point out how great the increase in the work has been.

During the year ending June 30, 1919, there were filed 62,755 applications for patents for inventions, while in the year ending June 30, 1920, there were filed 81,948. The total number of applications, including applications for the registration of trade-marks, prints and labels, filed in the former year was 75,657 and in the latter 102,940. The increase in the applications for patent was 30% and in the applications for the registration of trade-marks 72%.

INTERNATIONAL ECONOMIC IMPORTANCE OF PRECIOUS STONES IN TIMES OF WAR AND REVOLUTION

By Dr. GEORGE F. KUNZ
PRESIDENT, AMERICAN SCENIC AND HISTORIC PRESERVATION SOCIETY

ALMOST from time immemorial gold and silver have been acknowledged as the standard precious metals. For twenty-five centuries they have been used in coinage, varying from gold at eight times to forty-five times the value of silver and now receding to about fifteen times. Up to the present time seventeen billion dollars worth of gold has been mined, of which five billion has been lost, leaving twelve in circulation and in the arts. There are now in the governmental treasuries or in banks approximately nine billion dollars worth. Frequently treasures of gold are found in earthen or leaden pots, dating from five centuries before Christ to the Christian Era, which are absolutely perfect and as intact as the moment they arrived from the mint.

Although at various times in various parts of the world corn, rice, rock salt, cocoanuts, dates, shells, whale's teeth and wampun have been used as a medium of exchange, they only had a local value and were not international. The paper moneys of the world have little durability, and there is scarcely a paper note known that has held its value for more than a century. Even our own Colonial bills, and bills of the Confederate States have no value other than to an antiquarian. Of all known metals, nothing possesses the compactness in value, the rarity, the richness and the convertability in every capital of the world, of precious stones, whereas 100 ounces of gold would be as much as any individual could comfortably carry about with him, approximately $2,000 worth.

Precious stones in all times have been prized as the only objects that can be transported in great value with the least possible bulk. Many precious stones have such value that a million dollars worth do not weigh more than a few ounces to a few pounds, and in the great World War and the aftermath of the War, in Russia and other European countries, these were hurriedly bought and there are many instances on record in which they were the only objects that it was possible for the owner to flee with, sometimes at only half an hour's notice, and, as they have no international mark, as would a coin or a banknote, they could be converted in any country to which a refugee departed.

In regard to paper monies, with the exception of the money of the United States, all other issues have depreciated over 10 per cent., or, in some instances, as in Austria and Russia, have fallen to only 1 per cent. of the original value; and as precious stones exist to the value of $3,000,000,000, this is a large enough value to have an economic importance in times of war and stress. As to permanency of value, the Regent Diamond, sold to France in the time of Louis XV, today, after changes from kingdom to republic, consulate and empire, and again to republic, is itself unchanged and as precious as the day it was bought in its rough state by Thomas Pitt, in the early eighteenth century. Bonaparte pledged it to the Dutch Government to procure funds indispensable to the consolidation of his power. History tells us how the great diamond of Charles the Bold was placed as a loan with the Fuggers of Augsburg, the great money lenders of the fifteenth and sixteenth centuries, or by the inhabitants of India before money could be placed at interest, as forming the only absolutely transferrable international medium of exchange.

About 6,000,000 ounces of platinum have been found, worth about $80 per ounce, approximately $500,000,000, of which two-thirds has been used by dentists and chemists. Therefore it would not be a factor in world values; and is not so easily understood or recognized as is gold or silver.

Preciousness consists of indestructibility, rarity, portability and convertibility. Thus, gold is one of the most important of the precious metals. Alexander the Great, in his time realized that by transporting gold to India, instead of silver, his camels carried thirteen times as much in value. At that time the ratio was about thirteen to one.

The Sultana of Sulu owned a necklace of beautiful pearls. When visitors tried to buy them, she said "Why should I sell them?" They said, "We will give you money for them." She said, "What can I do with the money? If the enemy comes, it is too heavy to flee with. My pearls I could take with me, and if I need money I can always sell a pearl." The Sultana realized the portability and value of pearls.

THE RELATION OF ANTHROPOLOGY TO AMERICANIZATION

By Dr. ALBERT ERNEST JENKS

PROFESSOR OF ANTHROPOLOGY, DIRECTOR OF THE AMERICANIZATION TRAINING COURSE, UNIVERSITY OF MINNESOTA

AS an anthropologist I have long been interested in the practical application of the science of anthropology to the problems of modern American life. I can not better give you my view of the importance of this application of anthropology to modern problems than by quoting from my report to the Carnegie Institution of Washington in 1914, where under the section entitled "Modern Problems" and the sub-titles of "Ethnic Heredity," "Influence of Environment on Mankind," "Human Amalgamation," and "An Anthropological Laboratory," I discussed this question at some length. I here quote from the opening paragraphs of that section of the report:

"It must not be supposed that the anthropologist is limited in his interest and his field of work to man's evolution of the past. He knows man is still in the making. He studies man's present-day evolution in its individual and ethnic aspects. He makes his studies of both the past and the present, with an eye to the future, in order that those things which vitiated or benefited the evolutionary process in the past, and which vitiate or benefit it today, may serve as guides for future generations.

"The field of anthropological study of modern people is new and unoccupied, only the barest beginnings having been made. The horizon of this coming field for research among present and future man and ethnic groups is seen to extend indefinitely into the future. It would be difficult to overestimate the practical value of these continued studies. Their utility would be world-wide."[1]

But, however much individual scientists were interested in modern anthropological problems up to the year 1914, our nation as a whole seemed to be chiefly interested in those sciences which could add commercial value to commodities sold in the market. Experts were constantly at work importing to the United States, and distributing here with most careful study, plants and animals which have added millions of dollars to the wealth of the nation. In the meantime there were coming to our shores with very little restriction peoples of many different breeds and cultures who distributed themselves over the United States quite largely as chance or as profit for the moment dictated. Ferrero, the Italian historian, says in his *Ancient Rome and Modern America*: "My first surprise (on coming to the United States), and a very great one it was, arose from my examination at close quarters, of the policy pursued by the United States in dealing with the immense hordes of immigrants, who yearly pour into their harbors from all parts of the Old World." This question was of especial interest, as he said, "to a historian of Rome, like myself, to whom history has taught the great internal difficulties which were caused in every ancient state by the *metoipoi* or *peregrini* [i. e., aliens]."[2]

It was not until America was rudely awakened by a time of national peril that she realized the magnitude of the task before her of assimilating the various peoples in her midst. This problem of the assimilation of our immigrant peoples then became of such importance that it attracted nation-wide attention, and started a nation-wide move-

[1]Reports upon the Present Condition and Future Needs of the Science of Anthropology presented by W. H. R. Rivers, A. E. Jenks and S. G. Morley, at the request of the Carnegie Institution of Washington, printed 1914.

ment known as "Americanization." It is in this field of national endeavor that anthropology has an opportunity for paramount practical service to our nation.

The great problem of the assimilation of the immigrant in America is at base anthropological. Ethnic groups differ one from another. It is commonly supposed to be true that their differences are only "skin deep," but biologists know that ethnic groups differ beneath the skin. They know that the processes of pigment metabolism are so unerring and persistent that patches of skin taken from one person and grafted on another take on the proportion of pigmentation natural to the "stock" or seat on which the transplanted skin lives. They know also that ethnic differences are so much more than only "skin deep" that ovaries transplanted from one person to another person would reproduce children of their own kind without influence by the person who served as "stock" or seat for the transplanted ovaries. There are no experiments of this sort known to me, but what has been proved true with other animals would without question be true of human animals. Thus there is scientific reason to speak of different "breeds" of people whose differing physical characteristics are today due to the factors of heredity resident in the reproductive germ cells. Ethnic differences are not simply "skin deep." They are germinal. They begin at the functional innermost center of the person, and they continue through to the outside. The man who runs sees the outside differences between breeds of people. The anthropologist knows they begin inside in the seeds of the breeds.

Out of the physical man grows the psychic man. As out of these different physical characteristics of the different breeds of people come the psychic characteristics of those breeds of people, it should be expected that the reactions of the different breeds of people would exhibit differences. The practical handler of peoples knows such is the case—whether he is an administrator of colonies, a policeman in any cosmopolitan city, or boss of a gang of mixed "foreigners" on any American railway job. At the present moment it can not be said that these differing reactions of the different breeds of men are due to physical differences or to psychic differences or to social and cultural differences, or to something yet unnamed. All that is known is that different breeds of people commonly possess distinguishing reactions in many of the affairs of life.

The American assimilation problem centers in the various breeds of people who are in our midst. What facts and tendencies of strength and weakness for the future of America are in those various ethnic groups? Some peoples can, do and will continue to build into the

[2]Guglielmo Ferrero, *Ancient Rome and Modern America,* 1914, pp. 139-140.

American plan of development. Others do not, and should not be expected so to develop without due education and often tedious application. Others probably never would. What are the varying reactions of these different peoples in our assimilation process? These are questions for the most careful study, the accumulation of accurate data, and for effort at scientific conclusions and application of conclusions in order that an intelligent public opinion based on known facts, instead of sentiment or prejudice or commercial profits for the few, may dictate our policies and practices in regard to the peoples here.

In discussing this point further I wish to bring you not a theory of what might be done, but to tell you what is being done in the University of Minnesota in the practical application of anthropological knowledge to the problem of immigrant assimilation or "Americanization."

For fourteen years we have been developing anthropological courses in our university. Those courses have consisted not only of the usual foundation courses on the development of man, races and culture, but of courses dealing with modern anthropological problems, especially those of vital importance to our immigrant nation. They have dealt with the peoples who have come and who are coming to America as immigrants, with the dominant characteristics of the diverse foreign peoples now in the United States, their modification in America, and the importance of these peoples to the American nation. We have had courses on the American Negro, taking up the negro in Africa, the development of the negro in America, his present characteristics, conditions, developing tendencies and probable future. We have considered the facts and forces of amalgamation and assimilation in America and those psychic results so essentially American that we call them "Americanisms." We have had courses and seminars of method and research in some of the special ethnic problems of America.

Two years ago the regents of the university established an Americanization Training Course to help meet the national assimilation problem. Its object is the training of Americanization leaders to hasten the assimilation of the various peoples in America toward the highest common standards and ideals of America practicable for each generation. The course is founded on our anthropology courses which had already been developed. These courses were emphasized and strengthened. On top of them, we developed professional courses on the technique, the method and the organization of Americanization work; also courses on the principles of adult elementary education, covering language-study as a fundamental tool in assimilation of peoples, ethnic peculiarities of the language-habit, racial bases for development of educational subject matter, problems of the adult language-habit substitution, and voluntary *versus* compulsory nationalization of language. We also added such practical field courses as supervised work with foreign peoples in homes, residence communities, industrial plants, public schools, etc. There have been difficulties, since we were so largely in an untried field. Some of the courses of necessity were at first only experimental. Instructors had not always all the training we might have wished. But the contact with workers in the same field, especially as we have been able to bring them in during our summer sessions, when they have come as instructors and students from New York, California, and centers in our middle states, has given a splendid impetus to the development of the work today. The practical value of modern anthropological knowledge can no longer be questioned by one who knows the practical work done by those who have gone out from the training course. We have sent our trained Americanization leaders into several different states and into many different positions, such as those of state directors, city directors, school directors, directors with Y. M. C. A. and Y. W. C. A., churches, women's clubs, and as teachers in schools, homes, communities and industries.

We have sent into South Dakota a state director of Americanization, two regional state directors and two city directors. Professor M. M. Guhin, the state director, writes "Our work in this state is nothing more or less than demonstration work of the Americanization Training Course of the University of Minnesota." President H. W. Foght, of the Northern Normal and Industrial School of Aberdeen, writes, "Mr. Guhin is doing a great work for the State, and Americanization training will go forward as a permanent and distinct phase of education in this State."

Three of our trained leaders have gone to the iron-mining region of northern Minnesota. I quote from a letter of one of them to illustrate the practical use of Americanization training:

> I have had every opportunity to put into practice the work I received at the university. The superintendent of schools, for whom I work, had no idea of the methods used in Americanization work. He merely knew the results he wished accomplished. I was sent out to a mining location, and told to "Americanize" it. Had it not been for the practical courses which I had taken at the university as to the different methods of approach to different nationalities, ways of making oneself welcome in the foreign homes, methods of organization of classes and holding the attention of adult pupils, phonic drills for each nationality, and many other helpful suggestions which I use daily, I should have been entirely at sea in my new position. My experience with the foreign people themselves, which was a part of the Americanization Training Course, has been of especially practical value.

The Superintendent of Schools by whom two of these workers are employed has written for two others to begin at once, and requests three additional workers to begin next autumn.

Our leaders are making good in this practical effort to hasten assimilation in America, not only because they are trained in the professional, technical and practical courses, but, more especially, because through their anthropological courses, they are equipped to know the different necessary approaches to, and reactions of, the different breeds of peoples among whom they work. Their work is among peoples. They have been trained to know peoples. This Training Course is not yet fully manned or as complete as is desired, due to the almost universal shortage of funds in higher education. We need especially research men in physical anthropology, amalgamation, and environmental influence, as well as experts in certain practical fields. There should be research equipment to investigate many phases of the peoples in America. In fact, there should develop a genuine laboratory of research and of practical application of anthropological knowledge to American problems. The time is coming quickly when this will be developed somewhere.

Not only is this work being done in the University of Minnesota, but under the impetus of the Americanization movement many colleges and universities which had never before had anthropology courses of any nature have recently been putting in courses on modern peoples, especially our immigrant peoples, and some have added various professional courses on technique and method of adult education. Not only are these anthropology courses of value in purely Americanization work, but it will come to be recognized more and more that all economic, social and political problems in America today are intimately bound up with the reactions of the different peoples in our midst. More and more it will be seen that with America's vast heterogeneous population her public school educators, her social workers, her police and correction agencies will have to make practical use of anthropological knowledge of the various peoples with whom they deal.

This paper aims simply to focus attention on one phase of practical anthropological knowledge, namely, as applied to Americanization. In pragmatic America all sciences must be able to prove their practical worth in helping solve our momentous national problem, and it seems to me our experiment proves that modern anthropology is capable of practical service to our nation.

THE NEW WILD LIFE PRESERVE NEAR McLEAN, N. Y.

By Professor JAMES G. NEEDHAM
CORNELL UNIVERSITY

IN the early days of Cornell University, the good field naturalists who first came upon her staff began the exploration of their environment. The lake, the hills, the gorges and the upland reaches of the streams were all examined with a view to discovering what they contained of scientific interest and of educational value. Among the many interesting spots discovered were the bogs near McLean. These cold upland bogs with their strongly marked Canadian fauna and flora early attracted attention. These miniature wastes of water and moss, like those of the far north, lying upon the border of an agricultural region, and easily accessible from the university by a 15-mile ride by rail or motor, have continued to be one of the chief centers of biological interest in the university's rich environment.

After fifty years of visitation by naturalists and collectors and by university classes in many biological subjects, after all the generations of Cornell students have tramped the bogs, probed their beds for peat and marl, tested the springiness of the hanging border of Mud Pond

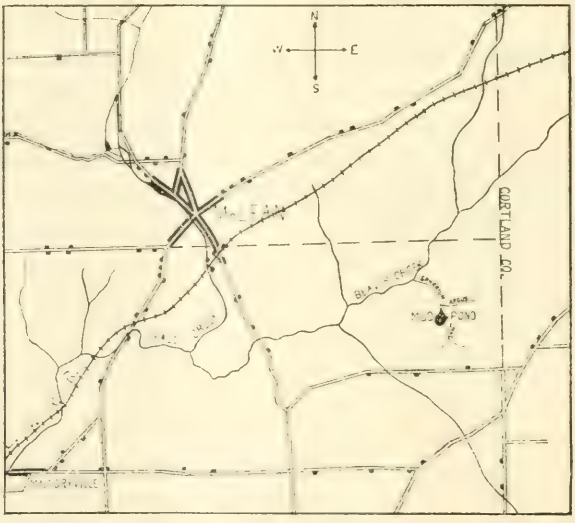


FIG. 1. MAP OF THE ENVIRONS OF THE McLEAN WILD LIFE PRESERVE. MUD POND IS WITHIN IT (SEE FIG. 2). THE CORTLAND-DRYDEN STATE HIGHWAY IS THE ONE PARALLELING ITS SOUTHERN BOUNDARY

with their weight, searched out the rare plants and animals, feasted on the wild berries, drunk from the roily springs, watched for the elusive trout in the dark waters of the meandering streams, and returned home wet and tired and heavy-laden and happy, it has come to pass that this fine bit of wild nature, instead of being "improved" and thus destroyed for the purposes of the naturalists, as have so many others, has been made a wild life preserve. Mr C. G. Lloyd of Cincinnati, himself a mycologist and an excellent field naturalist, has purchased the tract, and has given it into the keeping of the Trustees of the Lloyd Library, in order that it may be maintained in its natural state in perpetuity. An agreement has been made with the trustees of Cornell University whereby the president of the university appoints a professor from one of the biological departments to be custodian of the preserve. President Schurman designated the writer to be its first custodian.

This preserve is easily accessible from railroad station or state highway (Fig. 1), is compact, so that one may see much without traveling great distances. A survey of it was begun in the spring of 1916, by several graduate students in the Department of Entomology and Limnology in Cornell University, three of whom, J. T. Lloyd, P. W. Claassen, and R. N. Chapman, spent the Saturdays of that season in mapping with a plane table, and in collecting from the bogs. Professor A. A. Allen and Dr. C. P. Alexander also assisted in the beginning. American participation in the great world war put a stop to the work and prevented carrying out the survey plans; in the summer of 1916, Mr. Lloyd was in France and the others were scattered about in America, or devoted to more urgent tasks. Only occasional visits to take up the tag ends of the mapping, have been possible since 1916. The results thus far attained have been put together by Dr. Claassen in the accompanying map (Fig. 2).

The McLean Wild Life Preserve lies 15 miles northeast of Ithaca and one mile east of the village of McLean in the valley of Fall Creek at an elevation above the sea level of something more than 1100 feet. It lies in the lowland adjacent to an eastern tributary of Fall Creek known as Beaver Creek or Beaver Brook, and at the foot of slopes that are devoted to fields and pastures, in a region of morainal deposits of great irregularity. It is an uncultivated area of perhaps 100 acres. The basin is an irregular depression in the lowland at the foot of the slopes. It is rimmed about on the north and separated from Beaver Creek by two confluent esker-like ridges that run down from the hills like arms to inclose it. These ridges meet at the point where Sphaerium Brook has cut its way through to join Beaver Creek. The northern arm is the longer, and closely parallels Beaver Creek for the greater part of its length. Its surface is very irregular, as the contour lines on the accompanying map clearly show. Midway its length it rises steeply

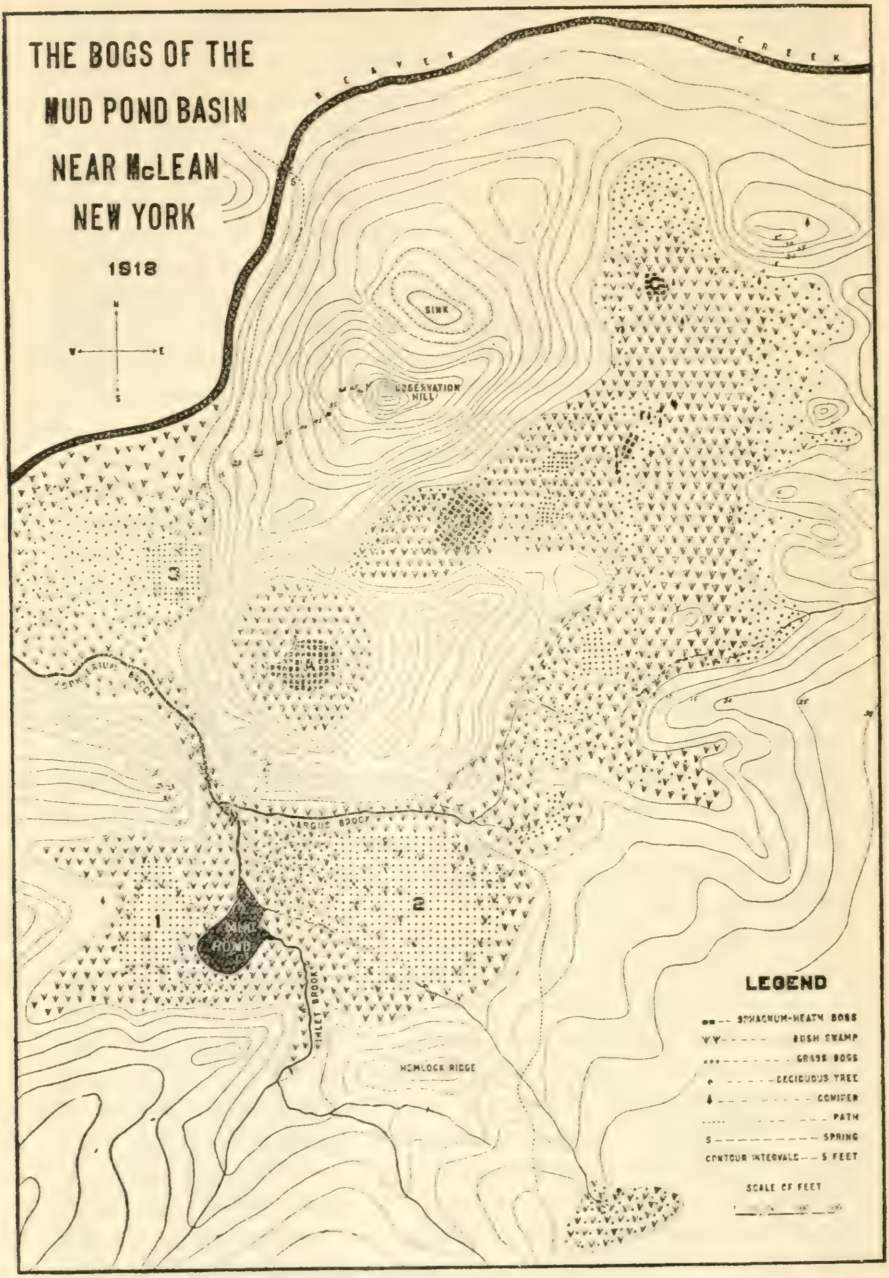


FIG. 2.—MAP OF THE MUD POND BASIN, INCLUDED WITHIN THE PRESERVE. THE WET AREAS ARE CAREFULLY SURVEYED; THE CONTOURS OF THE RIDGES ARE SKETCHED. MAP BY DR. P. W. CLAASSEN

from the bank of the creek to a height of 70 feet above the general level in a hump that is locally known as "Observation Hill." On its surface are a number of glacial potholes or sinks. One of them on the northern slope of Observation Hill is usually dry, its bottom being some ten feet above the level of the water in the Creek. Two others on the opposite side of the hill have a much greater depth,, their bottom being some 30 feet below the level of the surface of the creek. These two basins are occupied by the round bogs marked A and B on the accompanying map. There were probably other similar potholes along the inner margin of this ridge, as indicated by the remnants of bog cover at the point marked C and elsewhere on the map. Bog C, especially, has still a somewhat circular outline with zonal arrangement of vegetation about its borders, and a depth of peat in the center of 25 feet.

The southern end of the longer encircling ridge declines to an elevation of about 10 feet at the southernmost round bog (A), and then rises again sharply in a short recurrent ridge some 35 feet high, that projects hook-like into the basin, dividing it into two areas that are very different in character. Northward of this hook lie all the round bogs, covered with sphagnum and heath formation; southward of the hook lie only grass bogs from which heaths are conspicuously absent.

This difference is probably due to differences in the character of the water supply. The round bogs receive only the drainage from the short forested slopes immediately surrounding them. This is soft water—practically rain water. Into the grass bogs, on the other hand, there is poured the drainage from long reaches of tilled fields, together with the outflow from numerous hardwater springs, that feed the brooks, inflowing from the eastward and southward. This is hard water. These differences are clearly indicated by a few sample determinations made by Professor E. M. Chamot of "temporary hardness" expressed in parts per million calcium carbonate.

North side of hook	Bog A	16
	Bog B	16
South side of hook	Mason's Spring	160
	East "	160
	Mud Pond at Outlet	168
At confluence, upper end of Argus Brook in bush swamp		36

Striking as is the difference in surface vegetation of these two areas, the difference in deposits below the surface is still more striking. It is also more significant. By probing the depths of any of the round bogs one finds their basins filled entirely with peat. There is 35 feet of it at the center of Bogs A and B, and 25 feet of it in Bog C. Similar probing in the depths of the grass bogs reveals a surface layer of peat that is underlaid by a deep deposit of marl. At the edge of Mud Pond there is some 11 feet of peat overlying 24 feet of marl.

Probably when the glacier finally retreated from this region to the northward, leaving morainal deposits encircling the basin substantially as they yet remain, the entire basin was filled with water, and the shores of the primeval Mud Pond were approximately coincident with the innermost contours of our map. It had then more than fifty times its present area of open water. It was irregular in outline, somewhat narrowed in the middle portion, curving to northward beyond this, with a westwardly directed bay that was confluent with the pothole now occupied by round Bog B. Detached but adjacent to this was a small round open pond in the pothole now occupied by Bog A.

Then the filling began, and also the cutting down of the outflow channel by Sphaerium Brook. Both processes may have gone on rather rapidly by erosion for a little while, until the soil was firmly held by a complete ground-cover of vegetation. That there has been no very extensive cutting down of the outlet is indicated by three facts: the gradient is slight, the catchment area is small and the flow always limited, and the channel is bedded with cobble stones for the most part, too heavy for so slight a stream to move.

The filling of the pond has been mainly the work of aquatic plants. Those growing about the shore line and on the bottom have contributed their remains in the form of peat and marl, pushing ever farther and farther into open water and adding ever to the deposits, until all that remains open at the present day is a shallow basin 100 feet across. This is the present Mud Pond; and it is filling so rapidly that at the present rate it will be soon, perhaps in less than another half century, entirely overgrown.

Outside the Mud Pond basin, our map shows another grass bog lying in the angle between Sphaerium Brook and Beaver Creek. Though superficially similar to the other grass bogs this one is different in origin. This one was formed originally behind a beaver dam that crossed Beaver Creek some distance below its confluence with Sphaerium Brook. It appears to be maintained at the present time as the upbuilding process goes on, by flood time accretions of silts, deposited along the bank of Beaver Creek. It is everywhere shallow, its depth where samplings have been made not being greater than 8 or 9 feet. It is composed of impure peat, in which from top to bottom there is a goodly mixture of woody stems, of the average size of alder stems. Apparently this bog has been little changed throughout its history. It was formed upon the level flood plain of the creek by damming, the work being done at first by beavers, and later by the natural leveeing of the creek with increase of soil wash from surrounding farms.

The bottom of Mud Pond basin as a whole remains as yet unexplored. Random probings with a marl-sampler have been made in all the bogs and a few lines of soundings have been run across the grass bogs adjacent to the present pond. These seem to show in the buried contours a row of roundish potholes on the north and a single much larger and somewhat deeper basin on the south. These are connected by a shallower, valley-like depression lying between. These are the two major divisions of the basin, as already indicated, differing in the nature of their catchment areas and water supply; differing strikingly in their plant and animal life, and in the consequent bottom deposits.

The round bogs were once doubtless open circular ponds. They are now completely overgrown. Bogs A, B and C are very similar, though the filling of C is a little more advanced. Each has a central area of dense low-growing sphagnum and heath, surrounded by two zones of larger woody plants. First is a narrow zone of shrubs, and second a wide zone of water loving trees—yellow birch, red maple, black ash, etc.—extending to the foot of the slope. The latter zone is now a cut-over area, studded with stumps of trees only, among which the shrubbery of the first zone, tall ferns and other shade plants, brambles and other immigrants are all struggling lustily for place and standing room. A few scattering worthless trees remain, having escaped the axe.

The more shoal areas of the remainder of the basin, and all the principal areas of silt deposition, whether originally shallow or not, are covered with bush swamp, the dominant species in which is the speckled alder. This alder grows luxuriantly along the silt-strewn edges of all the brooks and about the borders of Mud Pond. Under its shadow in the wetter places grow acres of marsh marigold and skunk cabbage interspersed with swamp saxifrage, and in the plashy edges of the interrupted streamlets, the spreading Chrysosplenium. The alder grows in spreading clumps of usually 4 to 8 strong stems, which gather fallen twigs and leafage about their bases, and thus build up miniature islets in the swamp. On the summit of these such plants as meadowrue and marsh fern and bedstraw and red raspberry find lodgment. The older outer stems of the alder clumps, being loosely anchored in the mud, are borne down to the ground by the heavy ice-coats of winter, and new shoots from the center of the clump arise in their stead. Thus the holding unit is maintained. The alder is the most important plant in the later stages of land building in the basin.

The grass bogs are far less uniform in the character of their vegetation than are the round bogs. Their meadow-like appearance is due to the dominance in them of several species of tussock forming grasses and sedges. These species are of local and irregular distribution, and rarely occur in anything like a pure stand. Where the tussocks are highest—often knee height or higher, so that walking among them is no easy matter—their height is increased by at least two animal agencies; the ants of the marsh build their nests in the top of the tussocks, and in so doing heap up much material on their summits; the meadow mice excavate runways in the bottom of the narrow channel between the tussocks and eat new shoots springing from severed stems, and thus they deepen the narrow lanes between the tussocks.

The grass bogs lack the heaths of the round bogs, but they contain areas having a considerable admixture of sphagnum with here and there an overgrowth of cranberries. There are marsh ferns also in plenty; and in a wet spot in the largest one, a bit of cattail has obtained a foothold. The edges of all the grass bogs are being invaded by alder.

The filling of the basin is well nigh completed. The work of the plants has been supplemented and accelerated in recent times by human interference. Only one small and shallow pond remains open water and that is rapidly filling up with silt. The grass bogs are merely the openings in the herbaceous bog-cover that are not yet overgrown by alder or other shrub. The largest of these are the two that lie in the southern part of the basin. They are situated on either side of the pond but separated from it and from each other by the shore-bordering alders. A line of probings through the surface peat extending across the middle of the largest grass bogs from north to south at 50 feet intervals gave depths as follows: 5-15-17-19-18-17-18-17-17-3 feet of peat. The depth of the underlying marl was not determined. A single probing of the bed of the larger grass bog in the bush swamp above the surface of Argus Brook at its northeast corner revealed a depth of 18 feet of surface peat. It is altogether probable that a systematic sampling of the deposits of the whole of the whole basin, with careful examination and comparison of the samples, would reveal much of the actual history of the filling process.

The Preserve is being inclosed with a high fence, that will keep browsing farm animals outside. Stiles will be built over the fence at convenient points of access, and one principal encircling path through the woods about the borders of the basin will be kept open. Signs inviting naturalists to enter for study, but not for destruction, will be placed beside the stiles and another guide sign to motorists will be placed at the north side of the state road that runs between Cortland and Dryden a quarter of a mile to the southward. This Preserve is open to all naturalists and all are welcome to visit it.

HISTORY OF BIOLOGY*

By Dr. LORANDE LOSS WOODRUFF
PROFESSOR OF BIOLOGY, YALE UNIVERSITY

SOME practical acquaintance with plants and animals undoubtedly formed the chief content of the mental equipment of prehistoric man, and a considerable knowledge of agriculture and medicine was possessed by the Egyptians and Sumerians nearly 7,000 years ago. So biology has a very ancient pedigree. But biology as the science of life—the study of living phenomena for their own sake in which emphasis is shifted from the practical to the philosophical—really begins with the Greeks, and reaches per saltum a height which was not surpassed, indeed not again attained, for nearly twenty centuries.

Science reaching Greece from the South and East fell upon fertile soil, and in the hands of the Hellenic natural philosophers was organized into coherent systems through the realization that nature works by fixed laws—a conception foreign to the Oriental mind and the cornerstone of all future work because it gave purpose to personal scientific investigation. This attitude of approach is largely responsible for the transformation of the Greek scientific heritage from a collectivistic to an eponymous product.[1] It is not an exaggeration to say that to all intents and purposes the Greeks laid the foundations of the chief subdivision of natural science and, specifically, created biology, though the term biology was first used by Lamarck and Treviranus at the beginning of the nineteenth century.[2]

Aristotle, (384-322 B. C.) the most famous pupil of Plato and dissenter from the Platonic School, represents the highwater mark of the Greek students of nature and is justly called the Father of Natural History. Aristotle's contributions to biology are manifold. He took a broad survey of the existing facts and welded them into a science by relying, to a considerable extent, on the direct study of organisms and by insisting that the only true path of advance lay in accurate observation and description. But mere observation without interpretation is not science. Aristotle's generalizations—his elaboration of broad philosophical conceptions of organisms give to his biological works their perennial significance. Among the facts and supposed facts, and

*Delivered at Yale University, April 29, 1920; the third lecture of a series on the History of Science, given under the auspices of Yale Chapter of the Gamma Alpha Graduate Scientific Fraternity.

[1]E. Clodd: Pioneers of Evolution, 2d ed., 1907, pp. 29-32. C. Singer: Studies in the History and Method of Science, 1917.

[2]Lamarck: Hydrogéologic, 1802. G. R. Treviranus: Biologie, oder Philosophie der lebenden Natur für Naturforscher und Aerzte, 1802-22.

of course there are innumerable crudities if for no other reason than that adequate apparatus and biological technique were of the distant future, there are interspersed questions, answers, theories which show a recognition and remarkable grasp of fundamental biological problems. A study of Aristotle's works shows ancient pedigrees for some of the most "modern" questions of biology, though it is undoubtedly true, as Sachs insists, that one must continually inhibit the tendency to read the present viewpoint into the past, and not assign to earlier writers merits which, if they were alive, they themselves would not claim.

We have not mentioned a single discovery made by Aristotle—and with purpose. Aristotle's position as the founder of biology rests chiefly on his viewpoint and his methods. Plato relied on intuition as the basis of knowledge. Aristotle emphasized observation and induction, insisting that errors arise not from the false testimony of our sense organs but from false interpretations of the data they afford. "We must not accept a general principle from logic only, but must prove its application to each fact; for it is in facts that we must seek general principles, and these must always accord with facts from which induction is the pathway to general laws."[3] But it is not to be imagined that Aristotle always followed his own advice; few great men do—"no pilot can explore unsurveyed channels without a confidence which sometimes leads to disaster." It must be admitted that Aristotle frequently lapsed into unbridled speculation which tended to obscure the methods that time has shown produce the most enduring results, though, as Huxley has well said, "It is a favorite popular delusion that the scientific enquirer is under a sort of moral obligation to abstain from going beyond that generalization of observed facts which is absurdly called 'Baconian' induction. But any one who is practically acquainted with scientific work is aware that those who refuse to go beyond fact, rarely get as far as fact; and any one who has studied the history of science knows that almost every step therein has been made by the 'Anticipation of Nature,' that is, by the invention of hypotheses, which, though verifiable, often had very little foundation to start with; and not infrequently, in spite of a long career of usefulness, turned out to be wholly erroneous in the long run."[4]

While Aristotle's biological investigations were devoted chiefly to animals, his pupil and co-worker, Theophrastus (370-286 B. C.), made profound studies on plants, and the list of botanical facts which he observed and in many cases discovered includes nearly all the rudi-

[3]Aristotle: History of Animals, I, 6. H. F. Osborn: From the Greeks to Darwin, 1894, pp. 16-17, 47. T. H. Huxley: On Certain Errors Respecting the Heart Attributed to Aristotle, 1879 (Coll. Sci. Memoirs, IV, pp. 380-392); G. H. Lewes: Aristotle; a Chapter in the History of Science, 1864, pp. 108-13. T. E. Jones: Aristotle's Researches in Natural Science, 1912. W. Whewell: The Philosophy of Discovery, 1860.

[4]T. H. Huxley: The Progress of Science, 1887 (Coll. Essays, vol. 1, p. 62.)

ments of scientific botany. It is a remarkable fact that many details in plant anatomy, which were figured by the pioneers with the microscope, are to be found in the pages of Theophrastus.[5] He not only laid the foundations of botany, but also gave suggestions of much of the superstructure; an achievement which entitles him to rank as "the first of real botanists in point of time."[6]

With the Greeks, then, biology emerged from the shadows of the past and took concrete form—a fact which apparently the discerning mind of Aristotle appreciated since, though frequently referring to the ancients, he writes:

> I found no basis prepared; no models to copy. . . . . Mine is the first step, and therefore a small one, though worked out with much thought and hard labor. It must be looked at as a first step and judged with indulgence.

Before leaving the Greeks we must mention Hippocrates (460-370 B. C.), the Father of Medicine. Writing a generation before Aristotle, at the height of the Age of Pericles, Hippocrates crystallized the knowledge of medicine into a science, dissociated it from philosophy, and gave to physicians "the highest moral inspiration they have." "To him medicine owes the art of clinical inspection and observation, and he is, above all, the exemplar of that flexible, critical, well-poised attitude of mind, ever on the lookout for sources of error, which is the very essence of the scientific spirit. . . . The revival of the Hippocratic methods in the seventeenth century and their triumphant vindication by the concerted scientific movement of the nineteenth, is the whole history of internal medicine."[7]

Medicine, the most important aspect of applied biology, is the foster parent of zoology and botany since a large proportion of biological advances have been the work of physicians. Until relatively recently the schools of medicine afforded the only training, and the practice of medicine the chief livelihood for men interested especially in general biological problems.[8] The history of medicine and of biology, as a so-called pure science, are so inextricably interwoven that the consideration of one involves that of the other. Indeed the physicians form the only bond of continuity in biological history between Greece and Rome. The chief interest of the Romans lay in technology, and therefore it is natural that the practical advantages to be gained would ensure the advance of medicine.[9] As it happens, however, two Greek physicians were destined to have the most influence: Dioscorides, (c. 64 A. D.), an army surgeon under Nero, and Galen (131-201 A. D.), physician to the Emperor Marcus Aurelius and his son, Commodus.

Just as Theophrastus established botany as a pure science, so

[5]E. L. Greene: Landmarks of Botanical History, 1909, pp. 52, 53, 140-142.
[6]A. Haller: Bibliotheca Botanica, I, 31.
[7]F. H. Garrison: History of Medicine, 2d ed., 1917, p. 82.
[8]T. H. Huxley: The Connection of the Biological Sciences with Medicine. Nature, 24, 1881, pp. 342-46; (Also in Coll. Essays).
[9]W. Libby: An Introduction to the History of Science, 1917, Chapter 3.

Dioscorides was the originator of the pharmacopoeia, writing, as he did, not only a work which was the first one on medical botany, but one which, gaining authority with age, was the sole standard "botany" for fifteen centuries. Theophrastus was long overshadowed. Most of the botanical writings up to the seventeenth century were annotations on the text of Dioscorides.[10]

Galen was the most famous physician of the Roman Empire and his voluminous works represent both the depository for the anatomical and physiological knowledge of his predecessors, rectified and worked over into a system, and a vast amount of original investigation. Galen was a practical anatomist who described from dissections and insisted on the importance of vivisection and experiment, and therefore may be considered the first experimental physiologist and the founder of experimental medicine. Galen gave to medicine its standard anatomy and physiology for fifteen centuries.[11]

Any consideration of the biological science of Rome would be incomplete without a reference to the vast compilation of fact and fiction, indiscriminately mingled, made by Pliny the Elder (23-79). It was beside the path of biological advance, but long the recognized "Natural History," passing through some eighty editions after the invention of printing. Its prestige was largely due to the fact that it was written in Latin whereas the great works on biological subjects were in Greek.[12]

For all practical purposes we may consider that biology at the decline of the Roman Empire was represented in the works of Aristotle, Theophrastus, Dioscorides, Galen, and Pliny. Even these exerted little influence during the Middle Ages, being saved from total loss for future generations chiefly by Arabian scientists, and in the monasteries of Italy and Britain. We cannot pause to consider the various causes which resulted in the almost complete break in the continuity of learning in general and science in particular during the dormant period in western Europe.[13] Suffice it to say that contributing factors were wars and rumors of wars, the destruction of the libraries of Alexandria, the antagonism of Christian and pagan ideals, and the establishment by the Church, which held the gates of learning, of the written word in place of observation of nature as it is. "Truth and science came to mean simply that which was written, and inquiry became mere interpretation."

In so far as science was taught at all it was from small compilations of corrupt texts of ancient authors interspersed with anecdotes and fables. Under theological influence there arose the oft-quoted

[10]Greene, op. cit., pp. 151-154.

[11]M. Foster: Lectures on the History of Physiology, 1901. Garrison, op. cit., p. 97-101. M. Verworn: General Physiology, English trans., 1899, pp. 8-11.

[12]F. E. Hulme; Natural History Lore and Legend, 1895, pp. 20-29. Greene, op. cit., pp. 155-159.

[13]A. D. White: History of the Warfare of Science with Theology in Christendom, 1898. Clodd, op. cit., p. 34. Russell, op. cit., pp. 124 et seq,

Physiologus,[14] found in many forms and languages, which is at once a collection of natural history stories, and a treatise on the medicinal use of animals and on symbolism. The centaur and the phoenix take their place with the frog and crow in affording illustration of theological texts and in pointing out more or less evident morals. The line of demarkation between the Physiologus and the Bestiaries into which it gradually evolved is ill defined, while the remnants of the latter are incorporated in the early works of the Renaissance encyclopaedists.[15]

So low had science fallen that, strange to say, the scientific Renaissance may be said to owe its origin to the revival of classical learning and to the translation and study of the writings of Aristotle and others which had been under eclipse for a millennium. These were so superior to the existing science, if it may be dignified by that name, that, in accord with the spirit of the time, Aristotle and Galen became the bible of biology. The first works were merely commentaries on the classical authors, but as time went on more and more new observations were interspersed with the old until elaborate and voluminous treatises describing all known forms of plants and animals were produced. In short, the climax of the scientific Renaissance involved a turning away from the authority of Aristotle and an adoption of the Aristotelian method of observation and induction.

Botany was the first to show visible signs of the awakening, probably because of the dependence of medicine on plant products. "All physicians professed to be botanists and every botanist was thought fit to practice medicine." The Hortus Sanitatis, in a way the botanical counterpart of the Bestiaries, gave place to the Herbals.[16] At the hands of the Herbalists of Germany during the sixteenth century, such as Brunsfels, Tragus, Fuchs, and Valerius Cordus, we can trace the evolution of plant description and classification from mere annotations on Dioscorides to well illustrated manuals of the flora of western Europe.[17]

During the same century zoology made abortive attempts to emerge as a science, but the less immediate utility of the subject combined with the difficulty of collecting material and therefore the necessity of more dependence on traveler's tales, all contributed to retard its advance.

One group of naturalists, the Encyclopaedists, so-called from their endeavor to gather all possible information of living things, attempted the impossible. Gleaning from the ancients and adding such materials as they could collect led to the production of huge books of fact and fancy whose value bore no just proportion to the vast expenditure of labor, even in the case of the best—Gesner's Historia Animalium,

[14]White, op. cit. Also, F. Lauchert: Geschichte des Physiologus, 1889.
[15]Hulme, op. cit., pp. 31, 50.
[16]A. Arber: Herbals; their Origin and Evolution. A Chapter in the History of Botany. 1912.
[17]Greene, op. cit., pp. 164 et seq.

which appeared volume by volume between 1551 and 1587, and comprised some 4,500 folio pages of text and wood cuts.[18]

Although Gesner (1516-1565) was without doubt the most learned naturalist of the period and perhaps the best zoologist that had appeared since Aristotle, the direct path to progress was blazed by men whose plans were less ambitious than those of the Encyclopaedists. Thus, contemporaries of Gesner, men who were befriended by him, such as Rondelet (1507-1566) who gave descriptions of the fishes of the Mediterranean based for the most part on his own observations, and Belon (1517-1564) who illustrated the fishes and birds which he saw in France and the Levant, really instituted the zoological monograph which has proved the productive method of biological study.[19]

Even while the Herbalists, Encyclopaedists and Monographers were at work in natural history, making brave attempts to develop the powers of independent judgment which were oppressed to such an extent during the Middle Ages that the very activity of the senses seemed stunted, the emancipator of biology from the thraldom of the ancients appeared in the Belgian anatomist Vesalius (1514-1564). Disgusted with the anatomy of the time which consisted almost solely in interpreting the works of Galen by reference to crude dissections made by barber's assistants, Vesalius set his hand to the task of placing human anatomy on the firm basis of exact observation, and his great work De Humani Corporis Fabrica makes the year 1543 the dividing line between ancient and modern anatomy.[20] Galen's similar attempt failed because his followers made a bible of his work; but with Vesalius, the time was opportune and, in spite of the opposition of his former teacher Jacobus Sylvius and his pupil Columbus, thenceforth anatomical as well as biological investigation in general broke away from the yoke of authority and men began to trust their own eyes. His successor at Padua, Fallopius, says that Vesalius "so shewed me the true path of inquiry that I was able to walk along it still farther than had been done before."

The work of Vesalius is on anatomy, and physiology is treated somewhat incidentally, though it is evident that he was no better satisfied with Galenic physiology than with Galenic anatomy. The complementary work on the side of function came in 1628 with the publication of Harvey's tract, Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus. No rational conception of the economy of the animal organism was possible under the influence of the Galenic system, and it remained for Harvey (1578-1657) to demonstrate by a series of experiments, logically planned and ingenuously executed, that the blood flows in a circle from heart back to heart again, and

[18]L. C. Miall: The Early Naturalists, their Lives and Work, 1912, pp. 47-50.
[19]Miall, op. cit. pp. 40-47.
[20]W. Stirling: Some Apostles of Physiology, 1902, pp. 2-5. M. Foster, op. cit., p. 2.

thus to supply the background for a proper understanding of the dynamics of the organism as a whole. A new picture of the function of the blood was presented which quickly led to the discovery of the lymphatic system, and gave content to the study of the nutrition of the body.[21]

Harvey's use of distinctively quantitative factors is so important in its establishment of the experimental method in biology that his own statement is of great historical interest:

> I frequently and seriously bethought me, and long revolved in my mind, what might be the quantity of blood which was transmitted, in how short a time its passage might be effected, and the like; and not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other hand getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart; I began to think whether there might not be a motion, as it were, in a circle. Now this I afterwards found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passed through the veins and along the vena cava, and so round to the left ventricle in the manner already indicated. Which motion we may be allowed to call circular.[22]

With the work of Vesalius and Harvey, biologists had again laid hold of the great scientific tools—observation, experiment, induction, which since have not slipped from their grasp.

The Microscopists

Even while the marshalling of accurate descriptions of plants and animals was getting under way, and the study of microscopic anatomy and physiology was making rapid strides forward, an event occurred which was destined to make possible modern biology. This was the adaptation of the principle of the spectacles—the invention, probably by Roger Bacon, of convergent lenses, and therefore of the simple microscope. Then came the compound microscope as a development of the telescope at the hands of Galileo about 1610, and by the end of the century simple and compound microscopes were being made by opticians in the leading centers of Europe.[23]

The earliest clear appreciation of the importance of studying nature with instruments which increase the powers of the senses in general and the vision in particular, is found in a remarkable book, the "Micrographia" of Robert Hooke (1635-1703), published by the Royal Society of London in 1665, which is a demonstration of the advantages to be gained by the use of artificial devices of precision in studying

[21] J. G. Curtis: Harvey's Views on the Use and Circulation of the Blood, 1915. T. H. Huxley: William Harvey, Fortnightly Review, 23, 1878 (Also Coll. Sci. Mem., Vol. 4, p. 319).

[22] Harvey: De Motu Cordis et Sanguinis, English trans. by R. Willis, 1848. (See reprint in "Everyman's Library," pp. 55-56.)

[23] Miall, op. cit., p. 136.

nature. "The next care to be taken, in respect to the senses, is a supplying of their infirmities with instruments, and, as it were, the adding of artificial organs to the natural; this in one of them has been of late years accomplished with prodigious benefit to all sorts of useful knowledge, by the invention of optical glasses. . . . . It seems not improbable, but that by these helps the subtiliety of the composition of bodies, the structure of their parts, the various texture of their matter, the instruments and manner of their inward motions, and all the other possible appearances of things, may come to be more fully discovered. . . . . ."[24]

Although the work is replete with singular anticipations of the discoveries and inventions of other workers in various branches of science, the biologist's interest is chiefly in Hooke's application of his improved compound microscope to the study of plants and animals which paved the way for the more special, profound, and methodical studies of the contemporary students of nature. In the Micrographia are clearly described and figured for the first time the "little boxes or cells"[25] of organic structure, and his use of the word "cell" is responsible for its application to the protoplasmic units of modern biology. It is fair to say that the influence of the Micrographia permeated the sciences in various directions and the illustrations of microscopic objects were copied for nearly two centuries.[26]

The Micrographia was a mere incident in the varied interests of Hooke, while van Leeuwenhoek (1632-1723) spent a long life in studying nearly everything which he could bring within the scope of his simple lenses. Fascinated with the "world of the infinitely little," with a virgin field before him, and no literature on the subject to divert his energies, he was able year after year to send letters to learned academies, chiefly the Royal Society of London, describing what of necessity were discoveries. He saw the Bacteria—he is the first bacteriologist—the Infusoria—he is the first protozoologist—Yeast cells, Rotifers, Hydra; but the list is too long.[27] However, all of Leeuwenhoek's work is by no means dusultory. He displayed much ingenuity in studying the flow of blood through capillaries of the web of the frog's foot and bat's wing, the viviparous reproduction in aphids, the development of fleas, the dessication of rotifers. And all the time he was looking for evidence against the idea of spontaneous generation, being convinced "it is fully proved that no living creature is produced by corruption or putrefaction."[28] But Leeuwenhoek's contribution which attracted the most interest was his description of spermatozoa. Brought to his attention by a young physician,

[24]Micrographia, preface.

[25]Micrographia, observation XVIII, pp. 112-116.

[26]L. L. Woodruff: Hooke's Micrographia, American Naturalist, 53, 1919.

[27]Miall, op. cit., pp. 200-223. B. W. Richardson: Disciples of Aesculapius, 1900.

[28]Select Works of A. van Leeuwenhoek, edited by S. Hoole, 1800-7.

Hamm, Leeuwenhoek transmitted the discovery to the Royal Society. His imagination, however, outstripped his observations and he thought he saw evidence of a homunculus within the spermatozoon. Thus he came to regard the sperm as the true germ which had only to be hatched, as it were, by the female. He was thus the first of the school of 'spermists' which opposed the idea of the 'ovists' that all is performed in the egg.[29]

The patience of Leeuwenhoek would have been strained to the breaking point by the studies on insect anatomy made by Swammerdam (1637-1680) and eventually brought together in his Biblia Naturae. Instigated largely by the desire to refute the current notion, supported by certain statements of the great Harvey, that insects and similar lower animals are merely masses of organic matter which have been moulded, as it were, into a definite form, and are without complicated internal organs, Swammerdam spent his life in studies on their structure and life histories.[30] Revealing as he did, by the most delicate technique in dissection, the finest details observable with his lenses, Swammerdam not only set a standard for minute anatomy which, with that of his contemporary Malpighi, was not surpassed until the work of Lyonet and others nearly a century later, but also dissipated, for all time, the conception of simplicity of structure in the lower animals. Swammerdam thus quite naturally added one more argument to those of Redi and others against spontaneous generation:

> That vulgar opinion, . . which ascribes birth and growth of animals to putrefaction and chance, is diametrically opposite to sound reason. . . . in the smallest animals we constantly everywhere find as much order, contrivance, beauty, wisdom, and omnipotence in the Great Architect, as are shown in the viscera of the largest animals. For to these greater animals all others, however minute, are similar in the great respects of brain, nerves, muscles, heart, stomach, intestines, and parts subservient to generation, and to every other useful purpose; so that one might in a manner affirm, that God has created but one animal, though divided into an infinite number of kinds or species, differing from each other in the figures and inflexions, and extensions of their limbs, as likewise in their dispositions, food and manner of living.[31]

Contemporaries of Hooke, Leeuwenhoek, and Swammerdam were two men who may be considered as the pioneer histologists—Malpighi of Bologna and Grew of London. Grew (1641-1712) devoted all his attention to plant structure, while Malpighi, in addition to botanical studies which paralleled Grew's, made elaborate investigations on animals.

The versatility as well as the genius of Malpighi (1628-1694) is illustrated by his studies on the anatomy of plants, the function of leaves, the development of the plant embryo, the embryology of the chick, the anatomy of the silkworm, the structure of glands.[32] Skilled

[29]Phil. Trans. Royal Soc., 142, 1678.

[30]H. Boerhaave: Life of Swammerdam (Preface to the Biblia Naturae) F. C. Miall, op. cit., pp. 174-199. Also Miall's History of Biology, 1911.

[31]Biblia Naturae, English trans. Edited by John Hill, 1758, part 2, p. 71.

[32]Miall, op. cit., p. 145.

in anatomy but with prime interest in physiology, his lasting contribution lies in his dependence on the microscope for the elucidation of problems where structure and function, so to speak, merge—well illustrated by his ocular demonstration of the capillary circulation in the lungs; at once his first and greatest discovery and the first of prime importance ever made with a microscope—since it completed Harvey's work on the circulation of the blood. Malpighi wrote:

"I see with my own eyes a certain great thing. . . . It is clear to the senses that the blood flowed away along tortuous vessels and was not poured into spaces, but was always contained within tubules, and that its dispersion is due to the multiple winding of the vessels."[33]

The microscopists taken collectively created an epoch in the history of biology, so important is the lens for the advancement of the science.[34] Indeed we find that, broadly speaking, its development along many lines during the eighteenth and particularly the nineteenth century has gone hand in hand with improvements in the compound microscope itself and in microscopical technique. Again, the microscopists in general and Malpighi in particular opened up so many new paths of advance that from this period on it is not possible, even in the most general survey, to discuss the development of biology as a whole. The composite picture must be formed by emphasizing and piecing together various lines of work, such as classification, comparative anatomy, embryology, physiology, heredity, and evolution.

Classification

Classification has as its object that of bringing together things which are alike and separating the unlike. It is "discrimination, description, and illustration—the necessary census task which forms the groundwork on which great theories may be built up"[35]—a problem of no mean proportions when a conservative estimate today shows upward of a million species of animals and plants, leaving out of account the myriads of forms represented only by fossil remains. Naturally the earliest classifications were utilitarian, or more or less physiological: edible and harmful, useful and useless, fish of the sea and beasts of the earth. But as knowledge increased, emphasis was shifted to the anatomical criterion of specific differences and thenceforth classification became at once an important aspect of natural history—a central thread both practical and theoretical. Practical, in that it involved the arranging of living forms so that a working catalog was formed which involved nice anatomical discrimination, and therefore the amassing of a large body of facts concerning animals and plants. Theoretical, because in the process botanists and zoologists were impressed, almost unconsciously at first, with the 'affinity' of various

[33]Foster, op. cit., p. 96.
[34]J. Sachs: History of Botany. English translation, 1890, pp. 220-222.
[35]R. L. Praeger, in Oliver's Makers of British Botany, 1913, p. 220.

types of animals and of plants and so were led to problems of their origin.

From Aristotle who emphasized the grouping of organisms on the basis of structural similarities, we must pass over some seventeen centuries, in which the only work of interest was done by the herbalists and encyclopaedists, to the time of Ray (1628-1705) of Cambridge. As a matter of fact, the Theophrastan classification of plants as Trees, Shrubs and Herbs persisted until the end of the seventeenth century. Previous to Ray the term "species" was used somewhat indefinitely, and his chief contribution was to make the word more concrete by applying it solely to groups of similar individuals, which exhibit constant characters from generation to generation. Covering, as Ray's labors did, the classification of both animals and plants, it is probably not an exaggeration to regard him as the seventeenth century precursor of the great Swedish taxonomist, Linnaeus, for whom he paved the way.[36]

Like many another genius, Linnaeus (1707-1778) was a product of his time and, perhaps, one of the very best examples of the fact that "the most original people are frequently those who are able to borrow the most freely"—to see a great deal in what to others appears commonplace. Linnaeus was first and foremost a botanist. Garnering the best the past had to offer in taxonomy and bringing to bear on it his supreme talent for "classifying, coordinating and subordinating," Linnaeus gave botanical students at once a practical method of classification of flowering plants, based chiefly on the number and arrangement of the stamens. At the same time he insisted on brief descriptions and the scheme of giving each kind of organism a name composed of two words, in which the second word indicates the species and the first, the genus, a group of closely similar species. In short, to name an organism is to classify. Linnaeus' success with botanical taxonomy led him to extend the principles to animals and even to the so-called Mineral Kingdom, the latter showing at a glance his lack of appreciation of any genetic relationship between species.[37]

Indeed the terms genus and species to Linnaeus expressed a transcendental affinity since he believed that species, genera, and even higher groups represented distinct, consecutive thoughts of the Creator. Accordingly, the ultimate goal of taxonomy was to determine the so-called scala naturae. Thus, Linnaeus crystallized two dogmas—constancy and continuity of species—which permeated biology and reached, in slightly different form, their high water mark, indeed a reductio ad absurdum, in Agassiz's Essay on Classification a century later—as fate would have it, just a year before Darwin's Origin of Species.[38]

[36]S. H. Vines: Robert Morrison and John Ray, in Oliver's Makers of British Botany, 1913, p. 9.

[37]J. Sachs, op. cit., p. 108. F. C. Miall: History of Biology, p. 66.

[38]Miall, op. cit., p. 157.

Though today Linnaeus' conception of fixity has been replaced by modifiability of species; the affinity which he recognized and expressed in transcendental terms has given place to similarity based on descent, and his artificial classifications have been superceded by natural classifications, which express, or attempt to express, this genetic connection between species—nevertheless, his greatest works, the Systema Naturae and Species Plantarum created an epoch in biological history, and are by common consent the base line of priority in zoological and botanical nomenclature.[39]

An aftermath of Linnaeus' labors must be mentioned. Naturalists in general and botanists in particular were so captivated with the facility which the Linnean system afforded for cataloging, that collecting and naming became a dominant note for nearly a century. The few who employed microscope and scalpel are outstanding figures on the path to progress.[40]

Comparative Anatomy

The first step toward scientific classification was made, as we have seen, by Aristotle in emphasizing anatomical characters as taxonomic criteria, so that to all intents and purposes classification implies comparison of structural details. Indeed Aristotle recognized the unity of structural plan throughout the chief animal groups, and in reference to man he says "whatever parts a man has before, a quadruped has beneath; those that are behind in man form the quadrupeds back." Not only did he appreciate homology, but also correlation of parts and division of labor in the economy of the animal body.[41] And Theophrastus approached plant morphology in the same philosophical spirit—witness his recognition of the flower as a metamorphosed leafy branch.[42] But it probably would be reading too much into the past to assign the origin of comparative anatomy of animals in the modern sense of the term to Greek, Roman, or early Renaissance science, since description rather than comparison was the key-note. The same may be said of the anatomical work of Vesalius, Harvey, and Malpighi though the latter compared the microscopic structure of various organs, and in his Anatomy of Plants, which shares with Grew's Anatomy the honor of founding vegetable histology, emphasizes the importance of the comparative method. Owing to the less marked structural differentiation of plants in comparison with animals, plant anatomy does not lend itself as readily to descriptive analysis so that an epoch in the study of comparative anatomy is less defined in botany

[39]Systema Naturae, 1735, 10 ed., 1758. Species Plantarum, 1753.

[40]F. W. Oliver: Makers of British Botany, 1913, p. 193. For the point of view of the early part of the nineteenth century, cf. W. Swainson: On the Study of Natural History, 1834.

[41]E. S. Russell: Form and Function; A Contribution to the History of Animal Morphology, 1917, Chapter 1.

[42]Greene, op. cit.

than in the sister science. Therefore both reason and expediency warrant confining our attention to the comparative anatomy of animals.

Probably the first consistent attempt to make a comparative study of the form and arrangements of the parts of animals is represented in a volume published in 1645 by Severinus (1580-1656) of Naples in which he concluded that many vertebrates are constructed on the same plan as man, though Belon, nearly a century earlier, figured and compared the skeletons of bird and man side by side "in the same posture, and as nearly as possible bone for bone."[43] Tyson (1650-1708) of Cambridge at the end of the seventeenth century definitely instituted the monographic treatment of comparative morphological problems in his study of the anatomy of man and monkeys.[44]

Comparative anatomy, however, as a really important aspect of biological work, in fact, as a science in itself, was the result of the life work of Cuvier (1769-1832) of Paris during the first quarter of the last century. It is true that his immediate predecessors, such as John Hunter (1728-1793), the founder of the Hunterian Collection, the nucleus of the anatomical Museum of the Royal College of Surgeons in London, Camper (1722-1789) of Groningen, and Vicq d'Azyr (1748-1794) of Paris, added synthesis to analysis and reached a broader view-point in anatomical study, but Cuvier's claim to fame rests on the remarkable breadth of his investigations—his grasp of the comparative anatomy of the whole series of animal forms.[45] And not content merely with the living, he made himself the first real master of the anatomy of fossil vertebrates and as such is the founder of paleontology.[46]

Cuvier's position in the history of anatomy is largely due to his emphasizing, as Aristotle had done before him, the functional unity of organisms—that the interdependence of organs results from the interdependence of function and that structure and function are two aspects of the living machine which go hand in hand. Cuvier's famous principle of correlation—"Give me a tooth," said he, "and I will construct the whole animal"—is really an outcome of this viewpoint. Every change of function involves a change in structure and therefore, given extensive knowledge of function and of the interdependence of function and structure, it is possible to infer from the form of one organ that of most of the other organs of an animal. "In a word, the form of the tooth implies the form of the condyle; that of the shoulder blade that of the claws, just as the equation of a curve implies all its properties."

43F. C. Miall: History of Biology, pp. 18-19.

44Cf. Garrison, op. cit., p. 240.

45Cf. Russell, op. cit., Chapter 3.

46T. H. Huxley: The Rise and Progress of Paleontology, Nature, 24, pp. 452-55, 1881. (Also Coll. Sci. Mem. Vol. 4). O. C. Marsh: History and Methods of Paleontological Discovery, Presidential address, Amer. Assn. Adv. Sci., 1879.

Although Cuvier undoubtedly allowed himself to exaggerate his guiding principle until it exceeded the bounds of facts, he was above all in his science and philosophy a hard-headed conservative and autocrat. He opposed with equal vigor the influence of the Naturphilosophie of Schelling and his school with its transcendental anatomy, Platonic archetypes and the like, as well as the evolutionary speculations of Lamarck and his school. From the vantage points of today we know that in one case he was right and in the other wrong—though in so far as the facts then extended, his opposition was justified in both cases.

Cuvier's immediate successors in France were Milne-Edwards and Lacaze-Duthiers; in Germany, Meckel, Rathke, Müller, and Gegenbaur; in England, Owen and Huxley, and in America, Agassiz, Cope, and Marsh Among these, Owen (1804-1892) perhaps demands special mention. At once a peculiar combination of Cuvierian obstinacy in regard to facts and of transcendental imagination, Owen spent a long life dissecting with untiring patience and skill a remarkable series of animal types, as well as in reconstructing extinct forms from fossil remains. Aside from the facts accumulated, probably his greatest contribution was making concrete the distinction between homologous and analogous structures, which has been of the first importance in working out the pedigrees of plants as well as animals—though Owen himself took an enigmatical position in regard to organic evolution.[47]

Physiology

Anatomy emphasizes the static and physiology the kinetic aspect of the organism, though, as we have seen, structure without function is a lifeless subject and function without structure is an impossibility, since, in Huxley's happy phraseology, physiology is the mechanical, and he would now add, chemical engineering of the living organism.

Animal and plant physiology was discussed by Aristotle, but as might be expected since physiology is more dependent than anatomy upon progress in other branches of science, with less happy results. Similarly, Galen was hampered in his attempt to make physiology a distinct department of learning based on a thorough study of anatomy, and the corner stone of medicine. Like Aristotle he attempted to develop a picture of the modus operandi of the organism, and with such success that fate foisted it upon uncritical generations through fifteen centuries. The worst of it was not that it was nearly all wrong, but that to question Galen's physiology or anatomy was little less than sacrilege until the labors of Vesalius and Harvey brought a realization that Galen had not quite finished the work.[48]

[47]Life of Richard Owen, by his grandson, 1894, vol. 2, pp. 89-96. Also, Essay on Owen's Position in Anatomical Science by T. H. Huxley, in above work.

[48]Foster, op. cit., p. 12.

Neither Vesalius nor Harvey made an attempt to explain the workings of the body by appeal to so-called physical and chemical laws; and for good reason. Chemistry had not yet thrown off the shackles of alchemy and taken its legitimate place among the elect sciences, while during Harvey's lifetime, under the influence of Galileo, the new physics arose. But by the end of the seventeenth century both physics and chemistry, aided by the philosophical systems of Bacon and Descartes, had forced their way into physiology and split it into two schools: the iatro-mechanical founded by Borelli (1608-1679), who by incisive physical methods attacked a long series of problems, frequently with brilliant results; and the iatro-chemical school, which developed from the influence of Franciscus Sylvius (1614-1672) as a teacher rather than as an investigator.[49]

This awakening brought a host of workers into the field and the harvest of the century was garnered and enriched by Haller (1708-1777), the "abyss of learning" of the time, in a comprehensive treatise which at once indicated the erudition and critical judgment of its author and established physiology as a distinct and important branch of biological science, rather than a mere adjunct of medicine.[50] Great as was this contribution of Haller in crystallizing physiology and setting the dividing line between the old and the modern, unfortunately the weight of the author's authority was ranged in favor of two theories which were, in crude form, attracting the attention of biologists—the idea of special vital force and the preformation theory of development.

Perhaps the most significant lines of advance in Haller's century were in setting the physiology of nutrition and respiration—both of which waited upon the work of the chemists—well upon their way toward modern form. Réaumur (1683-1757) of Paris, and Spallanzani (1729-1799) of Pavia may be singled out for their exact studies of gastric digestion which, against the background of the pioneer work during the previous century by van Helmont (1477-1644), Sylvius (1614-1672), Stensen (1638-1686), de Graaf (1641-1673), Peyer 1653-1712), and Brunner (1653-1727), established solution of the food as the main factor in digestion, though it was not clear how these changes differed from ordinary chemical ones. So physiologists of a vitalistic turn of mind cloaked their ignorance under the term "animalization," and left for eighteenth century investigators the establishment of the fact that food in passing along the digestive tract runs the gamut of a series of complex chemical substances, or enzymes, each of which has its part to play in putting the various constituents of the food into such a form that they can pass to the various cells of the body.[51]

[49]Foster, op. cit., Chapters 3 and 6.
[50]A. Haller: Elementa Physiologiae Corporis Humani, 1757.
[51]W. B. Johnson: History of the Progress and Present State of Animal Chemistry, 1803.

On the side of respiration a somewhat closer approach was made toward a true understanding of the process, but there was a better foundation on which to build. The Galenic notion that respiration is a process of refrigeration—a getting rid of the innate heat of the heart and of fuliginous vapors—had been superceded, through the efforts of Harveyan experimentalists—the chemist Boyle (1627-1691), the versatile genius Hooke, the physician Lower (1631-1690), and the lawyer-chemist Mayow (1643-1679). The climax only awaited the overthrow of the Stahlian phlogiston theory, which presented an inverted picture of combustion, and the actual discovery of oxygen. This came in the work of Black, Priestley (1733-1804), Lavoisier (1743-1794), and Girtauner (1760-1800) which made it clear that the chemical changes taking place in respiration involve essentially a process of combustion, and it chiefly remained for later work to show that this takes place in the tissues rather than in the lungs.[52]

Enough perhaps has been said to indicate the trend of physiology away from the maze of Galenic spirits in which science lost itself, toward the modern atmosphere of science with its *working hypothesis*, that life phenomena are an expression of a complex interaction of physico-chemical laws which do not differ fundamentally from the so-called laws operating in the inorganic world, and that the economy of the organism is in accord with the law of the conservation of energy —probably the most far reaching generalization of science during the past century. Although it is difficult to discriminate, certainly the names of Liebig, Wöhler (1800-1882), the brothers Weber, Ludwig (1816-1895), Helmholtz (1821-1894), Müller (1801-1858) and du Bois-Reymond (1818-1896) in Germany; Dumas (1800-1884), Magendie (1783-1855) and Bernard (1813-1877) in France; Donders (1818-1889) in Holland; and Hall (1790-1857) in England were, individually and collectively, chiefly responsible for the reformation of physiology.[53]

Most of the firm foundation on which physiology of animals rests today has been built up by work on vertebrates, though since the middle of the nineteenth century, when the versatile Müller showed the value of studying the physiology of higher and lower animals alike, the science of comparative physiology may be said to have been established.[54] Perhaps it is not an exaggeration to say that the tendency to focus evidence, in so far as possible, from all forms of life on general problems of function represents the present trend of physiological enquiry.

[52] J. Loeb: Dynamics of Living Matter, p. 7. O. Hertwig: The Growth of Biology in the Nineteenth Century, Smithsonian Report, 1900, pp. 461-78.

[53] M. Verworn: General Physiology, English trans., 1899, pp. 16-20. Stirling, op. cit., p. 106.

[54] P. B. Hadley: Johannes Müller, Popular Science Monthly, 1908.

The less obvious structural and functional differentiation of plants retarded progress in plant physiology as it did in plant anatomy. Probably of most historical, and certainly of most general interest is the development of our knowledge of the nutrition of green plants.

Aristotle's notion that the food of plants is prepared for them in the ground was still prevalent at the end of the sixteenth century when Cesalpino, the most philosophic botanist of his day, thought that food enters and passes through vessels and fibers of plants much as oil in a lamp wick, and Jung conceded that plants are not mere passive absorbers of ready-made food, but possess the power of selection from the soil the ingredients needed. Van Helmont (1577-1644), on the border line between alchemist and chemist, who precociously brought to bear the chemical point of view on animal physiology, made the first experiment in plant nutrition on record. He planted a small tree in a large vessel and weighed it. Then after five years, during which time it had only been supplied with water, he found that it had increased some thirty fold in weight and "not suspecting that the plant drew a great part of its materials from the air was forced to exaggerate the virtues of rain-water."[55] Malpighi, however, from his studies on plant histology, gave the first hint of the fact of supreme importance that the crude sap, which enters by the roots, is carried to the leaves where, by the action of sunlight, evaporation, and some sort of a fermentation it is "digested" and then distributed as food to the plant as a whole. But, it is Hale (1677-1761) to whom the botanist looks as the Harvey of plant physiology, for in his Vegetable Statics, published in 1727, he laid the foundations of the physiology of plants by making "plants speak for themselves through his incisive experiments." For the first time it became clear that green plants derive an important element of their food from the atmosphere, and also that the leaves play an active rôle in the movements of fluids up the stem and in eliminating superfluous water through evaporation.[56]

Still the picture was incomplete, and so it remained until the biologist had recourse to further data from the chemist. In 1779 Priestley, the discoverer of oxygen, showed that this gas under certain conditions is liberated by plants. This fact was seized upon by Ingen-Housz (1730-1799) who demonstrated that carbon dioxide from the air is broken down in the leaf during exposure to sunlight, the plant retaining the carbon and returning oxygen—the process of carbon-getting being quite distinct from that of respiration in which carbon dioxide is eliminated. It remained then for de Saussure to show, by quantitative studies of the plant's income, that, in addition to the fixation of carbon, the elements of water are also employed while from the soil various salts including the element nitrogen are obtained. But

[55]Thomson, The Science of Life, p. 70.

[56]F. Darwin: Stephen Hales, in Makers of British Botany, 1913, p. 65.

it was nearly the middle of the last century before the influence of Liebig (1803-1873) and the incisive experiments of Boussingault established the fundamental part played by the chlorophyll of the green leaf in making certain chemical elements available to animals. The realization of the cosmical function of green plants—the link they supply in the circulation of the elements in nature—is a landmark in biological progress, and we may leave the subject here since, except for details in regard to some of the more evident chemical products of photosynthesis and the influence of external factors, the matter still stands essentially where it was in de Saussure's day.[57]

Histology

Studies on the physiology of plants and animals naturally involved the progressive analysis of the physical basis of the phenomena under consideration, but the Aristotelian classification of the materials of the body into unorganized substance, homogenous parts or tissues, and heterogenous parts or organs practically represents the level of analysis until the beginning of the last century. It is true, as we have mentioned, that Hooke in 1665 discovered that cork tissue under the microscope seemed to be composed of little bòxes or "cells," and somewhat similar though more extensive observations were made by the contemporary students of the microscope. But another century had nearly elapsed before these microscopic elements were looked at from the point of view of their relation to the development of organisms. Wolff (1733-1794) in 1759 attempted to show the falsity of the prevailing idea that all organisms are preformed in the germ and that the adult state is attained merely by an unfolding and enlarging, by a critical study of the development of animals and plants.[58] And he not only proved his point but also showed that both plants and animals in early developmental stages show a similar fundamental structure, "since every organ is composed at first of a little mass of clear, viscous, nutritive fluid, which possesses no organization, but is at most composed of globules. In this semi-fluid mass cavities are now developed; these, if they remain round or polygonal, become the subsequent cells; if they elongate, the vessels; and the process is identically the same, whether it is examined in the vegetating point of a plant, or in the young budding organs of an animal." But Wolff's refutation of preformation, chiefly through the opposition of Haller, proved abortive, and his observations on cells were so far ahead of the times that they had but slight influence on biological advance. It was not until the revival of interest in plant anatomy early in the last century that the cell became a particular object of study—and still it

[57]H. A. Spoehr: The Development of Conceptions of Photosynthesis since Ingen-Housz, Scientific Monthly, 9, 1919, p. 32.

[58]C. F. Wolf: Theoria Generationis, 1759. W. M. Wheeler: Wolff and the Theoria Generationis, Woods Hole Biol. Lectures, 1898, pp. 265-284.

was the cell wall rather than the contents on which attention was fixed. Then the English botanist Brown discovered the cell nucleus in 1831,[59] quickly followed by the classic investigations of the botanist Schleiden (1804-1881) and the zoologist Schwann (1810-1882), published in 1838 and 1839,[60] which taken together clearly showed that all organisms are composed of units or cells which are at once structural entities and centers of physiological activities. Each cell carries on a double life; one a quite independent and self-contained life; the other a dependent life in so far as the cell has become an integral part of the organism. The life of the organism is the life of the individual cells which compose it. And further, not only are all organisms congeries of cells, but the egg is a cell and the development of animals and plants consists in the multiplication of this initial cell into the multitude of different kinds which constitute the adult: "The elementary parts of all tissues are formed of cells in an analogous, though very diversified manner, so it may be asserted that there is one universal principle of development for the elementary parts of organisms, however different, and that this principle is the formation of cells."[61]

Unquestionably the launching of the cell theory represents one of the greatest generalizations in biology, and only needed for its consummation the full realization that the viscid, jelly-like material, which zoologists interpreted as the true living matter of animals, and the quite similar material, which botanists considered the true living part of plants, are practically identical. This conception was grasped in the early sixties by Schultze (1825-1874) in the formulation of the protoplasm theory, and thenceforth not only morphological elements —cells—but also the material of which they are composed—protoplasm —was recognized as fundamentally the same in all living beings. Indeed, the realization of a common physical basis of life in both plants and animals—a common denominator to which all vital phenomena are reducible—gave content to the term biology and created the science of life in its modern form.[62]

Embryology

The enunciation of the cell theory came, as we have seen, from combined studies on the adult structure and on the development of plants and animals from the germ or egg, and accordingly implies that the science of embryology has a history of its own. As a matter of fact, Aristotle discussed the wonder of the beating heart in the hen's egg after three days' incubation, but there the subject practically rested

[59]J. B. Farmer: Robert Brown, in Makers of British Botany, 1913, p. 119.

[60]M. J. Schleiden: Ueber Phytogenesis, 1838. T. Schwann: Mikroscopische Untersuchungen ueber die Uebereinstimmung inder Structur und dem Wachstum der Thiere und Pflanzen. English translations by H. Smith, 1847.

[61]Schwann, op. cit., English trans. p. 165.

[62]E. B. Wilson: The Cell in Development and Inheritance, 2d ed., 1900. Verworn, op. cit.

until Fabricius (1537-1619), early in the seventeenth century, published a treatise which illustrated the obvious sequences of events within the hen's egg to the time of hatching.[63] This beginning was built upon by a pupil of Fabricius, the celebrated Harvey, who added many details of interest and insisted, as Aristotle had before him, that the embryo arises as a gradual differentiation of unformed material of the egg.[64]

However, little progress in embryology was possible without the microscope which was first applied to the problem by the versatile Malpighi, in two treatises sent to the Royal Society in 1672.[65] One has but to study his splendid series of illustrations to realize how animal development was placed upon a plane so advanced that for over a century it was unappreciated. One conclusion of Malpighi, however, was seized upon by contemporary biologists. Apparently, unbeknown to him, some of the eggs which he studied were slightly incubated so that he thought traces of the future organism are preformed in the egg. This error, coupled, for example, with Swammerdam's observation of the fact that parts of the adult insect are delineated in the larva ready to pupate, crystallized the preformation theory which denied all true development or epigenesis, as advocated by Aristotle and Harvey, and held that the future adult characters pre-exist in miniature in the egg. Even the acute observations of Wolff in his embryological classic, to which we have referred, failed of fruition since it negated the preformation idea which, in the years that had elapsed since Malpighi, had become the dominant question in embryology. Indeed the theory was carried to a reductio ad absurdum by Haller, Bonnet (1720-1793) and others who accepted the logical conclusion that:

> Each seed includes a plant: that plant, again,
> Has other seeds, which other plants contain:
> Those other plants have all their seeds; and those,
> More plants, again, successively inclose.
> * * * * * * * * *
> So Adam's loins contain'd his large posterity,
> All people that have been, and all that e'er shall be.
>
> Amazing thought! what mortal can conceive
> Such wond'rous smallness! Yet we must believe
> What reason tells: for reason's piercing eye
> Discerns those truths our senses can't descry.

So Baker expressed it in one of the few departures from prose permitted in the Philosophical Transactions of the Royal Society.[66]

The truth of the matter is that the time was not ripe for theories of development. The preformationists were wrong but so were Aristotle, Harvey, and Wolff who went to the other extreme and denied all egg

63Locy, op. cit., p. 43. Russell, op. cit., p. 113.
64W. Harvey: Exercitationes de Generatione Animalium, 1651.
65Locy, op. cit., p. 202.
66H. Baker: The Microscope Made Easy, 2d ed., 1743, p. 252.

organization and therefore tried to get something out of nothing. It remained for the present generation of embryologists to work out many of the details of the origin of the germ cells and their organization, and to reach a level of analysis deep enough to suggest how "the whole future organism is potentially and materially implicit in the fertilized egg cell," and thus that "the preformationist doctrine had a well concealed kernel of truth within its thick husk of error."[67]

The real step to progress, Baker's implicit confidence in "reason" to the contrary, came in the accurate and comprehensive studies of von Baer (1792-1876) published in the thirties of the last century.[68] Taking his material from all the chief groups of higher animals von Baer founded comparative embryology. Among his achievements may be mentioned the clear discrimination of the chief developmental stages, as cleavage of the egg, germ layer formation, tissue and organ differentiation; the importance of the facts of development for classification, and the discovery of the egg of mammals. His observations on the origin and development of the germ layers, which afforded the key to many general problems of morphogenesis, and his emphasis on the resemblance between certain embryonic stages of higher animals and the adult stages of lower forms, were exaggerated and crystallized by his successors, under the influence of the evolution theory, as the germ layer theory and the recapitulation theory, or von Baer's law. Both were of the greatest importance in stimulating research for half a century—and if the present generation has not inherited its forebears' implicit faith in the theories, it at least has profited immensely by the facts they accumulated.[69]

From every point of view von Baer created an epoch in embryology synchronous with the formulation of the cell theory by Schleiden and Schwann, and it thenceforth became the problem of the embryologist to interpret development in terms of the cell. Time will not permit us to follow the establishment of the fact that the egg and the sperm are really single nucleated cells; that fertilization consists in the fusion of egg and sperm and the orderly arrangement of their chief nuclear contents, or chromosomes; that the new generation is the fertilized egg since every cell of its body as well as every chromosome in every cell is a lineal descendant by division from the egg, and so from the germ cells which united at fertilization to form it. Such, however, are the chief results of cytological study since von Baer; but embryologists have not been content to employ merely the descriptive method, and the

[67]Thomson, op. cit. C. O. Whitman: Woods Hole Biological Lectures, 1894, pp. 205-272. E. B. Wilson: The Problem of Development, Science, 21, 1905, pp. 281-294.

[68]K. E. von Baer: Ueber Entwickelungsgeschichte der Thiere. Beobachtung und Reflexion, 1828-37. Cf. Huxley: Philosophical Zoology Selected from the Works of K. E. von Baer, in Scientific Memoirs, February and May, 1853.

[69]Locy, op. cit., pp. 214-222.

dominant note of the most modern research under the influence of Roux is physiological—the experimental study of the significance of fertilization, the dynamics of cell division, the basis of differentiation, the effect of environmental stimuli, and so on.[70]

Genetics

It is but natural that the study of inheritance could be little more than a groping in the dark until embryology, under the influence of the cell theory, afforded a body of facts which clearly indicated that the fertilized egg is typically the sole bridge of continuity between successive generations. Indeed the present science of genetics has a history confined solely to post-Darwinian times and mostly to this century.

Although clearly suggested by a number of workers, the conception of the continuity of the germ cells—or germ plasm—was first forced upon the attention of biologists and given greater precision by Weismann (1834-1914) in a series of essays culminating in 1892 in his volume entitled The Germ Plasm. He identified the chromatin material which constitutes the chromosomes of the cell nucleus as the specific bearer of hereditary characters, and emphasized a sharp distinction between the cellular derivatives of the fertilized egg—on the one hand, the somatic cells which by division and differentiations build up the body of a higher plant or animal; and on the other, the germ cells which are destined to play but little part in the life of the individual which bears them, but instead are to be liberated and give rise to the next generation. The importance of this distinction can hardly be over emphasized for at once it makes clear that, for all practical purposes, the bodily characteristics of an individual are negligible from the stand point of heredity, since the offspring are descendants not from the body cells, but from the germ cells which it carries—and these in turn from the germ cells of the preceding generation. As Weismann insisted, this view makes it difficult to conceive how modifications of the soma can so specifically affect the germ cells which it bears that the latter can reproduce the modifications—in other words that so-called "acquired characters" can not be inherited. And there is no satisfactory evidence that such characters are inherited. The practical bearings of this conclusion are obviously of the highest importance, lying as they do at the very root of many questions in regard to the factors of evolution, not to mention such practical ones as education and eugenics.

While this viewpoint has been gradually gaining content and precision, the science of heredity has been advancing not only by exact studies of the structure and physiology of the germ cells, but also by statistical investigations of the results of heredity—the various characters of animals and plants in parent and offspring.

[70] Wilson, op. cit.

The first studies of this type which attracted the attention of biologists were made by Galton (1822-1911), who in the eighties and nineties of the last century amassed a large amount of data in regard, for example, to the stature of children with reference to that of their parents, and formulated his well known "laws" of inheritance.[71] But the epoching making work which eventually created the science of genetics was that of an Austrian monk, Gregor Mendel (1822-1884), who combined in a masterly manner the experimental breeding of pedigreed strains of plants and the statistical treatment of the data thus secured in regard to the inheritance of sharply contrasting characters, such as the flower color in sweet peas. Mendel's work was published in 1865 in an obscure natural history periodical[72] and he himself abandoned his teaching and research to become the Abbot of his monastery. Thus terminated prematurely the productive work of one of the epoch makers of biology, and the now famous "Mendelian laws" of inheritance were unknown to science until 1900 when other biologists, coming to similar results, unearthed his forty-year-old paper. We can pause only to say that the fundamental principle of the segregation of the genes of the alternative characters within the germ cells, which Mendel's work indicated, has been extended to other plants and to animals, and from being, as at first thought, a principle of rather limited application, now seems to be the key to all inheritance. And the present results are extremely convincing because cytological studies on the architecture of the chromosome-complex of the germ cells keep pace and afford a picture of the physical basis—of the mechanism by which the segregation and distribution of characters by the Mendelian formula takes place.[73] Such is the deeply hidden germ of truth in the old preformation theories!

Origin of Life

With our present conception of the complexities of organisms it is difficult to realize that up to the seventeenth century naturalist and layman saw nothing more incongruous in the spontaneous origin of nearly all kinds of plants and animals than does the boy of today who believes that horse hairs soaked in water are transformed into worms. Even Aristotle thought that certain of the vertebrates, such as eels, arose spontaneously, and Harvey accepted the same view of the origin of many forms of life. It remained for Redi (1626-1698) to lay aside discussion for experiment. By protecting decaying meat from contamination by flies he demonstrated that these insects are not developed from the flesh and that the apparent transformation of meat into maggots

[71]F. Galton: Natural Inheritance, 1889.

[72]G. J. Mendel: Versuche über Pflanzen-Hybriden, Verhandlungen des naturforschenden Vereines in Brünn, Bd. 4, 1865.

[73]T. H. Morgan: The Physical Basis of Heredity, 1919.

is due solely to the eggs of flies being deposited thereon.[74] But the time-honored doctrine was not overthrown by this experiment or the long series which Redi made, for the presence of parasites within certain recondite parts of higher animals baffled Redi himself, while improvements in the microscope soon revealed a microcosm whose origin seemed plausibly explained as spontaneous. Biogenesis, or all life from preexisting life, was placed on a secure foundation only within the past sixty years by the working out of the remarkably complex life histories of internal parasites and by the classical demonstrations of Pasteur and others that micro-organism are not the result but the cause of decay; a fact which is at the basis of and is attested by the methods now universally in use in food preservation and aseptic surgery—to mention but two instances.[75] The vicissitudes of the doctrine of biogenesis—" la génération spontanée est une chimère," wrote Pasteur—is an eloquent illustration of the aphorism of the old London microscopist that "the likeliest method of discovering truth is by the observations and experiments of many upon the same subject."[76]

Organic Evolution

Since we have every reason to believe that all life now arises from preexisting life and has done so since matter first assumed the living state, it apparently follows that the stream of life is continuous from the remote geological past to the present and that all organisms of today have an ancient pedigree. This leads us to a question which has interested and perplexed thinking men of all times, how things came to be as they are today? It was the Greek natural philosophers who projected the idea of history into science and attempted to substitute a naturalistic explanation of the Earth and its inhabitants for the established theogenies, and thus started the uniformitarian trend of thought which culminated in the establishment of organic evolution during the past century.

Again it is Aristotle who is singled out among the Greeks for his combination of sound philosophy and induction which reaches no higher expression than in his statements regarding the relationships of organisms. He says, in substance: Although the line of demarcation is broadly defined, yet nature passes by ascending steps from one to the other. The first step is that of plants; which, compared with animals, seem inanimate. The second step nature takes is from plants to plant-animals, the zoophytes. The third step is the development of animals, which arise from an increased activity of the vital principle,

[74]F. Redi: Esperienze Intorno alla Generazione Degl'Insetti, 1668. English trans. 1909.

[75]T. H. Huxley: Biogenesis and Abiogenesis. Presidential Address, British Assn. Adv. Sci., 1870. Collected Essays, Vol. 8, L. L. Woodruff: The Origin of Life, in the Evolution of the Earth and Its Inhabitants, R. S. Lull, editor, 1918.

[76]Baker, op. cit., p. V.

resulting in sensibility; and with sensibility, desire; and with desire, locomotion. Man is the head of animal creation. To him belongs the God-like nature. He is preeminent by thought and volition. But although all are dwarf-like and incomplete in comparison with man, he is only the highest point of one continuous ascent.[77]

Broadly speaking, Aristotle apparently held substantially the modern idea of the evolution of life from a primordial mass of living matter to the highest forms, and believed that evolution is still going on—the highest has not yet been attained. In looking for the effective cause of evolution Aristotle rejected Empedocles' hypothesis of the chance play of forces, which embodied in crude form the idea of the survival of the fittest, and substituted secondary natural laws to account for the fact that "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end." As Osborn points out, Aristotle's rejection of the hypothesis of the survival of the fittest to account for adaptations of organisms was a sound induction from his necessarily limited knowledge of nature—but had he accepted it he would have been "the literal prophet of Darwinism."[78]

Although the thread of continuity of evolutionary thought is not broken from Aristotle to the present, no historical interest will be served in following the poetical expression by Lucretius, the discussion at once broad and narrow of the most liberal medieval Churchmen, the "Arab philosophy—a system of Greek thought expressed in a Semitic tongue and modified by Oriental influences," or the vagaries of the Renaissance naturalists and speculative evolutionists, who, with a minimum of fact and a plethora of imagination were the worst enemies of the evolution idea. In truth, the great natural philosophers from Bacon and Leibnitz to Kant and Hegel laid the broad foundation for our modern attack on evolution, but from the strictly biological viewpoint, two Frenchmen, Buffon and Lamarck, and two Englishmen, Erasmus Darwin and his grandson, Charles Darwin, stand preeminent, and the greatest is Charles Darwin.

Buffon (1707-1778) was a peculiarly happy combination of parlor entertainer and scientist—entertaining by each new volume of his great Natural History the social set of Paris, and instructing them at the same time. And it was largely between the lines of his Natural History that Buffon's evolutionary ideas found expression; but expressed they are, though sometimes difficult to decipher—beyond the ken, Buffon hoped, of the censor and dilettant, for apparently he was not of martyr stuff.[79] It is not strange, therefore, that there are some differences of opinion amongst biologists today as to just how much

[77]Lewes, op. cit., pp. 189-96. Osborn, op. cit., p. 48.
[78]Osborn, op. cit., pp. 55-57.
[79]S. Butler: Evolution Old and New. 3d Edition, 1911, p. 78. A. O. Lovejoy: Buffon and the Problem of Species, Pop. Sci. Monthly, 1911.

weight is to be placed on some of Buffon's statements, but certainly it is not exaggerating to ascribe to him not only the recognition of the factors of geographical isolation, struggle for existence, artificial and natural selection in the origin of species, but also, which is equally important, the propounding of a theory of the origin of variations. He thought that the direct action of the environment brings about modifications of the structure of animals and plants and these are transmitted to the offspring.[80]

When Buffon's influence was at its zenith, Erasmus Darwin (1731-1802), a successful medical practitioner, expressed consistent views on the evolution of organisms in several volumes of prose and poetry.[81] Although a contemporary critic in the Edinburgh Review remarked that Darwin's "reveries in science have probably no other chance of being saved from oblivion, but by having been married to immortal verse," today biologists recognize him as the anticipator of Lamarck's doctrine that variations spring from within the organism through its reaction to environmental conditions. "All animals undergo perpetual transformations which are in part produced by their own exertions, in consequence of their desires and aversions, of their pleasures and their pains, or of irritations, or of associations; and many of these acquired forms or propensities are transmitted to their posterity."[82]

While Cuvier was extending and synthesizing the knowledge of anatomy of living and extinct forms and founding the so-called school of facts, his fellow-countryman Lamarck (1744-1829), on the basis of work first on plants and then on animals, carried on in fearless manner the evolutionary inspiration of Buffon and Erasmus Darwin (though the latter's works may not have been known to him), and established the coterie of evolutionists in Paris each of whose essays Cuvier hailed as a "new folly." Lamarck developed with great care the first complete and logical theory of organic evolution, and is the one outstanding figure in biological uniformitarian thought between Aristotle and Charles Darwin. "For nature," he writes, "time is nothing. It is never a difficulty, she always has it at her disposal; and it is for her the means by which she has accomplished the greatest as well as the least of her results. For all the evolution of the earth and of living beings, nature needs but three elements—space, time, and matter."[83]

In regard to the factors of evolution, Lamarck emphasized the indirect action of the environment in the case of animals, and the direct action in the case of plants. The former are induced to react and thus

80Thomson, op. cit., pp. 219-220.

81Botanic Garden, 1791, Zoonomia, 1794-96; Phytologia, 1800; Temple of Nature, 1802. It is said that Paley's famous "Natural Theology" was written to counteract the influence of the Zoonomia.

82Zoonomia, 1st ed., p. 503. Cf. E. Krause: Life of Erasmus Darwin, with a Preliminary Notice by Charles Darwin. 1879.

83Hydrogéologie, 1802.

adapt themselves, while the latter, without a nervous system, are moulded directly by their surroundings. And, so Lamarck believed, such bodily modifications—acquired characters—are transmitted to the next generation and bring about the evolution of organisms.[84]

Through the influence of Cuvier, and the relative weakness of Lamarck's successors—the foremost was Etienne Geoffroy-Saint-Hilaire (1772-1844)[85]—the French School of evolutionists dwindled to practical extinction, while in Germany, Goethe (1749-1832), the greatest poet of evolution, and Treviranus (1776-1837) "brilliantly carried the argument without carrying conviction," for the man and the moment must agree. Then in England the uniformitarian ideas of Hutton (1726-1797), elaborated by Lyell (1797-1875) in his "Principles of Geology, being an attempt to explain the former changes of the Earth's surface by reference to causes now in action" (1830-1833), created an epoch in geology. The prevailing doctrine of cataclysms, emphasized among biologists especially by Cuvier, gradually gave place to that of uniformity—an orderly evolution of the Earth—and paved the way for the next logical step—the evolution of the Earth's inhabitants.[86]

It has been truly said that the idea of development saturated the intellectual atmosphere. But intrenched prejudices which hampered the acceptance of evolution in the inorganic world were immeasurably augmented when the world of life was approached, and only an overwhelming amount of scientific evidence, impartially and convincingly presented could carry conviction.[87] This, in part, accounts for the slight influence of the work of the earlier evolutionists, as well as for the reception accorded the evolutionary views expressed anonymously in the Vestiges of the Natural History of Creation[88] by Chambers (1802-1871). The ten editions of this work (1844-1860) created a furor, especially in England, and were opposed alike by biologist and layman.

The case for evolution at the time, as it appeared to the erudite Whewell, is thus summarized in the first edition (1838) of his well known "History of the Inductive Sciences" and reiterated in the third edition (1857): "Not only is the doctrine of the transmutation of species in itself disproved by the best physiological reasonings, but the additional assumptions which are requisite, to enable its advocates to apply it to the explanation of the geological and other phenomena of the earth, are altogether gratuitous and fantastical. Such is the

[84]Philosophie Zoologique, 1809. English trans. by H. Elliot, 1914. Osborn, op. cit., pp. 165-167. A. S. Packard: Lamarck, the Founder of Evolution, 1901.

[85]Philosophie Anatomique, 1818.

[86]J. W. Judd: The Coming of Evolution, 1910.

[87]Cf. A. O. Lovejoy: The Argument for Organic Evolution before "The Origin of Species." Pop. Sci. Monthly, 75, 1909.

[88]A. Ireland: Introduction to the 12th Edition of the "Vestiges," 1884.

judgment to which we are led by the examination of the discussions which have taken place on the subject."[89]

And then appeared the greatest work of Charles Darwin (1809-1882)—the result of twenty years' labor. The Origin of Species (1859) presented a huge amount of data which most reasonably could be explained by assuming the origin of existing species by descent with modifications from others, and also offered as the modus operandi of their origin the theory of "natural selection, or the preservation of favored races in the struggle for life." In Darwin's words: "As many more individuals of each species are born than can possibly survive, and as, consequently, there is frequently recurring struggle for existence, it follows that any being, if it vary however slightly in any manner profitable to itself, under the complex and sometimes varying conditions of life, will have a better chance of surviving, and thus be naturally selected. From the strong principle of inheritance any selected variety will tend to propagate its new and modified form."

Facts and theories had been brought forward before in support of evolution—indeed the theory of natural selection had been suggested before Darwin's time and again independently by Wallace (1822-1913) just as Darwin was completing his long studies preparatory to publication.[90] But the stupendous task of thinking evolution through for the endless realm of living nature remained to be done, and Darwin did it convincingly by his brilliant, scholarly, open-minded, and cautious marshalling and interpreting of data.[91]

It was the combination of the facts and the theory to account for the facts which won the thinking world to organic evolution and "made the old idea current intellectual coin." Darwin supplied the Ariadne thread which led from the maze of transcendental affinity to genetic continuity. Now we know that evolution is a bird's-eye view of the results of heredity since the origin of life and that the facts of inheritance hold the key to the factors of evolution.

Darwin spent the twenty years subsequent to the publication of the Origin of Species, as he had spent the preceding twenty years, in study and research, the results of which appeared in nine additional volumes. Three of these perhaps may be singled out as primarily an elaboration of the "Origin": The Variation of Animals and Plants under Domestication (1868), The Descent of Man (1871) and The Expression of the Emotions (1872). Singly and collectively these volumes are a monu-

[89] 3d Ed., Vol. 3, p. 481.

[90] A. R. Wallace: The Origin of the Theory of Natural Selection. Reply on receiving the Darwin-Wallace medal of the Linnean Society, July, 1908. Pop. Sci. Monthly, Apr. 1909, p. 396. J. Hooker: The First Presentation of the Theory of Natural Selection. Op. cit., p. 402.

[91] Cf. the Darwin Centennial Number of the Pop. Sci. Monthly, April, 1909.

ment to genius and labor. Erasmus Darwin was wont to say that the world is not governed by brilliancy but by energy. His grandson revolutionized biological thought through their combination.

Among Darwin's early converts from the ranks of professional biologists must be mentioned Huxley (1825-1895)[92] and Hooker (1817-1911) in England, Haeckel (1834-1919) and Weismann in Germany, and Gray (1810-1888) in America—men with the courage of their convictions when courage was necessary, whose support did so much for the promulgation of evolutionary ideas.

> "Thoughts that great hearts once broke for, we
> Breathe cheaply in the common air."

Today no representative biologist questions the fact of evolution—"evolution knows only one heresy, the denial of continuity"—though in regard to the factors there is much difference of opinion. It may well be that we shall have reason to depart widely from Darwin's interpretation of the effective principles at work in the origin of species, but withal this will have little influence on his position in the history of biology. The great value which he placed upon facts was exceeded only by his demonstration that this "value is due to their power of guiding the mind to a further discovery of principles." Darwin brought biology into line with the other inductive sciences, recast practically all of its problems, and instituted new ones.

Such, in briefest form, is a survey of the epochs and epoch-makers in biological progress—a mere glance of the biologist into the past "to the mountains whence cometh his strength." Building upon these foundations the biological sciences are developing with amazing rapidity at the present time chiefly through the cumulative influence of an all pervading desire of students of life phenomena to observe nature at work—actually to control and modify biological processes. Today the investigator insists upon interrogating nature experimentally and observing the modus operandi. In a word, the modern biological ideal is to construct an account of the living organism which can be verified by actual observation provided the proper conditions are afforded. Biology has emerged from the phase of development in which the descriptive note was dominant and has become in fact an experimental science.

[92] T. H. Huxley: Darwiniana, Collected Essays, Vol. 2. Life and Letters, edited by his son, 1901.

THE PROGRESS OF SCIENCE

THE LETTERS OF WILLIAM JAMES

Henry James, maintaining in the third generation the literary traditions of a great name, has edited the letters of his father with additional text sufficient to form an adequate biography. When William James died ten years ago, it was remarked in this journal that "his letters would form a volume of surpassing interest, though it may be that they are too personal for publication." The letters now printed are indeed one of the treasures of literature and their intimate character makes vivid a man of such fine distinction that there is no sense of eavesdropping in reading correspondence intended only for a child or for a personal friend.

Mrs. Carlyle accused her husband of writing letters to her with a view to their posthumous publication. The letters of James are as free from any such intention as the biographical notes written by Darwin for his children. They have been selected and edited with care and good judgment. James's life can be read as an open book in which no page need be concealed.

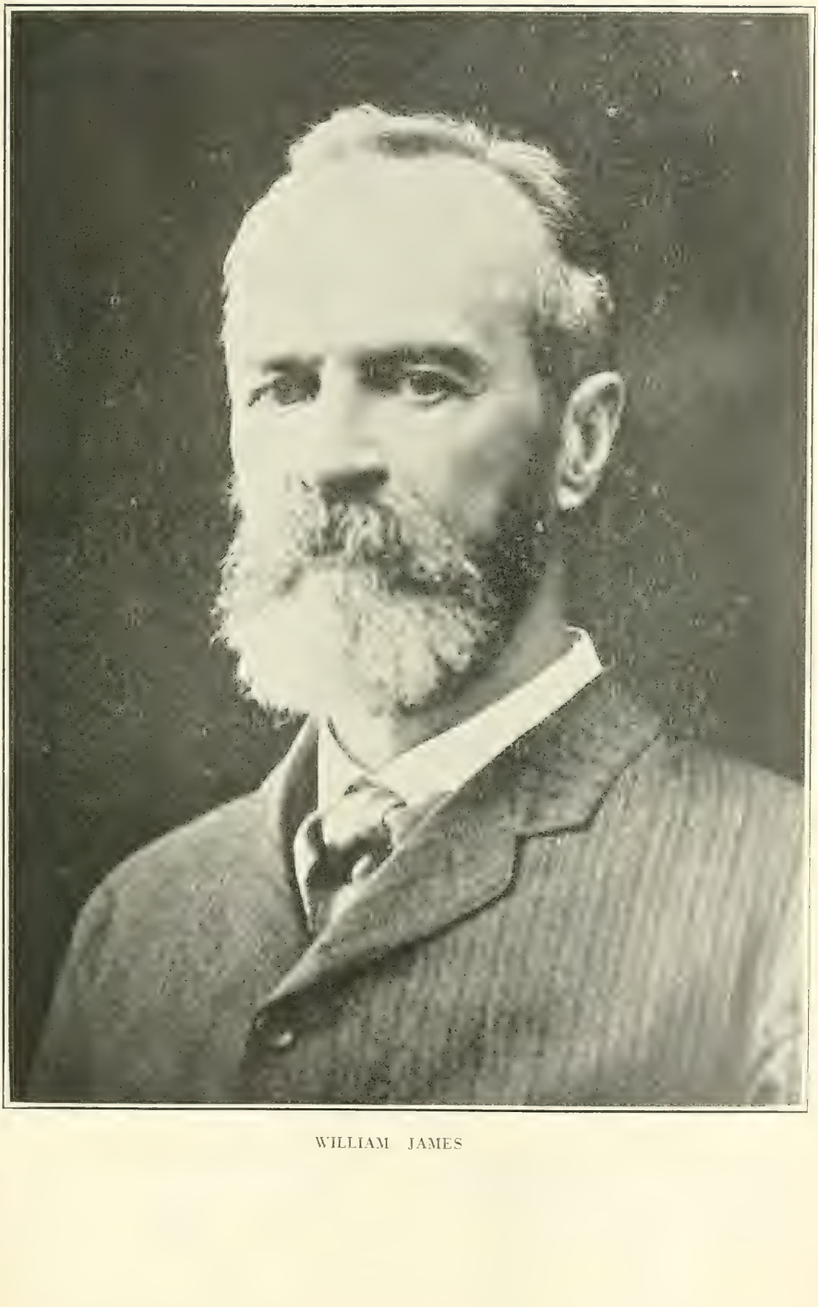
In an unpublished letter, James somewhat pathetically says:

> My whole life seems to consist in doing things to oblige other people, in order to get the field clear to begin my proper work, but every clearing only leads to a new crop of alien duties, so I *never* begin.

The letters show how largely this was true and are themselves a striking instance. James cast his bread prodigally upon the waters; it is fortunate that it has been returned to the world by giving a permanent place in American Literature to letters written in large measure to oblige other people or to fulfill family and personal obligations.

The best notice that can be given to letters of this character is quotations from them, and it may be as well to use those not accessible in the book. There are here reproduced a facsimile of the last page of a letter that shows James's characteristic handwriting and methods, and there is printed in full a letter written at about the same time in 1898, when he was interested in investigations of the medium, Mrs. Piper. It is as follows:

> I herewith return Münsterberg's letter, and the copy of yours to him. I confess I am astonished that he should have made objection to its insertion in the Psych. Rev. It is purely objective criticism and the personalities are all to the point of illustrating the difficulty of keeping practically to his professed point of view about measurement. I can't understand such sensitiveness in one who is himself so sarcastic in his criticisms, and I shall say so to him. Surely The Pschological Review is *the* place for such discussions.
>
> I think you have been unfair to M's article in merely advertising to this dubious epistemological aspect of it. I regretted that he had lugged such a subtlety into the Atlantic. But I rejoiced in any expression from an authority like him which might tend to destroy in the teachers' eyes the prestige of all this industrious mystification to which they are exposed about the immense help which is to come to them from psychological laboratories and measurements. It seems to me arrant bosh and humbug, in the main. Scripture is the loudest voiced sinner, though not the most influential, and he deserves to be sat down on hard. It is the *amount* of their claims, and the utter *unreality* of their tone that are so false. Of course teaching and psychology have got to keep in connexion, and M-g and I, as he says in his letter, keep them in connexion most thoroughly in our teaching of the elementary courses here. But to flourish elementary measurements before the teachers' eyes as his own "ideal" goal seems to me to be little short of criminal. It is following an idol of



WILLIAM JAMES

I never dreamed of your having sent it yourself

I note with exquisite gratification your benignant words towards psychical research. Continue along that line and you will be saved, will very likely after "passing away" become a "cabinet control" and instruct the younger generation in spiritual things.

"Yours for the truth"—

(as we always subscribe ourselves (when writing to each other))

Wm James

When I asked Munsterberg to come to Mrs P. he said: "I am a hypnotizer, and if I got such results as you relate, I should simply conclude that I had been hypnotized". "Then" I said, "bring your wife to see what she gets". "Oh no!—I should never suffer my wife to go to such a place!"—I call that real sportsmanlike keenness for new phenomena! However it is what he calls the "straight scientific path".

the cave out of all connexion with real life.

As regards my reply to you, make any rejoinder you think best. I should like to write a short (and strictly objective) report on Hodgson's report for the P. R.'s July number, but I promise in advance to keep dumb about your rejoinder in Science.

Your soul seems much burdened by . "psychical research"—I wish there were a better name for it! In the matter of St. Januarius, I thought that one of the Germans of the Marine Zoology Station had published an article about it, corroborating the phenomenon entirely, but explaining it as a periodical growth of bacterial slime which could be imitated artificially. (I wish that my memory were better). It surely is premature to say "so much the worse for the Universe," as you do, apropos of any sort of facts which might come true. It all depends on the *interpretation*. I must say that the "Scientist" mind seems to me to be characterized by as sectarian a spirit as any. And apropos of that, let me correct a misunderstanding which others as well as you have undergone as to the words "soi-disant scientist" once used, I forget where, by me. You supposed me to have meant to deny that the individuals in question were genuine scientists. All I meant was to cast contempt on the word "scientist," for which I have a dislike, though it is evidently doomed to acquire the rights of citizenship. It suggests to me the priggish sectarian view of science, as something *against* religion, *against* sentiment, etc., and I merely meant (I wish I could turn to the passage) to suggest the narrowness of the sort of mind that should delight in *self-styling itself* "scientist," as it proceeded to demolish psychical researchers, and not to imply in the least that all those who rejected psych. R. were spurious scientists (in the good sense of the term).

You probably won't read me to the end.

Yours as ever,

W. J.

The two volumes of "The Letters" have frontispieces showing James at the ages of fifty-three and sixty-five. The photograph here reproduced was taken by the Luxcroft Studio, Fitchburg, Mass., apparently when James was about fifty-five years old.

DINNER IN HONOR OF DR. KEEN

On January 20, 1921, a dinner was tendered to Dr. William Williams Keen, the eminent Philadelphia surgeon, at the Bellevue Stratford Hotel, in Philadelphia, in celebration of his eighty-fourth birthday. Between five and six hundred subscribers, representing all parts of the country, and all of the learned professions, and the fields of diplomacy, industry, finance, and the public services, joined in honoring Dr. Keen. In addition about four hundred ladies listened to the addresses which were followed by a reception.

The presiding officer and toastmaster was Dr. Keen's friend and colleague, Dr. George E. deSchweinitz, professor of ophthalmology in the University of Pennsylvania. The speakers, who dwelt on various phases of the activities of Dr. Keen's distinguished career, had all been closely associated with him in one or more of these fields of work. They were: Dr. J. Chalmers DaCosta, his one-time assistant, now Gross professor of surgery, in the Jefferson Medical College, in which chair he had succeeded Dr. Keen on the retirement of the latter from active teaching; Dr. William H. P. Faunce, president of Brown University, of which institution Dr. Keen is an alumnus, and of which he has been for many years a most active trustee; Dr. William H. Welch, of the Johns Hopkins University, and the Hon. David Jayne Hill, former ambassador to Germany.

The many letters of congratulation to the guest of the evening had been collected and bound in three volumes, and these were presented by Major General M. W. Ireland, surgeon general of the United States Army, who detailed Dr. Keen's connection with the Medical Department of the Army, beginning with his services in the field and in the hospitals during the Civil War, and down to, and including the World War, when he held

DR. W. W. KEEN

a commission as a reserve officer, with the rank of major. A bronze bust, by Samuel Murray, of Dr. Keen in his uniform as an officer of Medical Corps, U. S. Army, was presented to him on behalf of the subscribers to the dinner, by Dr. William J. Taylor, president of the College of Physicians, and for many years his private assistant.

Dr. Keen responded in an admirable address which is printed in the issue of *Science* for February 11.

THE FOREST SERVICE

According to the annual report of Chief Forester W. B. Greeley, the receipts of the National Forests have increased 93 per cent. from 1915 to 1920, while the total appropriations for the Forest Service, exclusive of deficiency fire-fighting funds, has increased only 8 per cent. The receipts for 1920 were 10 per cent. greater than for 1919, and an equal increase for the current fiscal year may be expected, unless too much new business has to be rejected on account of lack of funds and trained employees. The appropriations for the current fiscal year were increased only 3 per cent.

In addition to the actual revenue, according to the report, there is an enormous return to the public through the protection of the 500,000,000,000-odd feet of timber for future use, the protection of the headwaters of innumerable feeders of navigation, irrigation and hydroelectric power and the recreational facilities made available to hundreds of thousands of people. "There will always be national resources not measureable in dollars which in public benefit exceed the receipts paid into the Treasury," the report says.

The purchases aggregated at the close of the fiscal year 1,420,208 acres in the White Mountains and the Southern Appalachians and 12,094 acres in the Ozark Mountains of Arkansas. The original program of acquisition contemplated the purchase of about 1,000,000 acres in the White Mountains and not less than 50,000,000 acres in the Southern Appalachians. Nearly one half the proposed White Mountain area has been acquired, but slower progress has been made in the southern areas.

Further appropriations to carry on the purchase work within the areas have been recommended by the National Forest Reservation Commission. "To leave these Eastern forests in their present half finished condition would subject them to formidable fire hazards and other difficulties of management."

There is need also for some action to reduce the danger to the National Forests from the 24,267,723 acres of private lands that are intermingled with land belonging to the government. Most of this land is forested and its misuse, mismanagement and neglect jeopardize the government's holdings. General legislation is urged to acquire the private land by purchase or exchange.

The 1919 fire season was unusually severe and long drawn out, the report states. It was the third successive year of severe drought in the northwest, and the worst of the three. Fires began to occur before much of the customary work of preparation had been done, and this imposed a further handicap upon the forest force, which had been depleted by the loss of many experienced men. The total number of forest fires in the National Forests was 6,800, or 1,227 greater than in the previous year. The area of National Forest lands burned over was 2,000,034 acres, the estimated damage was $4,919,769, and the total cost of fire fighting was $3,039,615.

SCIENTIFIC ITEMS

We record with regret the death of William Thompson Sedgwick, professor of biology in the Massachusetts Institute of Technology since

1883; of Mary Watson Whitney, professor of astronomy emeritus, and from 1889 to 1910 director of the observatory of Vassar College; of Lincoln Ware Riddle, assistant professor of cryptogamic botany in Harvard University and associate curator of the Farlow Herbarium of Cryptogamic botany; of Sir Lazarus Fletcher, keeper of minerals in the British Natural History Museum from 1880 to 1909 and then director of the museum until 1919; and of Dr. Wilhelm Foerster, professor of astronomy at the University of Berlin, at one time director of the Observatory.

Dr. Wallace Walter Atwood, lately professor of physiography at Harvard University, was inaugurated as president of Clarke University, on February 1.

Dr. J. Norris Russell, of Princeton University, has been awarded the gold medal of the Royal Astronomical Society.

The Edison medal, awarded annually for work in electrical engineering by the American Institute of Electrical Engineers, will be presented this year to Dr. M. I. Pupin, professor of electromechanics at Columbia University.

The third half-yearly report on the progress of civil aviation in England by the government, states that regular air services have now been established from London to Paris, Brussels and Amsterdam, and that passenger, mail and goods traffic is increasing. The total number of aeroplane miles flown in the half-year ending September 30, 1920, is nearly 700,000, whilst the aggregate since May, 1919, exceeds 1,000,000. The number of passengers by air exceeds 30,000, whilst the goods carried weigh little less than 90 tons. In value the imported goods exceed £500,000, whilst the exports and re-exports are about half that amount. As part of the mail services, about 50,000 letters have passed each way between London-Paris, Brussels and Amsterdam. The fatal accidents are given as in the ratio of 1 per 50,000 miles flown or per 5,000 passengers carried.

THE SCIENTIFIC MONTHLY

APRIL, 1921

THE HISTORY OF PHYSICS*

By HENRY ANDREWS BUMSTEAD

LATE PROFESSOR OF PHYSICS IN YALE UNIVERSITY

THE beginnings of anything like a connected history of the science which is now called physics may be placed with considerable definiteness about the beginning of the 17th century and associated with the great name of Galileo. It is of course true that innumerable isolated facts had been known for many centuries which are now included among the data of this science; and many tools and simple machines which are now regarded as applications of physical principles had been devised and used. Even prehistoric man knew some of these—to his very great advantage. But, with one important exception which will be mentioned later, there was, in the ancient world, no connected body of knowledge in this field which can properly be called scientific. In this respect physics differs radically from mathematics, or astronomy, natural history, or medicine, each of which began its modern career with a store of scientific knowledge that had been obtained and put in order before the Renaissance.

The reason for this difference is doubtless to be found in the fact that the progress of physics is dependent, almost from the first step, on the method of experiment as distinguished from the method of observation. For some unknown psychological reason, the appreciation of the possibilities of experiment as an intellectual tool and the ability to make use of its technique appear very late in the history of human development. A few individuals like Archimedes understood and practiced it, and it is difficult to understand why the seed which they sowed proved sterile. Certain inhibitions, common (despite their very different temperaments) to the Greeks, the Romans and the men of the Middle Ages, seem to have prevented the infection from spreading from its original foci. I have no theory to offer as to the cause of the removal of these inhibitions during the 16th and 17th centuries; but whatever the cause we must, I think, recognize that

*A lecture delivered at Yale University, October 21, 1920, the fourth of a series on the History of Science under the auspices of the Yale Chapter of the Gamma Alpha Graduate Scientific Fraternity.

about that time a new factor made its appearance in the intellectual world which has survived and grown and has produced momentous results.

Some of you no doubt will be disposed to question the novelty which I have attributed to the methods used by Galileo and his successors. You will say with truth that men have been experimenting since long before the dawn of history; that by this means they improved their weapons, food, clothing, shelter and means of transport so that the enormous advantage in material surroundings which the Roman of the Augustan Age had over the prehistoric cave dweller may properly be said to be the result of a long course of progressive experimentation. But what I have, for the sake of making a distinction, called the experimental method in science is a very different thing from the slow empirical improvement of tools and appliances which went on before the beginnings of the modern era. The two kinds of activity differ fundamentally in the objects which they seek to attain and in the means they adopt for the accomplishment of their purposes.

The difference of objective is well illustrated by a remark of Galileo's at the very beginning of one of his most important works, the "Dialogue Concerning Two New Sciences." He says that he has long thought that the workmen in a great shop such as the Arsenal at Venice must know many things which would be of great service to philosophers if they could only be persuaded to use them. And he does in fact take such workman's knowledge got by the old empirical process and employ it for a purpose for which it had never been used before; to find out for example something about the laws and regularities governing the strength of materials and their dependence upon the size and shape of the object considered. The knowledge thus gained might or might not be useful to the workman, but it was of great consequence to the philosopher. Every scientific experiment has an objective of this kind—that is, every one that can properly be called an *experiment,* that has in it an element of originality and adventure into the unknown and that is not a mere routine test by known methods. Its purpose is much more general than the improvement of a tool or a telephone; and because of its generality it may incidentally do more to improve implements and technique in widely diverse fields of industry than thousands of experiments of the old cut-and-try kind extending over many centuries. The geometrical rate of increase resulting from this is sufficiently obvious from the industrial history of the past hundred years. Its continuance however is strictly conditioned upon the retention of the attitude of Galileo's philosopher; he may glance out of the corner of his eye at the by-products of his work but he must not think too much of them and must keep clearly in view his own philosophical mission.

As I have said the modern experimental method differs from the older empiricism in procedure as well as in purpose. The actual experiment is only a part of the process and does not come first in order of time; before it can be begun advantageously, there must be much careful thought and planning which often involves mathematics and deductive reasoning of the most old-fashioned kind. But there are no artificial hazards and rules of the game, such as those which the Greeks were so fond of imposing in mathematical problems. Any sort of logic (or the lack of it) is permissible since the final test is to be the experiment and not consistency of argument; it will indeed be a test of the premises no less than of the reasoning process. The greatest masters are those who make most use of apparently non-logical processes—intuitions and "hunches" which are perhaps the results of subconscious reasoning from data but dimly perceived.

The experiment itself is an observation made under highly artificial and carefully prearranged conditions, and it is this which gives the method its greatest advantage over simple observation of natural phenomena. This is well illustrated by Galileo's work upon the principles of mechanics and in their application to the particular case of the motion of falling bodies. Centuries of inescapable observation of moving bodies had led to no correct idea of the simple laws underlying their behavior, because these laws had been obscured by the effect of friction—a secondary condition of the problem. Galileo's experiments consisted in reducing these effects until the true nature of the phenomena could be observed. The famous experiment at the Leaning Tower of Pisa was a spectacular demonstration of one point of his theory designed to confute his Aristotelian critics; but the really important and fertile experments were quite simply arranged with the help of iron balls, inclined tracks, boards, nails and bits of string. With the simplest material means he laid the foundations of dynamics and, with it, those of physical science as a whole. Lagrange remarks that Galileo's contributions to mechanics "did not bring him in his lifetime as much celebrity as those discoveries which he made about the system of the world, but they are to-day the most enduring and real part of the glory of this great man. The discoveries of Jupiter's satellites, of the phases of Venus, of sun spots, etc., needed only telescopes and assiduity; but extraordinary genius was needed to disentangle the laws of nature from phenomena which are always going on under our eyes, but of which the explanation had always eluded the search of philosophers."[1]

[1]The necessary brevity of this lecture may result in giving the impression that Galileo had no forerunners. This is of course not the case. Archimedes has already been mentioned—a lonely genius who laid firmly the foundations of the statics of solids and liquids. Stevinus, sixteen years older

The world was ready for the structure which was to be erected upon the foundations laid by Galileo In the next generation, Torricelli in Italy and Pascal in France showed by bold reasoning and experimentation that Nature's *horror vacui* was due to the weight of the atmosphere; while Guericke in Germany and Boyle in England discovered other important properties of gases. In dynamics, the direct succession fell to Christian Huygens of Amsterdam, a natural philosopher of very high rank and a worthy successor of Galileo. He completed the theory of the pendulum and by its use determined the acceleration of gravity; invented and constructed the pendulum clock and escapement, discovered the theorems of centrifugal force, and was the first to use what is now called the principle of *vis viva* or kinetic energy. His investigations in optics are also of great importance and he was one of the first proponents of the wave theory of light.

To try to give in a small fraction of a single lecture any adequate account of the mighty deeds of Newton is, of course, to attempt the impossible. Fortunately the main features of his achievements are so familiarly known that a brief recapitulation is all that is necessary. Born in 1642, the year of Galileo's death, his genius developed with extraordinary rapidity. It appears to be quite certain that the essential parts of all his great discoveries were made before he was twenty-five years old, although most of them were published much later. The delay was due partly to lack of facilities for publication but mainly to Newton's carefulness in verification and in working out all possible consequences of his hypotheses. His first great discovery (made in the year in which he received the bachelor's degree at Cambridge) was the "direct and inverse methods of fluxions" which are in all essentials identical with the differential and integral calculus, but with a less convenient and fertile notation. This discovery belongs of course primarily to the history of mathematics; but both physics and astronomy may proudly claim it as belonging partly to them for two reasons; first, because it was the exigencies of their problems which led directly to it; and second, because it was an absolutely indispensable tool for the mechanical and astronomical discoveries of Newton and his successors. In the same year (1665) Newton "began to think of gravity extending to the orb of the moon"; he soon found from one of Kepler's laws that the forces which keep the planets in their orbits must vary inversely as the square of their distances from the sun. He applied this rule to the earth and moon and found an approximate agreement between the force necessary to keep the moon

than Galileo, made notable additions to the Archimedean statics. And a century earlier Leonardo da Vinci (a miracle of versatility) had made important discoveries in statics, and had found the true law of the refraction of light. Most of Leonardo's scientific work, however, remained buried in his manuscript notes and has only recently been revealed to the world.

in her orbit and the force of gravity at the surface of the earth. "All this," says Newton in later life, "was in the two plague years of 1665 and 1666, for in those days I was in the prime of my age for invention, and minded mathematics and philosophy more than at any time since."

During the twenty-one years which elapsed before the publication of the *Principia* in 1687, Newton, in the midst of other duties and of investigations on other subjects, recurred again and again to the astronomical and dynamical problems which had engaged his youthful attention. It was only after ten or twelve years that he cleared up the difficulties of centrifugal force (Huygens' previous work being then unknown to him) and thus discovered that the two remaining laws of Kepler were consequences of his gravitational law. In the last three or four years of the period under consideration he appears to have worked steadily at the development of the subject and to have discovered the large number of important theorems and relations which make the *Principia* the most stupendous and overwhelming publication in the history of science.

In all this work there are three streams of discovery which may be separated by logical analysis, but which are so closely intermingled that it is difficult to see how any one of them could have gone on without the other two. Nobody has ever been able to believe that Newton could have extended the Galilean dynamics to the intricate motions of the planets except by the aid of the method of fluxions or its equivalent; and certainly nothing could have been done without a knowledge of the law of gravitation. On the other hand, the solution of astronomical problems required and facilitated a more exact formulation of the principles of mechanics than Galileo had been able to give; although mathematically intricate, they are dynamically simpler than terrestrial problems since no appreciable frictional or dissipative forces are present; and they furnish tests and verifications of dynamical laws of far greater accuracy than can be obtained in any other way.

Under such conditions it seems futile to attempt to decide whether physics is most indebted to Newton for the formulation of the laws of motion, for the discovery of the law of inverse squares, or for the invention of the fluxional calculus. Any one of the three (if it could have been produced alone) would have made his name immortal; the fact that we owe all three to one person places him upon a pinnacle of greatness which has not even been approached by any other man of science.

I must not neglect to mention also Newton's contributions to optics which, while not of the fundamental importance of those we have just been discussing, were nevertheless worthy of their author. I need only to recall to your memory that he investigated the composition of white light, the colors of thin films, diffraction, and the possibilities of achromatism in refracting telescopes. He was not infallible; for he decided that it was impossible to make an achromatic refractor, and he supported the corpuscular theory of light against the undulatory theory of Huygens. In both cases, however, the evidence obtainable in his time strongly supported his position; and I think it was this, rather than the mere authority of his name, which caused the corpuscular theory to prevail during the following century.

In the eighteenth century the development of mechanics and of gravitational theory was carried on by the three Bernoullis, Euler, Clairaut, d'Alembert and others. This development reached its culmination near the end of the century in the publication of Lagrange's "Mécanique Analytique" and of the "Mécanique Céleste" of Laplace—works which for completeness and finish have seldom if ever been excelled. The period was not characterized by new discoveries of the first magnitude but by the careful working out of the theories founded by Galileo and Newton and the perfection of mathematical methods for dealing with complicated problems. This was an admirable preparation for the great outburst of discovery which began toward the end of the eighteenth century and was continued still more conspicuously in the first years of the nineteenth.

In other branches of physics and in chemistry, the ground was also being prepared in a different way by the accumulation of experimental facts and relations which formed the raw material for the generalizations of the period which was to come, and served as starting points for notable advances. It is necessary therefore to go back and to trace briefly the course of the tributary streams of discovery which were soon to join the main current. We shall have to consider what had been learned about magnetism, electricity, light and heat.

The ancients were acquainted with the curious property possessed by the lode-stone of Magnesia of attracting iron, and also knew that when amber was rubbed it attracted bits of straw and other light bodies. Nothing came of this knowledge for centuries; but at some unknown time prior to the Crusades, the north-seeking property of the magnetized needle was discovered and the mariner's compass was invented. The science of magnetism was indeed almost the only part of physics that made any progress during the Middle Ages. In the thirteenth century Petrus Peregrinus of Picardy, experimenting with a spherical lode stone and a needle, found that the stone possessed two "poles" which appeared to be the seat of the magnetic power.

The true founder of both magnetic and electric science, however, was William Gilbert of Colchester, physician to Queen Elizabeth. Twenty-four years older than Galileo, Gilbert must be regarded as one of the pioneers of the experimental method. His work had not the scope and depth which characterized that of the great Italian, nor were its consequences so immediate and so revolutionary; but he was nevertheless a truly scientific experimenter and, considering the time in which he lived, we must regard him as a prodigy of originality. He showed quite conclusively that the behavior of the compass was due to the fact that the earth itself was a great magnet. For two thousand years it had been supposed that amber alone was capable of being excited by friction to attract other bodies; Gilbert found that many bodies could be thus excited and that among them were such commonplace substances as glass, sulphur and resin. His experiments and his reasoning were sound, and he devised a hypothesis of "electric effluvia" which was helpful to electrical science for a long time.

During the eighteenth century the experimental knowledge of both electricity and magnetism progressed rapidly. The conduction of the electrified state by metals was discovered by Stephen Gray; the Leyden jar was invented; du Fay found that there existed two opposite states of electrification which he called vitreous and resinous and that these behaved, as to attractions and repulsions, like the two poles of a magnet. America made her first contribution to physics in the very important work of Benjamin Franklin. Toward the close of this period of activity the doctrines of electric effluvia and of Cartesian vortices had been definitely replaced by the theory that the forces observed were due to action at a distance between charges of a single electric fluid and matter (Franklin), or to a similar action between two fluids (Coulomb). Eventually the law of variation of this force with the distance was experimentally determined by Coulomb and found to be the familiar inverse square relation of Newton. The same law was shown by Coulomb to hold for the forces between magnetic poles also; and either one, or two, magnetic fluids had to be predicated to account for the variation in the strength of magnets. Indeed the application of gravitational theory to these forces rendered inevitable the introduction of such imponderable fluids to take the place of the material masses which play the same rôle in the case of gravitation.

I have already mentioned briefly Newton's researches in optics and his adherence to the corpuscular theory in which he was followed by most philosophers. This introduced another "imponderable" which was however supposed to consist of excessively minute discrete corpuscles instead of a continuous fluid. Many important optical phenomena had been discovered. Descartes had published the mathematical law of refraction which however was not his own discovery but was apparently communicated to him by Snell of Leyden; Newton had discovered and properly interpreted the composite nature of white light and had investigated the simpler cases of diffraction and of what is now called interference; Huygens had observed double refraction in Iceland spar and had given the proximate explanation of it (on the wave theory) which is still current; and he observed that the two beams which had passed through the spar differed from each other and from ordinary light in the peculiar way which we now indicate by calling them polarized. Time is lacking for any discussion of the ingenious arguments by which the two rival theories of light were supported.

The quantitative study of heat begins with Galileo's construction of the first thermometer—an air-thermometer of considerable sensitiveness but of inconvenient design. Improvements of one kind or another were made by many men and the fixity of certain temperatures (such as that of melting ice) was established. The first really reliable thermometers were made by Fahrenheit in the first quarter of the eighteenth century. All of the early thermal experiments and theories were confused by the failure to distinguish clearly between temperature and quantity of heat, and by the great and apparently capricious differences between the heat capacities, or specific heats, of different substances. All these difficulties were finally cleared up in a masterly manner by Joseph Black near the end of the period we are considering. He established calorimetric measurements on a firm basis, and showed quite clearly that in all such experiments heat behaves like a substance which passes from one body to another and sometimes becomes "latent" for a time (as when ice melts) but which is never created or destroyed. All these conclusions are true within the range of Black's experiments; and it was only at a later date that the exceptions were seen to be of great importance and not explicable by appealing to latency or to a variation in heat capacity. What was known at that time thoroughly justified a substantial theory of heat as the most convenient hypothesis available; and thus another imponderable fluid took its place as a respectable and useful article in the physicist's creed. Many unavailing attempts were made to show the identity of two or more of these hypothetical substances. Thus, on account of the phenomena of radiant heat, it was proposed to identify caloric with the light corpuscles; but the fact that light passed through glass while radiant heat did not, was an insuperable obstacle to this view. There was always in the background the possibility that both heat and light were forms of motion, but at the period now under consideration the substantial theories undoubtedly held the field. This state of things led to very sharp boundaries between the different fields of physics and discouraged the natural inclination to apply the principles of dynamics (which by this time had come to seem almost intuitive) to other physical phenomena. There was no great encouragement to apply the principles of mechanics to the imponderables; so far as experiment showed they lacked not only the conspicuous property of weight but also the most essential dynamical characteristic of ordinary matter, inertia. The natural and fertile method of dealing with them was to take as postulates for the mathematical development of the subject certain empirical relations as simple and fundamental as possible. It was not until the establishment of the conservation of energy in the late forties of the nineteenth century that the barriers between the different "physical forces" were broken down.

The intervening period however was one of brilliant discovery in both mathematical and experimental physics. In the theory of heat two works of this period must at least be mentioned. In 1822 Joseph Fourier publisher his *Théorie Analytique de la Chaleur* a work of genius which has had a profound effect in almost all branches of theoretical physics and upon pure mathematics as well. A still more momentous event in the history of science was the publication in 1824 of Carnot's *Réflections sur le Puissance Motrice du Feu.* His primary purpose was the investigation of the efficiency of heat engines which had recently become a matter of interest owing to the increasing use of the steam engine invented by Newcomen and Watt. In this paper Carnot makes use of an analogy; he saw that the production of work by an engine might be regarded as due to the fall of caloric from a higher to a lower temperature just as the work of a water mill is a consequence of the fall of water from a higher to a lower level. He follows a course of reasoning so simple yet so effective that it seems inspired; it is based upon the denial of the possibility of perpetual motion which even at that time was a pretty firmly established empirical fact owing to the consistent failure of all attempts to produce such motion. He thus establishes the general principle which is now called "the second law of thermodynamics" and which is of far wider application than could have been imagined by Carnot or any of his contemporaries. For it happens that nearly every phenomenon in the physical universe is attended by an evolution or absorption of heat and is therefore subject to the second law. It governs every chemical reaction as was shown by Willard Gibbs fifty years later, and the physical and chemical processes of life. It sets bounds to cosmological speculations and to forecasts of the future of the human race. Not the slightest deviation from it has ever been observed and the probability of such deviation is so minute that it must be regarded as one of the most firmly established of scientific facts.

In electrostatics and magnetism this period was marked by the development of the mathematical consequences of Coulomb's discovery that the inverse square law applies to these forces. Much of the gravitational theory could be taken over directly while the special applications to electricity were made by Poisson, Green, and others. In the meanwhile however another set of electrical phenomena had appeared. In 1791 Galvani, professor of anatomy at Bologna, gave an account of his experiments on the contraction of frogs' legs when touched with two different metals in series and, with much ability, supported the view that it was an electrical manifestation. He naturally supposed that the origin of the electrical disturbance was in the animal tissues. This was combatted a year later by Volta who referred the seat of the forces involved to the point of contact between the dissimilar metals, and gave good evidence that they were electrical. The effects however were very small, and interest flagged until 1800 when Volta invented the "pile" by means of which very appreciable results could be obtained. This at once excited much attention; and in the same year Nicholson and Carlisle in England in experimenting with the Voltaic pile observed the decomposition of water by electrolysis and shortly afterward Humphrey Davy advanced the chemical theory of the pile, which, after many years of struggle, eventually superseded the contact theory of Volta. There was a rapid advance in the knowledge of the electric current, of batteries, and of the electrolytic process. These experiments produced a profound effect upon chemistry through the electrochemical theory of Berzelius; and although this has long been given up, the most modern theories have, in a different form, reverted to the view that chemical forces are of electrical origin.

Many attempts had been made to discover some connection between the phenomena of electricity and those of magnetism but all had failed until 1820 when Oersted of Copenhagen observed and correctly described the action of an electric current upon a magnet brought near it. As soon as the news of this observation reached Paris, Ampère began the series of investigations which was to render his name immortal in electrical science. Within a week he had demonstrated to the Academy the attractions and repulsions of parallel currents; and during the ensuing three years his brilliant experimental and mathematical researches laid a sure and firm foundation for all the subsequent developments in electrodynamics. As was to be expected, he based his investigations on the Newtonian model, by using current-elements acting upon each other by forces in the line joining them. Again the law proved to be that of the inverse square; but the fact that the attracting elements were directed quantities added many difficulties which, in the state of mathematical science at that time, gave ample scope to the "Newton of electricity" for the display of his genius. The vector relations involved in the statement of his problem caused an indeterminateness which later gave rise to many rivals to Ampère's expression for the force between current elements. These all gave the same result when integrated around closed circuits which alone were amenable to experiment; and no one could succeed in devising experiments which would discriminate between them. One of these rival theories, that of Weber, is interesting as being in some respects similar to the modern theory of electrons.

Great as is the debt which electrical science owes to Ampère, it is exceeded by its obligation to Faraday whose marvellous experimental skill and instinctive perception of the inner nature of phenomena are still the wonder and admiration of all men of science. At twenty-one years of age he was a journeyman book-binder who had educated himself in some degree by reading the books which he was given to bind. The Encyclopaedia Britannica aroused his interest in science and he applied to Davy for employment in the Royal Institution. For a number of years, as Davy's assistant, his chief work was in chemistry; but Oersted's discovery turned his thoughts toward electricity and thereafter it was his principal field of work. In 1831 he made the capital discovery of the induction of currents which is not only of the most fundamental consequence to the theory of electromagnetism but is the foundation of the innumerable practical applications of electricity to the uses of man. Of his many other discoveries I shall mention only two; the quantitative laws of electrolysis which bear his name and which gave the first suggestions of an atomic theory of electricity, and the specific inductive capacity of dielectrics.

Because of the deficiencies of his early education, Faraday never acquired the technique of the mathematician. But, as Maxwell has pointed out, his mind was admirably fitted for dealing with quantitative relations. He overcame the handicap under which he suffered by devising his own methods of representing the quantitative side of phenomena—methods which not only enabled him to achieve his unparalleled success as a discoverer but which are so useful to others that they have held the field in elementary instruction in electromagnetism as well as in the most complicated problems of modern electrical engineering. His lines of force were to him real entities and he conceived of all forces as being transmitted from point to point in a continuous medium. The idea of action at a distance was repugnant to him. It is indeed to most physicists but Faraday was not tempted as most of us are to use distance forces because of their mathematical convenience and thus to escape the prodigious difficulties of imagining a medium with the necessary properties to account for the forces. Faraday's prejudices were to have important consequences in the next generation as we shall see when we come to speak of Maxwell.

The year 1800 is an important date in the history of optics as it is in that of electricity; for in that year Thomas Young took up the cudgels for the wave theory of light which had been almost completely neglected since the time of Huygens. In the following year he explained the colors of thin films (Newton's rings) by means of the "interference" of waves; and in 1803 he applied the same idea to certain problems of diffraction, but in a way which was afterward proved to be wrong. He was drawn into a controversy with the great Laplace who had worked out a theory of double refraction on the corpuscular basis; and for a dozen years or more Young found little sympathy and support for his views among scientific men of established reputation. Indeed he was far from having a good case; the explanation of diffraction was not satisfactory; there was no explanation of polarization since waves in the tenuous and fluid ether were quite naturally supposed to be compressional like sound waves in air; and, for the same reason, no satisfactory explanation of double refraction appeared to be possible.

The first defect was remedied by the work of Fresnel, presented to the Paris Academy in 1816, in which the author began that brilliant series of experimental and mathematical investigations which left the wave theory completely victorous over its rival. He gave the true theory of diffraction by a slit and a wire and showed that it agreed with the results of his experimental measurements. Poisson, who was one of the referees of his paper, noted the fatal objection that Fresnel's theory would require a bright spot in the exact center of the shadow of a circular object. When, however, the matter was put to the test of experiment under suitable conditions, the bright spot was found and this naturally produced a reaction in favor of Fresnel's theory. It appears to have been Young who took the bold step of suggesting that the vibrations in light waves were transverse and that thus polarization could be explained. Fresnel at once took up this suggestion and succeeded in bringing into line all the intricacies of crystalline refraction, including that in biaxial crystals which had been discovered a few years before by Brewster and had been a stumbling block to all other theories. Later he took up the theory of reflection and refraction by ordinary transparent bodies with equal success; and since the completion of his series of memoirs there has never been a doubt in the mind of any competent person that light has the kinematical properties of transverse wave motion.

On the dynamical side, however, matters were not so clear. Only a solid can transmit tranverse elastic waves and it was difficult to believe that the ether could be a solid and yet allow the free motion of material bodies through it without the slightest detectable resistance. This was the origin of the great problem of the existence and properties of the ether—a problem which has excited the most eager interest of physicists for a hundred years and is still with us. Many of the most important discoveries, mathematical and experimental, have arisen from attempts at its solution. It at once stimulated the mathematical study of the theory of elastic solids and of the applicability of this theory to the phenomena of light. The work of Gauchy, Green, McCullagh, Stokes and Kelvin in this field may be said to have created a new era in mathematical physics and even in mathematics itself; for the treatment of continuous media required methods which differed in many ways from those appropriate to distance forces of the Newtonian type. It was also the first attempt to apply in all strictness the principles of dynamics to natural phenomena outside the restricted field of mechanics proper. It was never perfectly successful, but so nearly that there was constant encouragement to persevere. We shall have occasion to look at a second phase of this gallant attack upon the mysteries of Nature when we come to deal with the work of Clerk Maxwell.

About the middle of the century occurred the epoch-making discovery of the conservation of energy which brought all kinds of physical and chemical phenomena into much more intimate relation with each other than had previously been suspected. Incidentally, it greatly strengthened the tendency, of which I have just spoken, to seek for a strictly dynamical foundation for all such phenomena.

The discovery arose primarily in a reconsideration of the nature of heat, and its history is so curious and interesting that it is with regret that I recognize the impossibility of giving an adequate account of it within the limits of this lecture. As we have seen, the belief that heat was a substantial fluid had prevailed for many years and had proved useful; but there had always been a suspicion (extending back to the time of Hooke and Newton) that it might be an effect of motion—either of the fine particles of which ordinary matter was made up, or of light-corpuscles within matter. At the end of the eighteenth century, Count Rumford had made experiments which ought to have started things in the right direction, but were disregarded. Carnot himself, in some posthumous notes which were not published until 1878, gave so clear an outline of the true theory that we cannot doubt that the course of science would have been greatly altered, as Mach remarks, if Carnot had not died of cholera in 1832. The caloric theory was finally overthrown by the labors of two men, Mayer and Joule, quite independently and neither having in the beginning any knowledge of the work of the other. Mayer, a Jewish physician of Heilbronn, began his process of reasoning with the observation that venous blood is a brighter red in tropical than in temperate climates. He was so ignorant of the terminology of physics that he could not make himself understood at first and suffered many rebuffs in consequence. His persistence however was sublime; he learned to write so that physicists could understand him, unearthed forgotten experiments, and eventually, without any experiments of his own, gave conclusive evidence for his theory and obtained a good value of the mechanical equivalent of heat. There could scarcely be a greater contrast than that between him and his fellow discoverer. Joule was a Manchester brewer and amateur of science, a skilful and accurate experimenter who year after year turned out unimpeachable quantitative evidence of the equivalence between mechanical work and heat in all sorts of transformations. A third collaborator in placing the new theory on a firm foundation was Helmholtz whose celebrated memoir of 1847 showed clearly the generality of the new principle and its applicability to all branches of science; he gave it suitable mathematical formulation and demonstrated its great power in finding relations between phenomena of apparently different kinds.

The next step was the reconciliation of the new principle with that of Carnot, and it proved to be a difficult one. It puzzled Kelvin for several years and delayed his complete adherence to Joule's theory; ultimately he saw his way clearly and as a result of his work and that of Clausius the modern theory was established upon the two principles which stand side by side as the first and second laws of thermodynamics. These two empirical principles are probably the most firmly established and most thoroughly verified of all the so-called laws of nature. In the classical treatment of the subject they are regarded as axioms, and deductions are made from them so that, in form, the science is like geometry. As I have previously intimated, the results obtained are of great generality and of far-reaching consequence in practical applications as well as in philosophical implications. It is one of the great triumphs of theoretical physics.

Side by side with this theory there grew up another method of dealing with the subject which was less general and more hypothetical but has proved to be an invaluable aid to research. As soon as it was recognized that heat and mechanical energy are mutually convertible, it became inevitable that physicists should seek for a detailed mechanical theory of heat. The obvious hypothesis was that heat consisted of the energy of motion of the small particles, or molecules, of matter whose existence had been more or less generally accepted since Dalton's introduction of the atomic theory to account for the chemical laws of definite and multiple proportion. In order to develop this theory, the laws of mechanics had to be applied statistically to enormous aggregates of molecules reacting upon each other in various ways. The simplest state of matter from this point of view is the gaseous one; and in the hands of Clausius and Maxwell the kinetic theory of gases made great progress in a few years. Atomic and molecular theory became at once definite and quantitative. One of Dalton's atoms might be of any size so long as it was small enough to escape individual observation and had the correct ratio of mass to other atoms; but the atoms and molecules of the physical theory had definite and calculable mass, size, velocity and free-path. They became very real to physicists and were constantly used in reasoning and in planning experiments.

About twenty-five years ago a determined attack upon all atomic theories was made by Ostwald and his followers among the physical chemists—largely through ignorance of the real evidence upon which they were based. They ridiculed such theories as metaphysical figments of the imagination and attacked them as obstacles to real advance in the philosophy of nature. The faith of physicists however was not for a moment shaken; and it has been justified by the progress of discovery in the intervening years. The last doubting Thomas has been convinced and only those who deny the objectivity of matter itself can now question the real, physical existence of atoms and molecules.

Through the labors of Boltzmann, Gibbs and others, the application of statistical mechanics to molecular problems was developed and generalized so as to be applicable to other states of matter than the gaseous one; and attempts were made to reduce the whole of thermodynamics to a mechanical basis. The subject is a very difficult one with many pitfalls for even the most wary; and we must conclude, I think, that the attempt has met with a defeat that is probably final. It has, however, led directly to the quantum theory of Planck, a great generalization which is the most puzzling and the most promising treasure in the possession of the physicist of today.

The next great landmark of which we must take note is the unification of the theories of electrodynamics and of optics by Clerk Maxwell. He himself tells us that, impressed by the value and fertility of Faraday's ideas, he decided, in beginning his serious study of electricity, to read no mathematics on the subject until he had mastered Faraday's "Experimental Researches." Maxwell was a highly trained and original mathematician and his first papers on electrodynamics were devoted to the expression in clear mathematical form of some of Faraday's hypotheses and modes of thought. Like his chosen master he rejected action at a distance and concentrated his attention upon the hypothetical medium by means of which electromagnetic forces might be transmitted. In several memoirs published during the sixties he gave details of mechanical models which were adapted to this end. By gradual steps these auxiliaries were done away with and at the same time the theory far outgrew its original purpose of translating Faraday into mathematical language. Maxwell showed clearly that all the known facts of electrodynamics could be attributed to the action of a medium and by strict mathematical reasoning he deducted the properties which this medium must have. These turned out to be identical in all details with those which we must attribute to the luminiferous ether in order to account for the phenomena of light. Thus was born the electromagnetic theory of light and two great domains of physics were brought together under a single system of hypotheses clearly expressed in the form of differential equations.

The publication of Maxwell's "Treatise on Electricity and Magnetism" in 1873 was an event of the first importance in the history of science. The new theory was slow in making its way, especially on the continent of Europe, and Maxwell himself died in 1879. His work was taken up, however, by a group of devoted adherents among whom we may mention Heaviside, Lodge, Rowland, Poynting, Gibbs, J. J. Thomson, and Larmor. In 1886 Hertz, whose attention had been some years before directed to Maxwell's theory by Helmholtz, made an accidental observation which to his acute mind offered the possibility of a direct test of the finite speed of propagation of electromagnetic action. His brilliant series of experiments demonstrated the existence, speed, and properties of electromagnetic waves and served as a complete verification of Maxwell's theory. All of you know that the wonders of wireless are a direct consequence of the experiments of Hertz; but to the physicist this is less interesting and significant than the steady growth in scope and authority of Maxwell's equations, which come nearer to the ideal of a "world formula" than anything else known to the modern man of science.

For something like ten years it was generally supposed that the main outlines of the science of physics had been drawn in fairly satisfactory, and perhaps final, form. There was still much to be done but it would be concerned with details—with perfecting theories and increasing the accuracy of measurements. A great deal of very valuable work of this kind was done in many fields; as an example I may refer briefly to the development of accurate measurement in spectroscopy.

The use of the spectroscope as a method of chemical analysis was placed on a sound basis about 1860, by Bunsen and Kirchhoff, and the application of this method was extended, by the brilliant discovery of Kirchhoff, to the atmospheres of the sun and stars. You all know something of the wonderful results which have followed the application of the spectroscope to astronomical problems and of the growth of the borderland science which is called astrophysics. Great improvements in spectroscopic apparatus were made by Rowland, Michelson, and others, and there grew up a body of skilful spectroscopists, who devoted themselves to the accurate measurement of the wave lengths of the innumerable spectral lines given out by the different chemical elements and to the discovery of empirical relations between the numerical values of these wave lengths. It was hoped that such observations would throw light upon the structure of atoms but for many years no progress was made in this direction. Indeed it is only recently that the results of a generation of spectroscopists are beginning to be useful for this purpose and only after the clue to a theory of atomic structure had been given by investigations in other fields. Spectroscopy is almost the only part of physics in which a large mass of data was accumulated before the existence of a guiding hypothesis or theory to direct the work. The method of simple induction and classification which has played so large a part in some other sciences seems to be unsuited to the problems of physics.

Accurate measurements, however, do sometimes produce brilliant discoveries—when they fall into the right hands. A classical example of this is the discovery of argon by Lord Rayleigh as the result of a quite prosaic undertaking to redetermine with great accuracy the density of nitrogen. As a sequel to Rayleigh's work, a whole family of chemical elements, whose existence had been entirely unsuspected by chemists, was discovered by Ramsay. But it is only in rare instances that this sort of thing occurs; usually an accurate measurement leads to no exciting result, but takes its place among the solid foundation stones of the science. And for perhaps a decade there was fairly widespread opinion among physicists that this was what they must look forward to, and that the future of physics lay "in the last place of decimals."

These anticipations of a useful, if somewhat dull, old age for the science were happily disappointed in the last years of the century by the remarkable outburst of unexpected discoveries among which the Röntgen rays came first in point of time. This was followed almost at once by Becquerel's discovery of radioactivity, the identification of the subatomic "corpuscle" or electron by J. J. Thomson, and the investigations of the ionization of gases which have led to many important result. No physicist who has reached middle age can forget the romantic interest of the ten years following 1895, when startling discoveries followed each other in rapid succession and the physical journals were awaited with an impatience not unlike the desire for newspapers in wartime. But the news was all good news, and recorded an almost unbroken series of victories.

These discoveries were, as I have said, unexpected but they were not in any real sense accidental. They came as the result of a careful and prolonged study of the electrical discharge through rarefied gases—a complicated set of phenomena very difficult to put in order. Twenty years earlier, Maxwell had predicted that the next great step in our knowledge of the relations between electricity and matter would come from a study of the discharge through gases; and it had been prosecuted in that spirit by many men though the clue which they sought eluded them for twenty years. When it did come at last, it was in a form which was, so far as I know, entirely unpredicted and unexpected. This was so much the case that it took us more than fifteen years to find out quite certainly just what the X-rays were. It was not until 1912 that Laue's discovery of the diffraction of X-rays by crystals and the subsequent work of W. H. and W. L. Bragg made it quite certain that these rays were of the same nature as light but with wave lengths only about 1/5000 of those in the visible spectrum. This had indeed been for some time the prevailing hypothesis as to their nature but there was little quantitative evidence to support it; and only a year or two previous to the discovery of crystalline diffraction W. H. Bragg himself had brought forward many reasons for thinking that X-rays might be corpuscular. The study of these very short waves has already given us invaluable knowledge of the nature of the atoms of different elements and promises still greater advances in the future; it has provided a new and powerful method of studying crystal structure and has revolutionized our conception of the nature of chemical combination in crystalline bodies; and it promises to have practical applications as useful in industry as ordinary spectroscopy.

The discovery of the radioactivity by Becquerel followed almost immediately upon Röntgen's discovery of the X-rays, and was in a sense a direct consequence of it; they are alike too in that they have both had important medical applications which have drawn much public attention. Madame Curie's sensational discovery of radium was an early incident in the history of this subject. But by far the most important development in this field was the establishment by Rutherford and his pupils of the cause and source of energy of these radiations. He has shown in the most conclusive way that they are due to the disintegration of the atoms of the radioactive elements—uranium, thorium, radium, etc—and that a spontaneous transmutation of these elements is going on constantly. The genealogy of the radioactive elements is known more accurately than that of most royal families; and the birth and mortality statistics of the various kinds of atoms are in all the text books. Thus a part of the dream of the alchemists has come true, but only a part; for up to the present all attempts to produce artificially the transmutation of the heavy elements have failed. In fact we have not been able to affect in the slightest way the spontaneous transmutation of the radioactive elements; it can neither be retarded nor accelerated by any agency at our command. We do know, however, that vast stores of energy are locked up in the atoms of the heavier elements and if the time should ever come when this can be released and controlled by man it will doubtless cause a revolution in industrial processes more fundamental than that which followed upon the introduction of steam and electricity. One small step in this direction has been taken within the past two years. Rutherford has obtained evidence that the nitrogen atom may be broken up by bombardment with alpha rays, and that one of the products of this process is hydrogen. It is perhaps too early to regard this as being definitely established; and, even if it be true, the amount of matter transmuted in this way is excessively minute while the quantity of energy released in the process (if any) is far below what could possibly be measured experimentally. We have however become accustomed to small beginnings which ultimately produce great results; and a modern physicist would be rash indeed who should attempt to set bounds to the possibilities of future discovery in this direction.

The discovery of the electron was also an event of the first importance in the history of our science. It is the ultimate atom of negative electricity and is a constituent of all material atoms. It can also exist in the free or "disembodied" state, as for example in the cathode rays, the beta rays from radium, and in the electronic stream from incandescent bodies. In the last of these forms it has proved to be of great practical use to telephony and wireless telegraphy in the audion or thermionic tube which is the cause of most of the remarkable advances in these fields during the past five or six years. To the phyicst and chemist of today the electron is an indispensable concept in both theoretical and experimental investigations; and its reality can be questioned only on those philosophical grounds which may put in doubt the existence of matter itself.

The nature of positive electricity is not so definitely known; but evidence is accumulating that it too exists in an atomic form as the "nucleus" of the atom of hydrogen—the residue left when the hydrogen atom is deprived of its single negative electron. It is becoming probable that the "nuclei" of other atoms are built up out of these and of negative electrons. If this group of hypotheses should stand the test of time we shall have to conclude that matter and electricity are different aspects of the same stuff—that the atoms of matter are formed by different collocations of the atoms of positive and negative electricity.

Another line of physical inquiry which has proved to be of deep and fundamental significance is the so-called quantum theory of Planck. It originated in the study (both experimental and theoretical) of the intensity and quality of the radiation from a "black body," or perfect radiator, when held at a definite temperature. The total intensity of such radiations were deduced theoretically by Stefan from the principles of thermodynamics and the predicted results have been amply verified by experiment. When however the attempt is made to predict the way in which the energy is distributed in the spectrum, so as to be able to tell what fraction of the total intensity is carried by any particular wave length, the problem becomes much more difficult. It is necessary to have recourse to statistical methods analogous to those used by Maxwell, Boltzmann and Gibbs in accounting for the thermodynamic properties of material bodies. First steps in this direction were taken by W. Wien but the deductions from his theory were not altogether in accord with experimental results. Planck succeeded in obtaining a formula which agreed with experiment, but only by making certain very daring hypotheses; the most conspicuous of these is that the emission, or the absorption of radiation, or both, takes place not steadily and continuously as we had always supposed but by finite, discrete "quanta." From one point of view this hypothesis of Planck may be regarded as extending the field of the atomic theory, hitherto restricted to matter, to energy as well. I can not hope to suggest even remotely in the brief time at my disposal how revolutionary Planck's assumptions really are; they are still very imperfectly understood and it has not yet been possible to reconcile them wholly with other facts and general laws which appear to rest upon very solid foundations. Indeed, if the results of Planck's speculations had been confined to the deduction of a formula for the radiation of a black body they would not, I think, have long engaged the serious attention of physicists. But they began to turn up unmistakably in many other fields of investigation—for example, in connection with the photoelectric effect, with X-rays, and in all theories of atomic structure. At present no one doubts that most of our fundamental ideas in mechanics and electrodynamics must be revised in the light of the quantum theory which however is itself still in a very immature state. The problem thus arising of bringing together under one system apparently discrepant bodies of phenomena is an exceedingly difficult one and we may have to wait for another Newton to solve it. But it possesses the greatest fascination for all theoretical physicists; they are able to congratulate themselves upon the possession of an unsolved problem of the first magnitude and of great difficulty and they know that as long as it lasts, life will not be dull for them.

I should be in despair if it were necessary to give, at the end of a lecture already too long, an account of Einstein, relativity and gravitation. Fortunately any need that you may feel for instruction on these subjects has doubtless been satisfied by the newspapers, the magazines, and by innumerable books, popular and otherwise. Let me say in all seriousness however, that the more one knows of the history and recent developments of physics the more sincere and ardent is one's admiration for the individuality and brilliant originality of Einstein's genius. It does not seem probable at present that his discoveries will have as great an effect upon the immediate future of physics as some of the others which I have just discussed. But the ultimate result of his work upon *methods* used in the theoretical side of physical science may well prove to be revolutionary; and it seems highly probable that it will change to some extent our philosophical views of the nature of the external world and of our relation to it.

It may have occurred to you that, in my hurried sketch of the progress of physics since 1895, I have made very frequent use of such terms as "important," "epoch-making," or "revolutionary." The truth is that all the various discoveries and theories which arose more or less independently and have been separately mentioned are constituent parts of one "revolution" which has not yet reached its climax. It is one of the greatest intellectual pleasures of the present day physicist to see how all these apparently diverse things are fitting into each other and taking their appropriate places in a general scheme which is rapidly assuming form and coherence. The new ideas in physics are having a profound influence upon the fundamental theories of chemistry and are bringing the philosophies of the two sciences much closer together. They have already made possible a rational theory of the periodic law of Mendelejeff, and have displaced the atomic weight as the controlling factor in the determination of the chemical properties of the elements. They have also given grounds for a very reasonable hope that the near future may see the development of a real theory of chemical combination, which is certainly much to be desired.

The general character of the profound change which is taking place in the fundamental ideas of both sciences may perhaps be stated briefly and inadequately in the following terms. The recent discoveries in physics have enabled us to experiment in several ways with the individual atom and to find out something of its properties and activities. Until recently we have been able to deal only with statistical averages of the behavior of vast numbers of atoms and molecules and all of our physical laws have been based upon such statistical knowledge. The apparent discrepancies between the older and the newer formulations may well be due to this difference. It is quite possible that the ultimate laws which govern the actions of atoms are quite different from the laws of mechanics and electrodynamics which are so familiar that they seem almost axiomatic. If this should be so, the familiar "laws" will in no way lose their validity within the field that they have ruled so long; but we shall know that they are not fundamental and primary, but secondary statistical laws in which much of the individuality of physical activities has been ironed out by the process of averaging. To come to this point of view is of course rather a wrench for those of us who have been nursed and reared in the old régime. But this discomfort is much more than compensated for by the fascinating and apparently inexhaustible field for research and speculation which is now being opened up for our use and pleasure.

PERIODICAL CICADAS IN BALTIMORE, MD.

By Professor E. A. ANDREWS
THE JOHNS HOPKINS UNIVERSITY

IN the northern parts of Baltimore as now extended to include fields and woods certain restricted areas long inhabited and well grown with shade and fruit trees about country and suburban residences were overrun with great numbers of the noisy and conspicuous periodical cicada, Cicada septendecim, popularly known as the seventeen-year locust, during the early summer of 1919 and the same was true in even greater force in 1902 as I have observed.

Upon digging into the earth under sod or in old plantations of shrubs and trees in 1916-'17-'18 one saw many tunnels or tubular holes smaller than one's finger, but many inches long, two feet or more under the surface and in each might be a clumsy light colored gnome-like creature with grotesquely large and powerful front legs and claws and provided with an enigmatically closed-in face and head, making it a matter of search to discover the concealed tube or sucking mouth—apparatus through which it had been many years drawing from the roots of trees and shrubs the juices that had enabled it to grow to the size and plumpness of a peanut (with some of like food value). These cicada young in the spring of 1918 pushed their tunnels up well toward the surface of the ground and led one to surmise that they might be about to emerge from the dark into the air above. In fact some few must have done so for later in the summer a very few were heard singing their unmistakable song in the trees and a few of their cast off pupal cases were collected at the foot of trees, smaller than the seldom found cases of the non-periodical cicada, or harvest fly, Cicada tibicem.

But in 1919 the holes in the ground were all extended up almost to the surface or even beyond, as described below, and finally after seventeen years of darkness each inhabitant emerged from its own tunnel into the dim light of late day to transform into the winged insect.

Excepting as below noted these tunnels present the mystery of no seeming place for discharge of the excavated soil: but Fabre has given a remarkable suggestion as to how the tunnels may be made in dense soil with no outlet for soil removal.

In April and May diggings under apple trees showed very many vertical tunnels, each straight and smooth lined, each ending very near the surface with a well made roof of earth hollowed out below as dome over the vertical burrow. In each sat one larva braced with its legs against the smooth sides but ready upon slight disturbance to shut up its legs and drop down to the moist bottom of the tunnel if not given time to slowly crawl down into safety. When the top was dug off from the tunnel the inhabitant soon fashioned a new arched roof at the top.

Where boards lay on the ground the holes that came up under these obstacles were prolonged out of the earth against the board and then turning at right angles extended many inches horizontally along under the board as circular passages with walls made up of small pellets stuck together and all smoothed off inside. Often the board itself furnished some part of the roof of these horizontal extensions of the burrow.

Is it the light or heat that is sensed in the vertical burrow to bring about a cessation of work when near the surface, and is it the absence of this contrast between deep down and near surface which leads the larva under the board to keep on and on where possible and so to impress upon the onlooker the idea that the larva is aware of the obstacle to emergence?

Very many such restrained larvae remained under the boards after those in the open had emerged, but finally most of those under the boards found a way to the edges and escaped. When such board was raised the larvae were often in the horizontal burrows and could be more readily caught as they ran but slowly along to the vertical burrow down which they went with speed so great that rapid cut off from below with knife or spade was the only chance of intercepting their flight.

In some regions, chiefly those well shaded or not with normal exposure to light and air the vertical tunnels rose up into the air in the form of a chimney closely resembling those made by burrowing crayfish. Each chimney is built up by additions of small pellets of mud brought from below, often of the hard subsoil or clay and hence conspicuous upon the darker top soil. Each may be one and a half to two inches or more in diameter and one to five inches in height and either straight vertical or bending to one side.

In any case when not being worked at, each chimney is capped over at summit completely by pellets that make the top like the sides all one mass of irregular roughened drying or dry mud easily kicked aside as of no importance, yet each chimney upon being broken from its continuation down into the earth is seen to have in it the same vertical tunnel as large as one's finger, nicely smoothed on all its walls and arched over at the top by the smooth dome that is present at the top of all the vertical burrows which stop short of reaching the surface of the ground.

Such chimneys arose in great numbers in a small garage shed, closed in and dark. They were found under a porch beneath which roots of Norway maple extended and where light was very dim. These little chimneys in great numbers stuck up in the tall grass close to the bases of trees, around the bottoms of cherry trees along a privet hedge, and under the hedge itself where the shadow is always deep. When knocked off they lay about like so many mud finger stalls.

The numbers of holes varied greatly but in many places there were ten in a square foot; yet all garden or flower bed soil contained none and the same was true of roads and paths even though the roots of the trees extended under them and the gravel might have permitted egress.

Observations upon such cicada pupae kept in jars of earth in 1902 showed that the peculiar face of the insect was used as a hod to bring up to the surface of the ground the small pellets of mud collected below and laboriously carried to the surface. As the tunnel making involves no transport of material, it is the more enigmatical that the chimneys and horizontal tubes under the boards are made by hard work of a kind not, apparently, known during the 17 years of underground life.

The earliest date recorded for the coming of these cicadas forth from the ground in Baltimore was the finding May 16 by Mr. Ibara of one male with expanded wings in Druid Hill Park and one male in Wyman Park. While at the same date I observed the wings of one individual on a flower bed in my garden, apparently an early pioneer that had been sacrificed to the eager birds.

On the 21st of May a pint or more of winged forms were recorded as collected on the south side of Professor Mast's house in Roland Park. On the following day I saw the first pupae emerging and going toward the trees in my lawn while many persons reported them as appearing in numbers in Govans and Mt. Washington. On May 23 there was a second emergence from eight to nine p. m. when there was still good daylight. Many reports stated that the cicadas were emerging at Embla Park and on Charles Street north of Homewood, in great numbers. On May 24 the cicadas emerged again before 8 p. m. and walked straight toward the trees.

From then on cicadas came out of the ground every evening from eight to ten p. m. and some few later in the evening but the numbers emerging in any one region fell off till very few indeed came out after the first of June. May 26 many emerged as early as 7:30. In general the emergence began earliest in the season in localities that had the warmer soil and later in cold clay or in regions on north of buildings. Localities a few hundred feet apart differed by 7 days in date of first emergence. But even in the latest region, under trees north of house the few last cicadas were coming out June 7th and no more came out June 8th. Thus the entire outburst from the ground life of seventeen years was concentrated within a maximum of three weeks time while in any one spot the emergence was restricted to a period of less than two weeks.

Having lived some seventeen years below ground, the first advent into the air is followed by a remarkable migration before the actual hatching out of the larva-like pupa into the imago or perfected winged insect.

Upon breaking slowly through the arched dome that ends its vertical burrow, the pupa thrusts its head into the air above while there is still daylight of rapidly diminishing intensity and seems to face in various directions before actually coming out of the burrow. But once upon the earth the pupa begins a most persistent rectilinear journey toward some neighboring object, tree, wall, grass or flower stalk, or building. Standing under an isolated tree, it is a remarkable sight that presents itself when from north, south, east and west and all intermediate radii the emerging pupae, as if all of one mind march steadily toward the tree trunk at the center of their entire area of emergence.

Arrived at the tree or other upright they do not hesitate to climb up it with slow but steady progress often for many feet of vertical toil, but when a horizontal outlying part, as a branch, is reached, the pupae turn aside from the vertical which they had so long persisted to maintain underground and again resort to the horizontal journey they had recently quitted when ascending from the earth to the tree trunk. Out toward the ends of the branch they climb upon the twigs and the leaves and there finally come to their journey's end. Here they stretch out their legs, so that the hooks on their ends firmly hold them and as darkness comes on the transformation is completed; each back splitting open to allow of the slow emergence of a conspicuous white and very soft creature which will hang head down in apparent danger of falling to the ground till strong enough to mount upon its shell, gain a firm footing, and slowly pump up its wing pads with air while allowing of the fermentative processes in its soft skin to fashion a dark and stiff encasing layer that will make it henceforth so well able to use its muscles and be protected from minor injuries. As the eyes color red and two squarish areas above the wing muscles early turn black, the generally yellow white of the hatching adult is the more striking.

The next morning few indeed remain in such undefended softness since with the coming of day most all of the night's product vibrate their wings and fly away with great speed and strength of flight, well able to elude many birds on the wing and as well able to dodge about the limb or take again to wing when in danger of attack.

The three stages of the first journey in the above-ground were strikingly shown in the case of many cicadas arising from the earth near clothes poles which they found after a horizontal walk of many feet and mounted vertically five feet then to crawl out horizontally along the slightly sagging line only $\frac{3}{16}$ of an inch thick to settle down and transform all along the line up to a maximum distance from the pole of forty-eight feet.

Concerning the first part of the journey above ground, the walk to the trees, two sets of observations suggest problems to be solved, as to orientation with reference to vertical objects. The first observations relate to the numbers going to one isolated tree; the others relate to the distances traversed as if impelled by the sight of that tree.

Having in advance of the emergence protected most trees by bands of tin about the trunk it was found that the cicadas could not climb up this smooth surface, unless some crack allowed of use of the front leg nippers, and thus as fast as they arrived at base of a tree they tended to accumulate there and were not rapidly dispersed up over the whole tree where they could not be counted, while by collecting the cicadas arrested by the tin barrier a fair estimate of the entire number arriving at any particular tree could be readily had.

The tree most observed was a very large pear, probably Doyenne Boussock, thirty feet high by actual measurement and with a spread of twenty-one feet; its branches were nine feet above ground at origin but sagged somewhat and were very dense so that the tree was a very dark object; the overhang of the limbs toward the south was about eleven as opposed to ten feet toward the north. This tree stood isolated on a cut lawn, fourteen feet from a privet hedge running East and West, five feet high and six wide and was 36 feet from a silver maple toward the southwest, twenty-five feet from a very feeble old pear tree of 12 feet height and 10 feet spread to the north and 22 feet from a cherry tree in hedge to North East having spread of 10 feet and height of 17 but like the old pear tree casting little shade. The trunk of the big pear tree was 3 feet 9 inches in circumference at base.

The cicadas which emerged from the ground under this big pear tree, went toward the trunk as if drawn by a powerful magnet, both from near the hedge and from all other radial directions, but meanwhile some few cicadas under the hedge and under the other trees above mentioned remained in their own areas of attraction and climbed up the hedge plants or strove to ascend the tree trunks. However, it was evident that the big pear tree drew the great majority of all cicadas emerging within a circle much greater than its branches overhung and absolutely controlled all cicadas emerging under its branches.

The following figures show the run of cicadas collected at the base of this big pear tree daily, evening and morning May 22 to June 3. Those collected in the evening represented most of those of the day but as a few came out late these were collected in the morning and added to the previous evenings count for the total of that day. Thus on the 26th, 550 were taken at 8:30 and 250 more at 11 p. m. and 110 were waiting at the tin the next morning at 9.

Numbers showing daily emerging of 4,983 cicada pupae from area 15 feet radius around one tree during thirteen days, May 22 to June 3 inclusive; 65, 240, 400, 338, 910, 784, 551, 738, 561, 234, 118, 39, 5.

That is, the first day saw only 65 emerge, but the second day 240 and so on till after a maximum of 910 on the fifth day, there was a slow falling off and then rapid decline on the last three days from 118 to only 5.

In like manner, other trees yielded daily crops of cicadas from their roots and these newly emerged parasites strove to attain the trunks and branches near at hand. Very large numbers were involved in small areas. In two weeks one hundred quarts of cicadas were gathered by hand from about one acre of ground while in addition probably as many more were consumed by Indian Runner ducks let loose morning and evening for the purpose of eating up the emerging cicadas, which they accomplished to the limit of capacity of each individual crop and with the greatest enthusiasm and persistence.

As it was found that one quart of winged cicadas contained from 270 to 330 individuals and weighed 10½ to 12½ ounces and that a quart of the emerging pupae contained 435 crawling individuals with weight of 17 ounces, it is evident that the entire number emerging from an acre of such suburban land runs up toward one hundred thousand with a combined weight of near one-tenth of a ton.

Turning to the second set of observations that relate to the possible modes by which the emerging pupae are able to find a tree to climb.

At the Northeast corner of a large lawn bounded North and East by hedges at right angles stood a black locust tree fifty or sixty feet in height at the end of a row of like trees running East.

It was found that the root system of this tree extended under the sod to a distance of at least seventy feet. Over this area the cicadas emerged in numbers and crawled toward the tree trunk along radii all over the quadrant represented by the area between the above hedges.

One cicada was watched from a point 61 feet from the locust tree as it went straight toward the locust tree although behind it on the same radius stood a smaller pear tree twenty-four feet away with height of some 18 feet. The large locust tree had few branches till toward the top and appeared as distinct area of but light foliage against the sky at the time of evening when the cicadas were emerging. Another cicada started from a point nearly in the center of the entire area, 36 feet from the locust tree. And a third from 27 feet though behind it was a small pear tree only four feet away. Standing on the lawn it was astonishing to see so many cicadas walking along all possible radii from such distances as if drawn to the trunk; while many moved along parallel to the hedges and turned not aside others went along all the radii between these two hedge radii that were at right angles to one another.

A great many cicadas emerged every evening, as May 22 and 23, and all marching toward the exact middle of the tree they became concentrated more and more as they drew near the tree. However, it happened that scarcely one of this host ever reached the tree, for while but five or six out of hundreds turned aside to mount up the privet hedge some six feet in height and width, the great majority after the long walk met with an obstacle in the shape of a chicken-net wire and tall flowering orchard grass some seven or eight feet in extent and one and a half wide lying across the line of march and but five feet from the trunk of the tree. Coming to these upright but slender grass stalks the cicadas all mounted up and there stretched out to transform. Some successfully transformed though most were collected when so easy of access.

The impression made by so many individuals on different days all centered toward the same object was of forced movements impelled by the tree's presence, but whether the cicadas moved thus radially on account of their life underground having been often radial along the root system or whether for the first time the tree appealed to them as being in some sense seen against the sky was not evident. When such crawling cicadas were interrupted they returned again to their radial course.

As bearing upon the use of the eyes in this orientation may be cited a few experiments made in the midst of the lawn: a kitchen table was placed radially and cicadas placed upon it with the result that the cicadas continued along the radius toward the tree till coming to the end of the table they fell off and resumed progress in the same direction on the grass. When reversed on the table they generally soon turned back into the direction toward the tree. When both eyes were blackened with asphaltum the cicadas wandered about on the table or on the grass not showing any distinct orientation. A few with but one eye blackened seemed to walk toward the tree without much hesitation, but these experiments were made too late in the evening to be well observed.

In general one was left wondering if the cicadas did not actually see the tree in some way and be influenced by it as if it were to them a conspicuous elevated area.

For a few days after emergence no noise came from the winged cicadas but on May 26th they were very plainly heard along Charles street road and on Cold Spring lane and on the 28th along Bellona Avenue and in the woods of Homewood.

From then on all day their peculiar cries resounded in and near all other regions of emergence while very many silent areas showed their absence. While at first heard only in the heat of the day, by May 31st when the temperature had risen to 89° and the air was dry their unwelcome noise lasted on late into the night and on the leaves of trees some were found pairing.

They continued noisy day and even at night, June 6, but then more and more showed the destructive fungus in their bodies. One last noisy one was heard June 28 after a week of near silence.

It was not this species of Cicada of which the poet sung:

Du kluges Kind der Erden,
Du Freundin schoener Lieder,
Wirst nie from Alter traurig.
Dich plagen keine Schmertzen,
Du hast, so wie die Goetter,
Kein Fleisch und kein Gebleute,
Bist du nicht ihres Gleichen?

During the period of mating the cicadas collected in great numbers upon trees and bushes often at considerable heights and too frequently upon trees remote from those under which they had emerged so that despite decimation from collecting, fresh flying insects from neighbors' trees again populated the partially cleaned area; but there was no evidence of any wide migration so that concerted action could readily have rid infected areas of a large part of the accumulations of seventeen years' growth. Not only was the tin placed about trees good protection when combined with collecting by hand or by duck aid, since it arrested the crawlers and held them restricted till the daylight made collecting easy; but later on when the trees were full of flying insects the tins still had useful features. Thus June 7th after a thunder storm many flying insects were beaten to the ground and under the above pear tree 150 were found struggling to climb up the trunk and held back by the tin since they preferred the old way of crawling and climbing to get to an elevation from which to take wing. In this connection may be noted that when a tree was shaken, while most flew away many pairing or separate fell to the ground and thus could be caught: June 4th at 8 p. m. 282 were thus gathered under the pear tree.

Upon the trees the cicadas tended to congregate upon the warm sunny aspects and to crowd upon certain outstanding branches or twigs, flying constantly from twig to twig as if in search of something and gradually aggregating upon certain favored trees though neglecting completely very few indeed.

By June 3 the females were rapidly laying eggs in the twigs of ash-leaved maple, apple, plum, peach, apricot, pear, etc.

By June 8 no more were emerging. June 17, many were dying, and before the end of that month practically all adults had ceased to exist.

Meantime the new generation was progressing. As is well known the fecundated female chooses top and outlying twigs for deposit of her eggs and walking along saws into the wood deep gashes in regular series within which the same efficient ovispositor that rips open the wood deposits nicely placed packets of elongated eggs.

So deep are these injuries to the twigs and so extensive the areas affected that many twigs fail to carry their usual sap and hence the leaves shrivel. By June 17th many trees showed so many terminal twigs with brown and shrivelled leaves that it seem as if they had been scorched by fire. By June 29th the rain and wind had broken off many of these too deeply injured twigs and strewn them on the ground. Such twigs taken into the dry laboratory showed after a week only dried and shrivelled eggs, so that it may well be that very many eggs perish when the twigs in which they are placed are so severely injured that the twigs fall off. On the other hand, the great majority of twigs were not so severely injured as to loose vitality, and these remaining upon the tree finally liberated the young. Such twigs cut off and placed in a jar of water and thus kept from too great drying yielded large numbers of the young.

From August 8 to 23 such stems taken indoors yielded large crops of small white larvae which coming out of the wood crawled along and soon fell off. When the water jar was placed in a large bowl the young falling off were unable to escape up the smooth sides and gradually collected in large numbers and could be removed before they dried up.

Unlike the pupae, which emerging into the light leave a darker for a lighter region, these newly hatched larvae go from the light towards the darker areas and so collect underneath overhanging objects. Unlike the pupae which strongly strive to crawl upward the newly hatched larvae tend to crawl downward.

When placed upon earth these little larvae soon managed to dig in and disappeared from the light downward into the dark earth.

Mr. Ibara found that such young in receptacles with grass attached themselves to the roots of the grass and apparently began thus to feed from the juices of these plants.

Amongst so many cicadas coming under observation there were notable diversities. Not only the well-known dwarf cicadas, but certain exceptional varieties were observed. The dwarfs often emerged in large numbers largely by themselves with few of the larger forms at the same time and place and were especially common under a very old russet apple tree.

Amongst 9½ quarts of the flying cicadas gathered June and chiefly perfected the night previous, there were two with white eyes, one with black eyes and one with chestnut brown face. The white-eyed cicadas have also lighter colored costal edges to the front wings and this might be considered a failure to completely darken the wing which at first was white and normally turns darker soon after hatching out from the pupa case. The white eye, however, is of fundamental nature since the normal red eye is one of the earliest areas of the body which stands out against the general whiteness as fiery red and in these two white-eyed individuals the absence of color in the eye dated back beyond the time of transformation.

Thus amidst about five thousand seven hundred cicadas two had white, one black and one chestnut colored eyes. Other collections showed that white-eyed and brown-eyed forms occurred now and then both in this same region and in Roland Park and thus from diverse groups that had been separated a couple of miles for seventeen years at least.

In the assumedly rather uniform and simple conditions of seventeen years of growth under ground there would seem little opportunity for light or other external conditions to exert any such modifying influence as might lead to white in place of red eye. Regarding the two periods of life, the short one as active larva getting into the ground and the concealed egg in the wood, as opposed to the germ life in the active adult, we seem safe in assuming that here as elsewhere the initiative to change in eye color came in the germinal material.

The injury done to trees and shrubs by the adult females in laying is not only the immediate death of important twigs when too severely cut by the ovispositor but in the leaving of wounds that may later cause injury. While the severely injured twigs may fall off soon and thus often lead to the failure of the cicada eggs from drying, the partly injured twig remains and begins to heal over, but this overgrowth rarely overtakes the young before it comes out of the wound. The following summer, 1920, many of the injured twigs were healed over more or less completely. Nevertheless the wood had been so deeply injured that a great many twigs bearing green leaves and such fruits as those of the Norway Maple were wrenched off by storms owing to the internal weakening caused by the previous season by the cicadas.

While the extensive pruning may not cause serious results in many shade trees, the dying off of twigs, the remaining of dead tips and the presence of innumerable wounds is of moment in some fruit trees and in the dogwood the pruning back by the cicadas tended to make considerable changes in fruiting, flowering and proportions of growth, while in some chestnut shoots recovering from dying down after the blight the wounds made by cicadas were placed with reference to new infestations of the blight so as to suggest that the blight had entered through these wounds in the firm young bark.

How serious the loss of sap of roots through long years of cicada sucking may be, remains to be found out.

The almost absolute completeness of the emergence in 1919 is seen in the fact that in 1920 search for these seventeen year locust yielded not one. Even in the region along Charles Street north of University Parkway where in 1919 the cicadas were swept up from the sidewalk in great numbers no cast off shells could be found in 1920 and but one solitary song in this region indicated that there had been an emergence of one of the race this season; all the others having come out in 1919 with practically no lag.

It is the phenomenal uniformity with which all these creatures in a given region run through their long period of growth to emerge within so few days after seventeen years and with so few exceptional hurried or lagging individuals that presents a problem in rhythmic growth of great interest as is also the question as to how far these insects may be guided by sight in the first use of their eyes upon coming from seventeen years of apparent darkness. These and other questions may be approached experimentally if attention is called to this field in time; and fortunately some broods of these insects come out at predictable dates in various parts of the country in different years so that observation can be spread over much of the long interval otherwise lost in any one locality.

THE BIOLOGY OF DEATH. II—CONDITIONS OF CELLULAR IMMORTALITY[1]

By Professor RAYMOND PEARL
THE JOHNS HOPKINS UNIVERSITY

1. Artificial Parthenogenesis

IN the preceding paper in this series it was pointed out that the germ cells of higher organisms are potentially, and under certain conditions in fact, immortal. What are the conditions of immortality in this case? Are they such as to support the thesis that the processes of mortality are essentially physico-chemical in nature, and follow physico-chemical laws?

The most essential condition of this immortality of germ cells was mentioned, but not particularly emphasized. It is that two germ cells, an ovum and a spermatozoon *unite*, the process of union being called fertilization. Having united, if they then find themselves in appropriate environmental conditions, development goes on, new germ cells and a soma are formed, and the same process keeps up generation after generation. Now while union of the germ cells is generally and in most organisms an essential condition of this process, it is also true that in a few forms of animal life, mostly found among the invertebrates, development of the ovum can take place without any preceding fertilization by a spermatozoon. The process of reproduction in this case is called *parthenogenesis.* In a number of forms in which parthenogenesis never occurs normally, so far as is known, it can be induced by appropriate extraneous procedures. The discovery of this extraordinarily interesting and important fact for a number of organisms, and the careful working out of its physico-chemical basis, we owe to Dr. Jacques Loeb, of the Rockefeller Institute for Medical Research. Artificial parthenogenesis may be induced, as Guyer, Bataillon and Loeb have shown in so highly organized a creature even as the frog, and the animal may grow to full size. The frogs shown in Figure 1, while they present much the same appearance as any other frog of the same species, differ in the rather fundamentally important respect that they had no father.

The rôle of a father was played in these cases by an ordinary dissecting needle. Unfertilized eggs from a virgin female were gently pricked on the surface with a sharply pointed needle. This initiation

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 29.

FIG. 1. ARTIFICIALLY PARTHENOGENETIC FROGS. (Loeb.)

of the process of development took place March 16, 1916, in one case, and February 27, 1917 in the other. The date of death was in the first case May 22, 1917 and in the other March 24, 1918.

In the course of Loeb's studies of parthenogenesis in lower marine invertebrates, he became interested in the question of the death of the germ cells which had failed to unite, or having united failed of appropriate environmental conditions. His researches throw light on some of the conditions of cellular death, and on that account they may be reviewed briefly here. He found that the unfertilized mature eggs of the sea-urchin die comparatively soon when deposited in sea-water. The same eggs, however, live much longer, and will if appropriate surrounding conditions are provided go on and develop an adult organism, if they are caused to develop artificially by chemical means or naturally by fertilization. Loeb concluded from this that there are two processes going on in the egg. He maintained, on the one hand, that there are specific processes leading to death and disintegration, and, on the other hand, processes which lead to cell division and further development. The latter processes may be regarded as inhibiting or modifying the mortal process. Loeb and Lewis undertook experiments based upon this view to see whether it would be possible by chemical treatment of the egg to prolong its life. Since in general specific life phenomena are perhaps on the chemical side chiefly catalytic phenomena, it was held to be reasonable that if some substance could be brought to act on the egg, which would inhibit such phenomena without permanently altering the constitution of the living material the life of the cell should be considerably prolonged. The first agent chosen for trial was potassium cyanide, KCN. It was known that this substance weakened or inhibited entirely a number of enzymatic processes in living material, without materially or permanently altering its structure.

It was found that normally the unfertilized egg of the sea-urchin would live in sea-water at room temperature, and maintain itself in condition for successful fertilization and development, up to a period of about twenty-three hours. After that time the eggs began to weaken. Either they could not be successfully fertilized, or, if they were fertilized, development only went on for a short time. After 32 hours the eggs could not as a rule be fertilized at all. The experiment was then tried of adding to the sea-water, in which the unfertilized eggs were kept, small amounts of KCN in a graded series, and then examining the results of fertilizations undertaken after a stay of the unfertilized eggs of 75 hours in the solution. It will be noted that this period of 75 hours is more than three times the normal duration of life of the cell in normal sea-water. The results of this experiment are shown in summary form in Table 1.

TABLE I

Experiments of Loeb and Lewis on the prolongation of life of the sea-urchin egg by KCN

Concentration of KCN	Result of fertilization after a 75 hours' stay in the solution
Pure sea-water	No egg segments
n/64000 KCN	No egg segments
n/16000 KCN	No egg segments
n/8000 KCN	Very few eggs show a beginning of segmentation
n/4000 KCN	Very few eggs show a beginning of segmentation
n/2000 KCN	Few eggs go through the early stages of segmentation
n/1000 KCN	Many eggs segment and develop into swimming larvae
n/750 KCN	Many eggs segment and develop into swimming larvae
n/400 KCN	A few eggs develop into swimming larvae
n/300 KCN	No egg segments
n/250 KCN	No egg segments
n/200 KCN	No egg segments
n/100 KCN	No egg segments

From this table it is seen that in concentrations of KCN from n/750 to n/1000 the eggs developed perfectly into swimming larvae. In other words, by the addition of this very small amount of KCN the life period has been prolonged to three times what it would normally be under the same environmental conditions. Concentrations of KCN weaker than n/1000 were incapable of producing this result, or at best if development started the process came very quickly to an end. In stronger concentrations than n/400 the eggs were evidently poisoned, and no development occurred.

Other experiments of Loeb's show that the lethal effects of various toxic agents upon the egg cell may be inhibited, or postponed for a relatively long time, by suitable chemical treatment, such as lack of oxygen, KCN, or chloral hydrate. A typical experiment of this kind made upon the sea-urchin, *Strongylocentrotus purpuratus*, may be quoted:

Eggs were fertilized with sperm and put eleven minutes later into three flasks, each of which contained 100 c. c. of sea-water + 16 c. c. 2-1/2 m $CaCl_2$. One flask was in contact with air, while the other two flasks were connected with a hydrogen generator. The air was driven out from these two flasks before the beginning of the experiment. The eggs were transferred from one of these flasks after four hours and fourteen minutes, from the second flask after five hours and twenty-nine minutes, into normal (aerated) sea-water. The eggs that had been in the hypertonic sea-water exposed to air were transferred simultaneously with the others into separate dishes with aerated normal sea-water. The result was most striking. Those eggs that had been in the hypertonic sea-water with air were all completely disintegrated by "black cytolysis." Ten per cent. of the eggs had been transformed into "shadows" (white cytolysis). It goes without saying that all the eggs that had been in the aerated hypertonic sea-water five and a half hours were also dead. The eggs that had been in the same solution in the absence of oxygen appeared all normal when they were taken out of the solution, and three hours later—the temperature was only 15°C—they were all, without exception in a perfectly normal two- or four-cell stage. The further development was also in most cases normal. They swam as larvae at the surface of the vessel and went on the third day (at the right time) into a perfectly normal pluteus stage, after which their observation was discontinued. Of the eggs that had been five and a half hours in the hypertonic sea-water deprived of oxygen, about 90 per cent. segmented.

Let us consider one more illustration from Loeb's work in this field. Normally, in the forms with which he chiefly worked, sea-urchin, starfish, and certain molluscs, an absolutely essential condition for the continuation of life of the germ-cells after they are discharged from the body is that two cells, the ovum and the spermatozoon, shall unite in normal fertilization. Put in another way, parthenogenesis does not normally occur in these forms. Fertilization is an essential condition for the continuation of life and development. But Loeb's painstaking and brilliant researches extending over a number of years show that when we say that fertilization is an essential condition for the continued life of the germ-cells outside the body our language tends to obscure the most important fact, which is simply that for the continuation of life in these cells only certain internal physico-chemical conditions and adjustments must be realized. It makes no essential difference to the result whether these conditions are realized through the intervention of the sperm, as in normal fertilization, or by purely artificial chemical methods initiated, controlled and directed at every step by human agency. We can, in other words, regard all cases of successful artificial parthenogenesis as fundamentally a contribution to the physiology of natural death, and a demonstration of its essentially mechanistic basis. The conditions of continued existence are physical and chemical and controllable as such. The methods finally worked out as optimum are very neat, and afford a complete demonstration of the thesis we have just stated. Thus, for example, the unfertilized egg of the sea-urchin, *Strongylocentrotus purpuratus*, will continue in life and develop perfectly normally if it is subjected to the following treatment: The eggs are first placed in sea-water to which a definite amount of weak solution of butyric acid has been added (50 c. c. of sea-water+2.8 c. c. n/10 butyric acid). In this solution at 15°C. the eggs are allowed to remain from 1½ to 3 or 4 minutes. They are then transferred to normal sea-water, in which they remain from 15 to 20 minutes. They are then transferred for 30 to 60 minutes at 15°C. to sea-water which has had its osmotic pressure raised by the addition of some salts (50 c. c. of sea-water + 8 c. c. of 2½ m NaCl, or 2½ m NaCl + KCl + $CaCl_2$ in the proportion in which these salts exist in sea-water). After the stay of from 30 to 60 minutes in this solution the eggs are transferred back to normal sea-water, the transfer being in batches at intervals of 3 to 5 minutes between each batch transferred. It is then found that those eggs which have been just the right length of time in the hypertonic sea-water develop into perfectly normal sea-urchin larvae. In other words, we have here a definite and know physico-chemical process completely replacing what was before this work universally regarded as a peculiarly vital process of extraordinary complexity, probably beyond powers of human control.

These three examples from Loeb's work on the subject of prolongation of life in the egg cell will suffice for our present purposes. The lesson which they teach is plain, and is one which has, as will be readily perceived, a most important bearing upon the general concept of life and death outlined in the preceding paper in this series. The experiments demonstrate that the conditions essential to continued life of the germ-cells outside the body are physico-chemical conditions, and that when these cells die it is because the normal physico-chemical machinery for the continuation of life has either broken down, or has not been given the proper activating chemical conditions.

Lack of space alone prevents going in detail into another extremely interesting and important development of this subject due to Dr. Frank R. Lillie of the University of Chicago. He has in recent years made a thorough analysis of the biological factors operating when the egg of the sea-urchin is normally fertilized by a spermatozoon. The conception of the process of fertilization to which Lillie comes is "that a substance borne by the egg (fertilizin) exerts two kinds of actions, (1) an agglutinating action on the spermatozoon and (2) an activating action on the egg. In other words, the spermatozoon is conceived, by means of a substance which it bears and which enters into union with the fertilizin of the egg, to release the activity of this substance within the egg." From the standpoint of the present discussion it is obvious that Lillie's results present nothing which in any way disturbs the conclusion we have reached as to the essentially physico-chemical nature of the processes which condition the continuation of life and development of the egg.

2. Tissue Culture in Vitro

Let us turn now to another question. Are the germ-cells the only cells of the metazoan body which possess the characteristic of potential immortality? There is now an abundance of evidence that such is not the case, but that on the contrary there are a number of cells and tissues of the body, which under appropriate conditions may continue living indefinitely, except for the purely accidental intervention of lethal circumstances. Every childs knows that all the tissues do not die at the same time. It is proverbial that the tail of the snake, whose head and body have been battered and crushed until even the small boy is willing to admit that the job of killing is complete, will not die till the sun goes down. Galvani's famous experiment with the frog's legs only succeeded because some parts survive after the death of the organism as a whole. As Harrison points out "Almost the whole of our knowledge of muscle-nerve physiology, and much of that of the action of the heart, is based upon experiments with surviving organs, and in surgery, where we have to do with changes involved in the repair of injured parts, including processes of growth and differentiation, the power of survival of tissues and organs and their transplantability to strange regions, even to other individuals, has long formed the basis of practical procedures."

The first successful cultures of somatic cells and tissues outside the body were those of Leo Loeb, described in 1897. His first method consisted in cultivating the tissues in appropriate media in test tubes. Later he used also another method which involved the transplantation of the solid medium and the tissue into the body of another animal. What has been regarded as a defect of both these methods is that they do not permit the continued observation of the cells of the growing cultured tissue. To Harrison is due the development of a method which does permit such study. In 1907 he announced the discovery that if pieces of the developing nervous system of a frog embryo were removed from the body with fine needles, under strictly aseptic precautions, and placed on a sterile cover slip in a drop of frog lymph, and the cover slip then inverted over a hollow glass slide, that the tissues would remain alive for many days, grow and exhibit remarkable transformations. By this technique it was possible to study the changes with a high power of the microscope and photograph them.

FIG. 2. PIECE OF TISSUE FROM FROG EMBRYO CULTIVATED IN LYMPH, 2 days old. The dark portion shows original bit of tissue. Lighter portions are new growth. (From Harrison.)

Figure 2 is a general view of one of these tissue cultures two days old. It shows a piece of nervous tissue from the frog embryo with cells growing out from it into the lymph. The lighter portions are the new cells. In his remarkable monograph Harrison shows nerve cells developing fibers at first thickened, but presently becoming of normal character and size. At the ends are pseudopodial processes, by which the growing fiber attaches itself to the cover slip or other solid bodies and pulls itself out, as it were. Figure 3 shows a particularly beautiful nerve fiber preparation made by Burrows.

The fibers grew from a preparation of the embryonic nervous system of the chick. There can be no doubt, as these figures so clearly show, of the life of these cells outside the body, or of the normality of their developmental and growth processes.

FIG. 3. GROUP OF NERVE FIBERS WHICH HAVE GROWN FROM AN ISOLATED PIECE OF NEURAL TUBE OF A CHICK EMBRYO. (From Harrison after Burrows.)

Under the guidance of Harrison, one of his students, Burrows, improved the technique of the cultivation of tissues outside the body, first by using plasma from the blood instead of lymph and later in various other ways. He devised an apparatus for affording the tissue culture a continuous supply of fresh nutrient medium. There is in this apparatus a large culture chamber which takes the place of the plain hanging drop in a hermetically sealed cell. On the top of this culture chamber there is a wick which carries the culture fluid from a supplying chamber and discharges it into a receiving chamber. The tissue is planted among the fibers of the wick, which are pulled apart where it crosses the top of the chamber. The whole system is kept sterile and so arranged that the growing tissue can be kept under observation with high powers of the microscope. The nutrient medium may be modified at will, and the effects of known substances upon the cellular activities of every sort may be studied.

Burrows began his investigations in this field on the tissues of the embryo chick. With the success of these cultures was established the fact that the tissues of a warm blooded animal were as capable of life, development, and growth outside the body as were those of cold-blooded animals, such as the frog. Burrows succeeded in cultivating outside the body cells of the central nervous system, the heart, and mesenchymatous tissue of the chick embryo. At the same time Carrel was carrying on studies in this same direction at the Rockefeller Institute. In his laboratory were made the first successful cultures in vitro of the adult tissue of mammals. He developed a method of culture on a plate which permitted the growing of large quantities of material. He found that almost all the adult and embryonic tissues of dog, cat, chicken, rat, guinea pig, and man could be cultivated *in vitro*. Figure 4 shows a culture of human tissue, made at the Rockefeller Institute. I am indebted to Doctor Carrel and Doctor Ebeling for permission to present this photograph here.

According to the nature of the tissues cultivated, connective or epithelial cells were generated, which grew out into the plasma medium in continuous layers or radiating chains. Not only could normal tissues be cultivated but also the cells of pathological growths (cancer cells). It has been repeatedly demonstrated that normal cell division takes place in these tissues cultivated outside the body. The complex process of cell division which is technically called mitosis, has been rightly regarded as one of the most characteristic, because complicated and unique, phenomena of normal life processes. Yet this process occurs with perfect normality in cells cultivated outside the body. Tissues from various organs of the body have been successfully cultivated, including the kidney, the spleen, the thyroid gland, etc. Burrows was even able to demonstrate that the isolated heart muscle cells

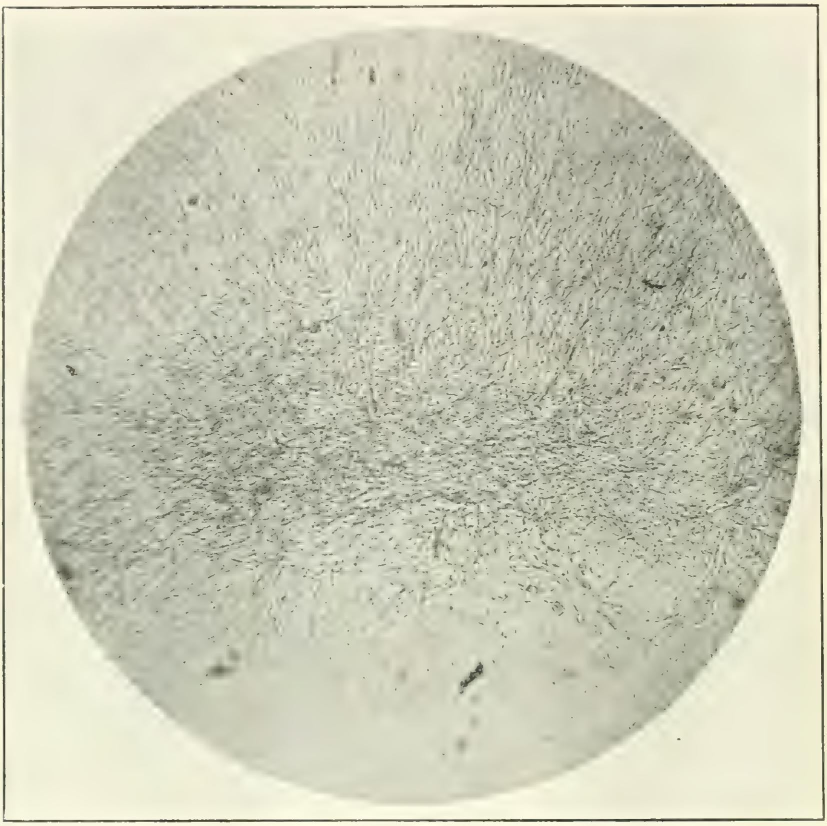


FIG. 4. HUMAN CONNECTIVE TISSUE CELLS FIXED AND STAINED WITH GIEMSA STAIN. The culture was made by extirpating the central portion of culture 285 in its 16th passage, washing the remaining portion of the culture with Ringer solution without removing it from the cover-glass, and dropping on fresh plasma and extract. The preparation shows the extent of growth obtained in 48 hours from peripheral cells remaining after extirpation of the fragment. (After Losee and Ebeling.)

of the chick embryo can divide as well as differentiate and beat *rhythmically* in the culture medium.

Perhaps even more remarkable than the occurrence of such physiological activity as that of the heart muscle cells *in vitro* is the fact that in certain lower forms of life a small bit of tissue or even a single cell, may develop in culture into a whole organism, demonstrating that the capacity of morphogenesis is retained in these isolated somatic cells. H. V. Wilson has shown that in coelenterates and sponges complete new individuals may develop *in vitro* from isolated cells taken from adult animals. By squeezing small bits of these animals through bolting cloth he was able to separate small groups of cells or even single cells. In culture these would grow into small masses of cells which would then differentiate slowly into the normal form of the complete organism. Figure 5 shows an example of this taken from Wilson's work.

It was early demonstrated by Carrel and Burrows that the life of the tissues *in vitro* which varied in different experiments from 5 to 20 days could be prolonged by a process of successive transfers of the culture to an indefinite period. Cells which were nearing the end of their life and growth in one culture need only be transferred to a new culture medium to keep on growing and multiplying. Dr. and Mrs. Warren H. Lewis made the important discovery that tissues of the chick embryo could be cultivated outside the body in purely inorganic solutions, such as sodium chloride, Ringer's solution, Locke's solution, etc. No growth in these inorganic cultures took place without sodium chloride. Growth was prolonged and increased by adding calcium and potassium. If maltose or dextrose, or protein decomposition products were added proliferation of the cells increased.

By the method of transfer to fresh nutrient media Carrel has been able to keep cultures of tissue from the heart of the chick embryo alive for a long period of years. In a letter recently received he says: "The strain of connective tissue obtained from a piece of chick heart

FIG. 5. PENNARIA. Restitution mass six days old, completely metamorphosed, with developed hydranths. Op. perisarc of original mass; x, perisarc of outgrowth adherent to glass. (From Wilson.)

FIG. 6. CULTURE OF OLD STRAIN OF CONNECTIVE TISSUE. 1614 passage. 8 years and 8 months old, lacking 2 days. 48 hours' growth. x20. (Ebeling.)

is still alive and will be *nine years old* the seventeenth of January, 1921." Figure 6 is a photograph showing the present condition of this culture.

This is indeed a remarkable result. It completes the demonstration of the potential immortality of somatic cells, when removed from the body to conditions which permit of their continued existence. Somatic cells have lived and are still living outside the body for a far longer time than the normal duration of life of the species from which they came. I think the present extent of Carrel's cultures in time fully disposes of Harrison's criticism to the effect that we are "not justified in referring to the cells as potentially immortal or even in speaking of the prolongation of life by artificial means, at least not until we are able to keep the cellular elements alive in cultures for a period exceeding the duration of life of the organism from which they are taken. There is at present no reason to suppose this cannot be done, but it simply has not been done as yet." I have had many years' experience with the domestic fowl, and have particularly studied its normal duration of life, and discussed the matter with competent observers of poultry. I am quite sure that for most breeds of domestic poultry the normal average expectation of life *at birth* is not substantially more than two years. For the longest lived races we know this normal average expectation of life cannot be over four years. I have never been able to keep a Barred Plymouth Rock alive more than seven years. There are on record instances of fowls living to as many as 20 years of age. But these are wholly exceptional instances, unquestionably far rarer than the occurrence of centenarians among human beings. There can be no question that the nine years of life of Carrel's culture has removed whatever validity may have originally inhered in Harrison's point. And further the culture is just as vigorous in its growth today as it ever was, and gives every indication of being able to go on indefinitely, for 20 or 40, or any desired number of years.

The potential immortality of somatic cells has been logically just as fully demonstrated in another way as it has by these tissue cultures. I fully agree with Leo Loeb when he says that the proof of potential immortality "can just as well be supplied by serial transplantation of tissues in the living body; but we can, I believe, go further, and state that as far as such potential immortality of tissues can be proved, the proof has already been given through the long-continued, apparently endless serial transplantation of tumors. Now tumor cells are merely ordinary somatic cells living under special conditions; and we may, therefore, conclude that, in the same sense as protozoa and germ cells, also, certain ordinary mammalian somatic cells possess a potential immortality." Loeb first announced this important conclusion nineteen years ago. To him unquestionably belongs the credit for first perceiving that death was not a necessary inherent consequence of life in the somatic cell, and demonstrating by actual experiments that somatic cells could, under certain conditions, go on living indefinitely.

Before turning to the next phase of our discussion let us summarize the ground we have covered up to this point. We have seen that by appropriate control of conditions it is possible to prolong the life of cells and tissues far beyond the limits of longevity to which they would attain if they remained in the multicellular body from which they came. This is true of a wide variety of cells and tissues differentiated in various ways. Indeed, the range of facts which have been ascertained by experimental work in this field probably warrants the conclusion that this potential longevity inheres in most of the different kinds of cells of the metazoan body, except those which are extremely differentiated for particular functions. To bring this potential immortality to actuality requires, of course, special conditions in each particular case. Many of these special conditions have already been discovered for particular tissues and particular animals. Doubtless, in the future many more will be worked out. We have furthermore seen that in certain cases the physico-chemical nature of the conditions necessary to insure the continuance of life has been definitely worked out and is well understood. Again this warrants the expectation that, with more extended and penetrating investigations in a field of research which is really just at its beginning, we shall understand the physics and chemistry of prolongation of life of cells and tissues in a great many cases where now we know nothing about it.

One further point and we shall have done with this phase of our discussion. The experimental culture of cells and tissues *in vitro* has now covered practically all the *essential* tissue elements of the metazoan body, even including the most highly differentiated of those tissues. Nerve cells, muscle cells, heart muscle cells, spleen cells, connective tissue cells, epithelial cells from various locations in the body, kidney cells, and others have all been successfully cultivated *in vitro*. We may fairly say, I believe, that the potential immortality of all the essential cellular elements of the body either has been fully demonstrated, or else has been carried far enough to make the probability very great that properly conducted experiments would demonstrate the continuance of the life of these cells in culture to any definite extent. It is not to be expected, of course, that such tissues as hair, or nails, would be capable of independent life, but these are essentially unimportant tissues in the animal economy as compared with those of the heart, the nervous system, the kidneys, etc. What I am leading to is the broad generalization, perhaps not completely demonstrated yet, but having regard to Leo Loeb's work, so near it as to make little risk inhere in predicting the final outcome, *that all the essential tissues of the metazoan body are potentially immortal.* The reason that they are not actually immortal, and that multicellular animals do not live forever, is that in the differentiation and specialization of function of cells and tissues in the body as a whole, any individual part does not find the conditions necessary for its continued existence. In the body any part is dependent for the necessities of its existence, as for example nutritive material, upon other parts, or put in another way, upon the organization of the body *as a whole. It is the differentiation and specialization of function of the mutually dependent aggregate of cells and tissues which constitutes the metazoan body which brings about death, and not any inherent or inevitable mortal process in the indidividual cells themselves.*

3. Senescence

A careful and unprejudiced examination will suffice to convince anyone of open mind, I think, that much of the literature on senescence is really of no fundamental importance, because it has unwittingly reversed the true sequential order of the causal nexus. If cells of nearly every sort are capable, under appropriate conditions of living indefinitely in undiminished vigor, and cytological normality, there is little ground for postulating that the observed senescent changes in these cells while in the body, such as those described by Minot and others, are expressive of specific and inherent mortal processes going on in the cells, or that these cellular processes are the *cause* of senescence, as Minot has concluded. It would rather appear that these visible cytological changes are expressive of effects not causes, and that they are the effects of the organization of the body as a whole as a system of mutually dependent parts, and not of specific, inherent and inevitable cellular processes.

Cells in culture *in vitro*, as we have seen, do not grow old. We see none of the characteristic senescent changes in them. From these facts it is a logically cogent induction to infer that when cells show the characteristic senescent changes, which were discussed in the preceding paper, it is because they are reflecting in their morphology and physiology a consequence of their mutually dependent association in the body as a whole, and not any necessary progressive process inherent in themselves. In other words we may justifiably, in the light of our present knowledge as I believe, regard *senescence as an attribute of the multicellular body as a whole,* consequent upon its scheme of morphologic and dynamic organization. This attribute is reflected morphologically in the component cells. But it does not originate in the cells, nor does it ever occur in the cells when they are removed from the mutually dependent relationship of the organized body as a whole. In short senescence is not a primary attribute of the physiological economy of cells as such.

If this conception of the phenomenon of senescence is correct in its main features, as I believe it is, it shows the essential futility of attempting to investigate its causes by purely cytological methods. On the other hand, by clearing away the unessential elements, it indicates where research into the problem of causation of senescence may be profitable.

MOTION PICTURES AND CRIME

By Dr. A. T. POFFENBERGER
COLUMBIA UNIVERSITY, NEW YORK CITY

ONE of the surprising things about the wave of crime which is reported to be raging throughout the country is the large number of very young persons found implicated in crimes of all sorts. Much attention has recently been given to the matter in newspaper articles and editorials, and blame is placed rather frequently upon the motion picture. Various sorts of censorship have been proposed, most of them drastic in form. The following article taken from a recent issue of the New York *Times* will serve as an illustration:

> Motion pictures portraying criminals at work have been barred in———. Chief of Police ——— announced today that three weeks ago he had given orders to movie censors not to issue permits for any screen drama that showed a crime committed, even though the end of the picture might show the criminal in a prison cell.
>
> "It will make no difference whether the criminal shown is a hero or a villain," said the chief. "Even the showing of a policeman disguised as a burglar is taboo."
>
> The order became public when three youthful robbers, who were sentenced to the State Reformatory, said their crimes had been inspired by a "crook" moving picture.

Prohibitions and censorships of any sort are distasteful to the American people, except in cases where the general welfare can be proved to be at stake. Therefore an inquiry into the accusations that have been made against the motion picture seems justified at this time when attention is being centered upon the means of crime prevention. The question is a psychological one, and concerns the effects of motion picture experience upon the mind of the young person. The average adult can not interpret the reactions of a child in terms of his own reactions, because there are fundamental differences between the two. A knowledge of child psychology is needed to understand what the motion picture means to the child.

As an agent of publicity, with its immense daily audience of young people, it has great possibilities for creating and developing in them a spirit of true Americanism, a respect for law and social order which are recognized as essentials for a democracy. Rightly used, the motion picture is indeed one of the most powerful educational forces of the twentieth century. Its possible influence in the Americanization of our foreign population, through a medium which shall be intelligible to all, regardless of race, is scarcely yet realized. But wrongly used and not carefully guarded, it might easily become a training school for anti-Americanism, immorality and disregard for law—a condition in which each individual is a law unto himself. We have therefore, in a sense, to meet an emergency, to begin in time to make of this truly public school the kind of educational force that it should be—to prevent rather than to prohibit.

In a consideration of the young, we must not fail to include that great class of unfortunates designated as the mentally deficient. They are individuals, who, though physically and chronologically adults, are still children mentally. The problem of the mentally retarded individual is essentially the same as that of the normal person of younger years. The moron, the highest type of the feeble-minded, usually defined as an individual whose mental development has ceased at about the age of eleven years, has most of the mental traits of the child of eleven years. He has, however, the physical strength, instincts and desires of the adult. The moron is seldom confined in an institution, because his defects are not considered by family and friends as great enough for that. As a result, this type of individual is at large, and must be protected from evil suggestions and from too complex an environment. Such persons, when the higher forms of control which they lack are supplied by guardians or are made unnecessary by simplified living conditions, may well become useful and self-supporting members of society. Without this control, they constitute a real danger, since their physical age, which may be from fifteen years up, places them in a position to act upon evil suggestions more readily than the child.

What, then, are the mental characteristics of these two groups, children and mentally deficient adults, which mark them off from normal adults?

One respect in which they differ from the adult is in suggestibility; another is the lack of ability to foresee and to weigh the consequences for self and others of different kinds of behavior; another is the lack of capacity and willingness to exercise self-restraint; and still another is an imagination less controlled and checked by reference to the realities. All these traits taken together make the child and the mentally deficient person especially susceptible to evil influences. That is why one expects the majority of certain kinds of crimes to be committed by persons of retarded mental development. And recent statistical studies of the relation between crime and mental defect confirm the expectation. One needs only to recall the epidemics of suicide and murder by such means as cyanide of potasium, chloride of mercury, carbolic acid and the like; to notice the likenesses in the technique of burglars at different periods of time; to note the cases of false testimony in court and false confessions of crime to realize the great suggestibility of such persons and their lack of foresight. Unlike the normal adult, they are unable to resist the suggestions of advertisements, posters, newspapers and magazines, and of their associates. Naturally, these traits may be played upon either for good or evil. One who knows the mechanism of suggestion would expect the prevalence of crime, especially when it is advertised by these agencies of publicity, to breed more crime.

Motion pictures, containing scenes vividly portraying defiance of law and crimes of all degrees, may by an ending which shows the criminal brought to justice and the victory of the right, carry a moral to the intelligent adult; but that which impresses the mind of the mentally young and colors their imagination is the excitement and bravado accompanying the criminal act, while the moral goes unheeded. Their minds can not logically reach the conclusion to which the chain of circumstances will drive the normal adult. A little questioning of such persons who attend moving pictures and read stories will indicate how different are the factors which impress their minds, from those which impress the intelligent adult. This failure to grasp the significance of the story is even more pronounced when it is conveyed only by the posters advertising it. Here it seems to be the rule to portray only the most glaring and exciting portion of the plot with no possibility of right interpretation. A survey of any group of posters advertising motion pictures, with only their direct appeal in mind, will show a surprisingly large portion of them suggesting murder, burglary, violence or crime of some sort. The pistol seems to be one of the commonest of the stage properties of the motion picture advertisement. And a very frequent pose is that of the frenzy of rage and the clenched fist ready to strike a blow. Those young people and even adults who are limited to the advertising posters for their entertainment may get evil and anti-social suggestions from them. Considering the almost unlimited audiences which the advertising posters command, their careful control would seem a greater necessity even than that of the play itself.

It is just on account of this susceptibility to suggestion that the mentally retarded criminal and the child criminal need a special kind of treatment and special courts to handle their cases. Indeed, much has been done in recent years toward the proper treatment of these two classes of criminals. What needs most emphasis now, however, is prevention, not cure. Proper control of their environment is the one factor which will do much to make of these two classes respectable members of society instead of criminals.

There are many sources of evil suggestions which can not be eliminated, so long as there are immoral and anti-social persons, and to that extent the atmosphere in which children develop and the feeble-minded live, must remain far below the ideal. But that is a good reason why those evils which can be eliminated should be. Such organs of publicity as moving pictures, newspapers, magazines, advertising posters and the like, should not be allowed to contribute to the necessary burden of evil suggestion by the character of their productions. The purely commercial spirit should be tempered by a spirit of social welfare and education.

The matters here discussed have not entirely escaped attention hitherto. For instance, there was introduced, some time ago, into the New York State legislature a bill providing for the limitation by newspapers of the publicity which may be given to reports of crime. The width and height of headlines for such material was specified. The nature of these provisions does not especially concern us here, but the fact that the matter is receiving attention is interesting.

These are preventive measures applied from the outside. The remedy should come from within. It can be done, and in fact has been done by newspapers. A survey, recently made of a large number of metropolitan newspapers, shows that they differ strikingly in the way they handle reports of crime. In some cases crimes are not featured in big headlines and favored positions, and only facts that the reading public can profit by knowing are printed. If the motion picture is to become the educational force that it is capable of becoming, the censorship must be an internal one. The old notion is outworn that it is necessary "to give the people what they want." It is the function of an educational medium and an entertaining medium also, to give the public what they should have, in order that they may learn to want it. The function of education is to create as well as to satisfy wants. The future of the motion picture is limited only by the foresight of its leaders.

AN ITALIAN BOOK ON EMPEDOCLES

By JONATHAN WRIGHT, M. D.
PLEASANTVILLE, N. Y.

THE recent appearance of an Italian book* on Empedocles emphasizes the growing conviction among historians of science that this almost mythical figure not alone furnishes us with a tie that binds the birth of science with magic, but that the fragments of his verse contain the germs from which sprang much of the subsequent medicine and not a little of the physics of the later Greeks. It also illustrates how impossible it is, even in a treatise of some six or seven hundred pages, to give any coherent account of him. Almost every line of the one hundred and fifty odd fragments lends itself to comment, but the comments of modern critics diverge into paths leading into fields of science, religion, medicine, poetry—all now quite remote from one another, but very much less so when the ancient commentators recorded his sayings and their criticisms on them in the "testimonials," Bignone calls them, ninety-eight in number, which the industry of German and Italian authors have assembled for us. To one interested as I have been in this ancient Sicilian of the old Magna Graecia the book, which I suppose from the mischance of war has been long in falling into my hands, is a veritable mine. Several of my essays on Empedocles have found their way into various journals of more recent issue. Nevertheless this book of the modern Italian cult of the history of science tempts me again to venture, under the veil of reviewing it, to say something of its subject, despite the impossibility of avoiding some repetition even of matter published in this journal.

In the review of a book the lack of coherency can be more readily pardoned than in an essay even on Empedocles, since in one there must be at least a leading thread of interest that binds disparate parts together, while in the other the writer is licensed to pick here and there subjects for his desultory converse with his readers. This is a privilege to be cherished when one has to deal with a personality of striking interest and at the same time with trends of thought which diverge so widely in modern time as does that of this citizen of Agrigentum, whose mouldering walls have been levelled in the dust of twenty-four centuries. Incoherence in the review of a necessarily incoherent book on the fragments of two poems as old as the Carthaginian invasion which levelled them can hardly be unexpected, but it can be avoided somewhat by omissions supplied to some extent

*Bignone, Ettore: I Poeti Filosophi della Grecia Vol. II. Empedocle Torino 1916.

in what I have previously written. When the reader comes to realize how the phrases preserved to us lead us off into the most distant, the deepest and the most exalted, realms of thought and yet often perceives that much which floats on the surface is really the froth of the human intellect, blind alleys of the mind and not a film on the surface which hides sunken treasures below, he must thereby be aware that we are in the infancy of intellectual development. Germs of mighty things, too, lie hidden in a chaos of confused activities of the mind, in a welter of striving after the truth which are scarcely more than instincts and impulses, but which have after all led nascent civilizations to their destiny.

I give the plural form to civilization, because the Greek civilization, which sprang up like a mushroom during the next generation, in the foot tracks of Empedocles, and his fellows, was not the only sprout from the germs that lay hidden in their thoughts. His genius was not altogether Greek, perhaps not essentially Greek at all, it is pointed out. The youth of the modern world was his epoch. He initiated tendencies, subsequently renewed by others, it is true, but his own cultural ancestry was Greek and Hindu fused into one. He animated not only the medicine of Hippocrates, but the sublime imaginings of the Neo-Platonists[1] and the industry of the Arabian successors of Alexandrian science, though on reference to Clement of Alexandria[2] I see no reason why Bignone should think from the text he looked on him with a benignity he was unaccustomed to accord to science, due to the declaration of Empedocles that he distrusted the evidences of sense. He was an orientalist and a westerner, a mystic and a man of science. In a world of autocracy he belonged to democracy. His thaumaturgy and his grovelling before a crowd were a part of it. Much of the philosophy of the Greeks after Aristotle came from the all but forgotten subterranean springs of Alcmaeon and Empedocles. His inspiration, for the most part unrecognized, of Alexandrian mysticism, flowing through Plato, found and made fertile the arid sands of Africa in which his own intellectuality had its origin. His affiliation, as I have pointed out before this Italian book came under my observation, was Egyptian. Sicily was the stepping stone from Carthage across the Mediterranean to the European continent. We see the stamp of the African on the face of immigrants from Sicily and lower Italy today, as they step on the wharves of Ellis Island.

We dimly see in the records, perhaps, his leanings to democracy but we observe the whisperings of oriental plotting, the silence of fear in the face of oriental despotism. His revolt, if such it was, in the interests of the people, was an oriental revolt. It was African. It is

[1]Whittaker, Thomas: The Neo-Platonists, 2nd ed. 1918. Cambridge University Press.

[2]Clement of Alexandria, transl. by G. W. Butterworth, Loeb Classics. Putnams 1919, pp. 55 and 145.

told that at a banquet given by the new democratic reform government of Agrigentum, already suspected of reactionary tendencies, Empedocles took note the people were not served with drink. Angered he told the waiters to pour wine for the common people, but they said they must wait for the magistrate of the council. When the latter arrived he was made king of the feast and set up a tyrannical rule saying they *must* drink and if any disobeyed wine should be poured on their heads. Empedocles did not breathe a word, but the next day, in his capacity of judge in the courts, he condemned to death both the arrogant bureaucrat and the chief under whom he served. The incident is rather mutilated in the telling, but it seems to bear the marks not only of a drunken brawl but of an oriental conspiracy. In some such way as this, quoted in the laconic language of Diogenes Laertius from the Sicilian historian, Timaeus, he began his revolt. He may have been the "champion of civil liberty," in the phrase of a modern Italian patriot, but some of us westerners wonder a little how a trivial affront could be magnified into a revolution which overthrew the government of a city of eighty thousand souls. We have to imagine the hidden undercurrents of discontent and suspicion and of fear that the Carthaginians were soon to come again as invaders, as indeed they did. For Agrigentum arose and flourished between one African invasion and another a century or two later. Quickly after the repulse of the first one, the fertile hinterland of Sicily poured its riches into the seaport and the commerce which enriched Agrigentum made her luxury and prodigality a byword of the Sicilian coast and the neighboring shores of Italy and reached the ears of the poverty stricken peasants of Greece itself. Sicily was the Eldorado, the California of the nascent civilization of Greece—and its grave, we may say, after reading the thrilling pages of Thucydides' account of the Sicilian expedition in which perished the flower of Athenian youth and her power, but we are still nearly a hundred years before that tragic event. Agrigentum survived it for a few years and was then overwhelmed herself by the Carthaginians, but the motive at the bottom of the Athenian venture—and probably of the Carthaginian also—was plunder. It had been told Agrigentum plutocrats were accustomed at festivals to stand in the highways and invite pleasing travelers to their hospitality. The foreigners had heard doubtless the funny story of the drunken revel when the banquet room reeled so in the sight of the feasters they thought they were in a bark tossed by stormy waves. To lighten ship the wine sick crew threw the goblets and platters and cushions out of the window. It is said of Plato, but it probably was some one else, when he came to visit Agrigentum, that he remarked: "They glut themselves with sensual pleasures as though they expect to die tomorrow and build their palaces as though they expect to live forever."

This was the environment of Empedocles. He was the product of ancient riches and had the time for culture which an opulent, even a sordid, environment gives to its fortunate ones, and we find it quite natural that he should be bitten by "parlor socialism." We indulge in a little doubt if he took the long chance in carrying out such ideas, but that is modern cynicism. It may have been different then. Very likely the paths of commerce over which had flowed the wealth of his family also brought to him as to the modern man of leisure the culture of the East. Doubtless it was thus the influences of the ancient civilizations, more than his own possibly extended travels, were exerted upon him, but there was an indigenous source of his mysticism, at least, which was less directly derived from the other continents that border the middle sea. Orpheus is but a name, scarcely more than legend, but he stands as a symbol in the history of Ancient Greece representing a psychological fragment of the life of a people, yet having a profound influence upon the mysticism and the philosophy which marked them and gave them a hue only occasionally visible at the period of their greatest glory. Later it sprang into prominence in the neo-Platonic philosophy and became assimilated to the religion of Christ. Just as we are able to perceive that the mysticism of the East always remained, at least in its essence, a heterogeneous element in the philosophy of the Periclean Greeks, so we perceive that the Orphic spirit, the yearning after immortality, the clinging to the supernatural is submitted in the dialogues of Plato to a searching analysis by Socrates which it has never received at the hands of Christian exegetists. Before them there had been no discussion of the immortality of the soul. Unquestioning faith in matters devoid of rational support was unknown to the intellectual processes of the Greeks of the golden age. The defiance of the Christian mysticism which declared belief in the miracle because it was impossible, would be incomprehensible in the personages of the Platonic dialogues. It is unknown to Plato no less than to Hippocrates and Aristotle, but Empedocles imagined a time when the universe was governed by physical laws unknown to our cosmology and Huxley, the modern rationalist and archmaterialist, declined to assert that our present knowledge is sufficient to lend any force to the assertion that nothing has ever happened outside the domain of natural law. We get traces of Orphic mysticism in Pindar and in Hesiod. In the theogony of the latter we can perceive the marks of Egyptian and Mesopotamian influence or that of the brown people who once filled the basin of the Mediterranean. How far either of these currents made up the stream of Orphism is not very clear. We can not help suspecting that Orpheus and the Thracian poets or rhapsodes are figures we see in a blurred way through the veil which hides the ancient Mycenian culture of letters, if there was one, from us. At any rate what is a mere trace in Pindar and in the still earlier Hesiod we find more pronounced not only in the fragments of his lustral poem but in those of the verses on cosmic philosophy by Empedocles.

In both of these hints of his relationship with the Pythagoreans seem very insistent, but how much the teachings of Pythagoras owe to a chthonic Orpheus and how much they owe to the curricula of the temples of Sais and Letopolis, how much is native Greek, how much is imported Egyptian, how much is a heritage from the peoples who antedated the supposed irruption from the north is still a question for Evans and the archeologists of the Aegean civilization. It is supposed to be Pythagoras to whom Empedocles alludes as a man of superhuman wisdom, of great prophetic power and vast mortal knowledge (frag. 129). Empedocles was born (492 B. C.?) probably not long after the death of Pythagoras and Alcmaeon, from the latter of whom Empedocles is supposed to have derived much of his philosophy, especially his medicine, is thought to have been a cautious follower of Pythagoras and, perhaps in his youth, a personal one. Empedocles, Pythagoras and Democritus, according to Philolaos, belonged among the Magi. This item of information is not specifically in accord with other testimony, but we have no knowledge how far into Greece the doctrine of the Persians penetrated during the domination of their empire in the Mediterranean. The term Magi was then doubtless interchangeable with that of philospher in our sense, but Pythagoras and Empedocles are not commonly spoken of as Magi. Democritus however and his father were on good terms with Xerxes and they were intimately associated at the time of the great invasion with the Magi who followed in the wake of the Persian myriads. It is in those of Pythagoras and Empedocles rather than in the traditions of Democritus that we surmise the influences of the Zoroastrians.

I should like to dwell on the excellence of the versification of Empedocles, to which Symonds[3] has paid tribute. Bignone hardly alludes to it and I am too lame in my Greek leg, at best, and all but helpless in the archaic and mutilated lines of Empedocles. Aristotle makes the rather paradoxical remark that he resembled Homer only in the metrical form of his poems, and one hardly knows whether to take that for a compliment or not.

I have emphasized the mystic side of the multiform legends of Empedocles, in spite of the fact it is not so clearly brought out as would seem helpful in the monograph I am taking for a text. Of all the activities of the mind affiliated with the earliest scientific thought, medicine can least afford to be blind to that side of it in the history of science. That is par excellence the *fons et origo* of its being. Modern commentators frequently refuse the name of science to medicine, but as we recede into the mists that hide its source, the one thing

[3]Symonds, John. Addington; Studies of the Greek poets, 2 vols. London. Block. 1902.

that looms up to us in absolute reality, though in uncertain outline, is the fact that science and medicine were indissoluble only when they were permeated with mysticism and a part of religion. Empedocles was a pupil of Parmenides at Elea and it is clear that he absorbed the ideas of the earlier Nature Philosophers, especially those of Heraclitus, but he was a poet as well as a philosopher; he was a conjuror who called the dead to life, a wizard with a tendency to pomp and parade and a flaunting of purple garments before the people, shod with brazen, some say golden, sandals. Like the Nigger Jim, when he confided to Huck that he "knowed most everything," he assured his favorite disciple, Pausanias, in solemn flowing verse that he knew about all there was to be known, about medicine especially, and was ready to impart all that mortal man could understand to any seeker of knowledge. Despite disclaimers of the more sophisticated, who know such things don't look well in cold print, one occasionally encounters such exalted and nave notions of the omniscience of modern science. One who has contributed much to it I once heard remark that the causes of about all disease are now known, so that unfortunately there was not much left for an anxious researcher to do in that direction. Alexander weeping for other worlds to conquer was also among the mourners. We see how natural it was for the pantheistic Empedocles, the thaumaturge and the mystic, to declare that in the final analysis prophets become poets and physicians.

He was by virtue of this primitive communing of man with nature, the first to question nature in all its comprehensiveness by any rational and experimental method and, as has been said, his theories, though frequently disputed and confuted, became the heritage of the ages that followed him. He was the first to introduce into Greek physics the idea of a force which operates on matter. For him it was not only the latter which occupied space, but the attributes of matter themselves, inclusive of the motive forces of attraction and repulsion, or as he symbolized them, Love and Hate. They had not only extension in space but consciousness. Indeed if God is force and not a neo-Platonic god above both force and matter, there is no denying this to modern theists. All ancient Greek philosophers confounded consciousness with knowledge. This Empedocles insisted upon. To deny it we are at once betrayed into hair-splitting verbal differentiations and we have to close the discussion by declaring that at least a discrimination is necessary in the analysis of phenomena and if the mystic says he knows a thing because of his consciousness alone he lays claim to powers we rationalists have no conception of and he also readily drifts also into the attitude of the Nigger Jim. Yet since we have to assume the existence of time and space from the same necessity, its metaphysical and irrational quality is no refutation of a consciousness which goes beyond knowledge. Modern science can no more get away from the unknowable, if it wishes to advance, than religion can. It can no more afford to ignore it than religion can ignore knowledge. The one must wrest the knowable from the unknown and the other can not recede entirely into the unknowable without disappearing altogether. This was better understood by ancient philosophers than by modern scientists for they were in closer contact with the idea of primitive man that the soul is just like other matter. It was all soul or all matter for him. Even for Locke the soul was a substance, but Pythagoras saw souls dancing in the sunbeam. It would have been of no use for a modern physicist to tell an ancient Egyptian that they are small aggregates of molecules, corpuscles of real matter intercepting and reflecting light. The Pythagorean would have said, "Certainly, why not?" We have gone a little further and have divided and subdivided these "souls" and have found them loaded with energy, made up wholly of energy, something very much like "force" indeed. So Empedocles, in separating force from matter, yes, even in being a pluralist instead of a monist, in leaning towards a tetrad of elements, instead of frankly accepting the view of Heraclitus and Parmenides that they are but mutations of a single thing, force, energy if you will; in this attitude Empedocles lay athwart the current of ancient thought, just as there are some physicists today who refuse to accept a pure monism. We would never have been anywhere in science if this revolt had *not* stemmed the precipitation of ancient logic. It was necessary for practical reasons, for analysis, for foreshortening the field of cosmic facts, for luring the investigator on to the incidental discovery of some of them, to believe in a false theory. A multiplicity of material elements, like a multiplicity of souls, was necessary to the human mind to account for phenomena until it had behind it the heritage of ten thousand years of thought. Most knowledge was arrived at in this way, built up from scaffoldings of erroneous theory. It is only occasionally that any such structure preserves such substantial parts as the atomic theory, but the very name of it, indivisibility, we have nullified in splitting the atom. Aristotle declared Empedocles grouped together with the elements his two forces, Love and Hate, and Bignone finds authority that thus he was sometimes credited with making six elements, but Aristotle says there were thus logically but two because he placed them and the other elements in apposition to one another—force and matter. We would say this makes him a dualist and keeps him still in court in modern times.

Empedocles was no less a philosopher, but too much of a poet, when he called the oceans the sweat of the earth, yet it must have been a comfort to his disciples, still clinging to the mutational doctrines of the monists. He recognized there was sweet water in the sea and it is not at all certain that Aristotle[1] was not describing in a faulty manner an experiment of Empedocles instead of having performed it himself when he asserted that if anyone will make a thin *waxen* flask, cork it, and sink it empty in the sea, in a night and a day it may be taken up full of water which is drinkable. He recommends the wrong (?) material for the flask, it would seem, but it is quite in line with the klepsydra experiment of Empedocles which Aristotle ascribes to him. I am avoiding further reference to Empedocles as an experimentalist, for to that I have already referred elsewhere, but he was as well an observer of facts, spread around him in the volcanic regions of the Mediterranean, for he recognized the igneous origin of some rocks and the aquaeous origin of others. If we thus get a glimpse of geology we turn to his idea of the sphere and we get one of geometry and find in it the origin perhaps of the Ptolemaic astronomy, much obscured it is true by mysticism and metaphysics, but essentially similar. The mystic part of it is said to have been Eleatic philosophy and we find that element of it again in Plato. The Pythagorean flavor of it is however apparent. Geometrically the sphere is a solid body, but mystically it is a divine, because a perfect, body inasmuch as it is of a mass the greatest, in proportion to its extent of periphery, of any possible geometric figure. Plato reasoned thus and it is probable that it was this geometric thought, "of a sphere, round, equal in everything to its own self," which led Empedocles to choose that form as the figure of God, the first gleam we get from a deist of a conception which is not anthropomorphic. Whether this identifies God with the universe itself I do not clearly understand, but it seems very probable that this was a pantheism worked out in details and carried to its logical conclusion. In a sphere turning around the earth he set the fixed stars like gems in a bracelet, but the planets were free and he looked upon the moon as torn off from the sun, which itself is the reflection of the fire of the whole universe. The testimony of doxographers as to these details of Empedocles' astronomy are confusing and contradictory, perhaps tinctured, some of them, with the later Ptolemaic formulas, and it is difficult to say how far he went in this scheme, but Aetius speaks of his view that the pole of the earth was inclined, presumably obliquely to the plane in which the sun performed its revolutions around it (?) in the revolving sphere. Like Thales he understood the nature of the lunar eclipses.

Now the space between the heavenly bodies he thought filled with demons and this belief is also ascribed to Thales by Laertius Diogenes. To my mind this is another significant hint they both had their astronomy direct from Babylon where the imaginations of the inhabitants filled the air they breathed with them, and all circumambient space. It is a heterogeneous pantheism but a logical one, the conception of spirits instead of a spirit pervading all. If a void or a vacuum or non-being, is as real a thing as being or matter, then the

[4]Aristotle: History of Animals, Lib. VIII, Cap. 3. II. Bohn, p. 198.

spirits become more mystical still for all but the Eleatics.

We see the pantheism of the atmosphere more primitive men breathed, though the experiments of Dr. Bose of late years, himself an orientalist, but confirms the assertion of Empedocles, twenty-five hundred years ago, that plants like all nature are endowed with sensibility and give responses to their environment, which are easily recognized by the comparatively modest extension technical art has given to man's senses. The physicists are now teaching us that the earth itself is constantly shifting its mass. For Empedocles like the plants and animals it breathes and sweats. It is not chiefly because Dr. Bose and Empedocles are orientalists and were penetrated deeply by ancient pantheism, though that at least gave direction to the earlier thinkers. thoughts. It is because the conclusions of Empedocles, however arrived at, contain the germs of truth in rich abundance. It was not orientalism which established the reality of the "emanations" of nature, essential in the belief of primitive man and carrying Empedocles to unverifiable and absurd deductions, it was the revelations of occidental science of that very spirit, spirits if you are a pluralist, that lies at the bottom of primitive pantheism. The theory of sight which Empedocles constructed, so irreconcilable with facts both ancient and modern, rested upon corpuscles (electrons) flying from the object to the eye, though in his view those that fly from the eye to the object were quite as important and given more prominence in his fragment on vision and the anatomy of the eye as recorded by Aristotle. Gomperz sees in his theory of the apperception of the senses, which worked through different sized and different shaped pores by selecting the fit from variously proportioned flying molecules, the counterpart of the childish theory of Ehrlich, which so captivated the imagination of American laboratories before the war, and which has been so helpful to us in serology, though such an ancient theory supported by such a modern theory has no claim to reality. But is it chance, which by the way Empedocles regarded paradoxically as the result of the action of certain laws of chaos, is it "chance" which directed two groping minds, twenty-five hundred years apart, into like channels of mental progress?

The doctrine of Spencer, an internal homogeneity becoming external heterogeneity, in the course of evolution, had its counterpart in the philosophy of the old Sicilian, though he apparently was haunted by the thought that there comes a time when the process is reversed and out of heterogeneity homogeneity again springs. Indeed it seems impossible to preserve the indestructibility of energy or matter in stellar space, unless we conceive of some cold storage for the flying emanations until they are again warmed into life, as Very[5] realizes in drawing attention to the wastage of stellar substance.

[5]Very, F. W. The Wasting of Stellar Substance. Scientia, 1-IV-1920.

PERFECT AND AMICABLE NUMBERS

By Professor L. E. DICKSON
UNIVERSITY OF CHICAGO

THE two types of numbers in our title have had a continuous history extending from the early Greeks to date, and may be justly called the most human of all numbers. To them were early attributed certain social qualities, and later also ethical import, while mystics of the middle ages believed that they possessed special powers as talismans. Continuously for twenty centuries a wide-spread interest has been taken in the purely numerical questions and puzzle problems which arose in the study of these remarkable numbers. We shall present here the more essential facts and fancies in the quaint history of these most human of all numbers.

A perfect number is one which equals the sum of its aliquot divisors, i. e., divisors which are less than the number itself. Thus 6 is a perfect number, being equal to the sum of 1, 2 and 3. The Pythagoreans called the perfect number 6 marriage "on account of the integrity of its parts and the agreement existing in it." In his *De Nuptiis Philologiae,* Martiano Capella stated that the perfect number 6 is attributed to Venus; for, it is made by the union of the two sexes, that is from triad, which is male since it is odd, and from diad, which is feminine since it is even.

To understand a later allusion, we need the definitions given by Nicomachus (about 100 A. D.) that 12 is an abundant number since the sum 16 of its aliquot divisors exceeds 12, while 8 is a deficient number since the sum 7 of its aliquot divisors is less than 8. He remarked that perfect numbers are between excess and deficiency, as consonant sound between acuter and graver sounds. In his *De Civitate Dei,* Aurelius Augustinus (354-430 A. D.) remarked that, 6 being the first perfect number, God effected the creation in 6 days rather than at once, since the perfection of the work is signified by the number 6. Alcuin (735-804), of York and Tours, added the remark that the second origin of the human race arose from the deficient number 8; indeed, in Noah's ark there were 8 souls from which sprung the entire human race, showing that the second origin was more imperfect than the first, which was made according to the perfect number 6. Rabbi Josef b. Jehuda Ankin, at the end of the twelfth century, recommended the study of perfect numbers in the program of education laid out in his book *Healing of Souls.* We shall return presently to the history of the arithmetical study of perfect numbers.

Two numbers, like 220 and 284, are called amicable if each equals the sum of the aliquot divisors of the other. Iamblichus states that Pythagoras remarked that the aliquot parts [divisors] of each of the numbers 220 and 284 have the power to generate the other, according to the rule of friendship; and that, when asked what is a friend, he replied "another I," which is shown in these numbers. According to Rau Nachshon (ninth century A. D.), Jacob prepared wisely his present to Esau of 200 she-goats and 20 he-goats, 200 ewes and 20 rams (Genesis, xxxii, 14), since this number 220 of goats is a hidden secret, being one of a pair of numbers such that the parts of it are equal to the other one 284, and conversely; and Jacob had this in mind; this has been tried by the ancients in securing the love of kings and dignatories.

Ibn Khaldoun related that "persons who have concerned themselves with talismans affirm that the amicable numbers 220 and 284 have an influence to establish a union or close friendship between two individuals. To this end a theme is prepared for each individual, one during the ascendency of Venus, when that planet is in its exaltation and presents to the moon an aspect of love or benevolence; for the second theme, the ascendency should be in the seventh. On each of the themes is written one of the specified numbers, the greater being attributed to the person whose friendship is sought." The Arab el-Magriti of Madrid (who died in 1007) related that he had put to the test the erotic effect of "giving anyone the smaller number 220 to eat, and himself eating the larger number 284."

The writer verified a few years ago that the only pairs of amicable numbers in which the smaller number does not exceed 6232 are 220 and 284, 1184 and 1210, 2620 and 2924, 5020 and 5564, 6232 and 6368. The second pair was discovered in 1866 by N. Paganini at the age of 16. It was missed by Euler, who in 1750 made the chief investigation of amicable numbers and listed 62 pairs. It would be easy, but not very interesting, to obtain further pairs, by the methods explained by Euler, by employing a table of prime numbers extending beyond the limit 100,000 of the table accessible to him. A prime number is one, like 2, 3, 5, 7, 11, which has no divisor other than itself and unity.

Let us return to perfect numbers and consider the main facts in their arithmetical history. We shall write 2^3 for 8 and 2^p for the product of p factors 2.

In his famous Greek text on geometry, Euclid proved that $2^{p-1}(2^p-1)$ is a perfect number if 2^p-1 is a prime. For $p=2, 3, 5, 7$, the values of 2^p-1 are 3, 7, 31, 127, which are all primes, so that 6, 28, 496 and 8126 are perfect numbers. These four numbers were mentioned explicitly by Nicomachus, who noted that they are the only perfect numbers in the respective intervals between 1, 10, 100, 1000 and 10,000. The last fact was twisted by Iamblichus (about 283-330 A. D.) and many later writers into the erroneous conclusion that there exists one and only one perfect number between any two successive powers of 10.

The fifth perfect number 33,550,336 was first given in 1456 in the manuscript Codex lat. Monacensis 14908; it corresponds to the value 13 of p in Euclid's formula. Many writers listed false perfect numbers, due to their belief that 2^p-1 is a prime for every value of p which is odd (i. e., not even). But Regius, in his Arithmetic printed at Strasbourg in 1536, noted that $2^9-1=511=7\cdot 73$ and $2^{11}-1=2047=23\cdot 89$ are not primes, while $2^{13}-1=8191$ is a prime and leads to the above fifth perfect number.

Cataldi, who founded at Bologna the most ancient known academy of mathematics, verified in 1603 that $2^{17}-1=131{,}071$ and $2^{19}-1$ are primes by the unnecessarily laborious work of trying as possible divisors each prime less than their respective square roots. He therefore concluded correctly that the sixth and seventh perfect numbers are $2^{16}(2^{17}-1)=8{,}589{,}869{,}056$ and $2^{18}(2^{19}-1)$. But he stated erroneously that 2^p-1 is a prime when $p=23$, 29 and 37. In fact, Fermat noted in 1640 that $2^{23}-1$ has the factor 47, and $2^{37}-1$ the factor 223, while Euler observed in 1732 that $2^{29}-1$ has the factor 1103. These errors cast doubt on the validity of Cataldi's claim that $2^{31}-1$ is a prime.

Fermat, who was a member of the parliament of Toulouse and an arithmetician of the highest ability, stated in 1640 the important fact that if p is a prime, 2^p-1 is divisible by no primes other than those of the form $2\,k\,p+1$. Hence if $2^{31}-1$ were not a prime each of its prime factors would be of the form of $62k+1$, so that it is unnecessary to consider most of the trial divisors tested by Cataldi. We shall see below that Euler knew a general principle which eliminates half of the trial divisors required by Fermat's rule. Closely related to all these facts is the second proposition stated by Fermat that, if q is an odd prime, $2^{q-1}-1$ is divisible by q, and his generalization that if q is any prime and n is any whole number not divisible by q, then $n^{q-1}-1$ is divisible by q. This result, which is the basis of the modern theory of numbers, is known as Fermat's theorem.

Mersenne, who acted as intermediary in the extensive correspondence between Fermat, Frenicle, Descartes, and other expert arithmeticians, quoted various arithmetical results due to them in his curious books, *Harmonie Universelle*, *Cogitata Physico Mathematica*, etc., published in 1634-1647. But when he made the oft-quoted statement that the first eleven perfect numbers are given by $2^{p-1}(2^p-1)$ for $p=2$, 3, 5, 7, 13, 17, 19, 31, 67, 127, and 257, he was relying only in part upon more modest facts communicated to him by his able correspondents, but mainly upon some unlucky personal guessing as to the hidden mystery of prime numbers. He pretended to know that the number $2^{127}-1$ of 39 figures is a prime, that the number $2^{257}-1$ (which exceeds the square of the preceding vast number) is a prime, and that all of the intermediate numbers 2^p-1 are composite,—and yet he admitted that "to tell if a given number of 15 or 20 figures is prime or not, all time would not suffice for the test, whatever use is made of what is already known." More than two centuries later it was shown that Mersenne erred at least in including $p=67$ in his list and in excluding the values 61, 89 and 107 of p. The fact that $2^{67}-1$ is composite was proved by Lucas in 1876, while its actual factors were found by Cole in 1903. The fact that $2^{61}-1$, a number of 19 figures, is a prime was proved independently by Pervusin in 1883, Seelhoff in 1886, Hudelot in 1887, and Cole in 1903. Both Powers and Fauquembergue proved in 1911-1914 that $2^{89}-1$ and $2^{107}-1$ are primes. It is not surprising that Mersenne's guesses were erroneous, but it is quite surprising that his errors have been detected, thanks to the powerful modern methods of testing whether or not 2^p-1 is a prime.

Euler, one of the greatest mathematicians of all ages, proved in 1732 that, if $p=4n-1$ and $8n-1$ are primes, 2^p-1 has the factor $8n-1$, so that 2^p-1 is not a prime when $p=11$, 23, 83, 131, 179, 191, 239, 251, etc. He noted that $2^{43}-1$ has the factor 431 and that $2^{73}-1$ has the factor 439. In 1741 he found that $2^{47}-1$ has the factor 2351, a case which had earlier deceived him. In 1772 he proved that $2^{31}-1$ is a prime. According to Fermat's result, every prime factor p is of the form $62k+1$. But p divides $2\ (2^{31}-1)=a^2-2$, where $a=2^{16}$, and Euler knew that every prime which divides any number of this form a^2-2 is of one of the forms $8n+1$, $8n+7$. Hence in $p=62k+1$, k must be of the form $4m$ or $4m+1$. Euler therefore considered only the possible prime factors of the form $248m+1$ or $248m+63$.

In 1877 Lucas proved that $A=2^{127}-1$ is a prime by a powerful new method. For so great a number (of 39 figures), it is clearly impracticable to test directly all the primes $2\cdot127\ k+1$ as possible factors, or even the half of them under Euler's simplification of Fermat's method. Instead, we use the recurring series 1, 1, 2, 3, 5, 8, 13, ----, which Leonardo Pisano had first employed in 1202 to find the number of offspring of a pair of rabbits. Each term of this series equals the sum of the preceding two terms. Write u_k for the kth term. One of Lucas's tests for primality applies to numbers having the remainder 3 or 7 when divided by 10. Since $2^5=32$ has the same remainder as 2, we may suppress multiples of 4 in the exponent of a power of 2 when finding the remainder on division by 10. Hence the remainder from our A is $2^3-1=7$. Writing $k=2^n$, Lucas verified that 127 is the least positive whole number n such that u_k is divisible by A; hence A is a prime by his test. Similar tests for primality due to Lucas were used by Fauquembergue and Powers independently in 1914-1917 to prove that $2^{89}-1$ and $2^{107}-1$ are primes and that 2^p-1 is not prime when $p=101$, 103, 109, the actual factors not being found.

The further known results are exhibited in the following table which gives the least prime factor of 2^p-1 for the various primes p, and the name of the discoverer of the factor and the date:

p	Factor	Discoverer	p	Factor	Discoverer
41	13367	Plana, 1863	151	18121	LeLasseur, 1881
53	6361	Landry, 1869	163	150287	Cunningham, 1908
59	179951	Landry, 1869	173	730753	Cunningham, 1912
71	228479	Cunningham, 1909	181	43441	Woodall, 1911
79	2687	Reuschle, 1856	197	7487	Cunningham, 1895
97	11447	LeLasseur, 1881	211	15193	LeLasseur, 1881
113	3391	Reuschle, 1856	223	18287	LeLasseur, 1881
			233	1399	Reuschle, 1856

To summarize the results quoted above, 2^p-1 is known to be composite for thirty-two of the primes $p<257$, but to be a prime and hence to lead to a perfect number $2^{p-1}(2^p-1)$ for the following twelve values: $p=2$, 3, 5, 7, 13, 17, 19, 31, 61, 89, 107, 127. Hence only the following eleven values now remain in doubt: $p=137$, 139, 149, 157, 167, 193, 199, 227, 229, 241, 257.

All that precedes relates to perfect numbers which are given by Euclid's formula $2^{p-1}(2^p-1)$. Is every perfect number of this form? In 1638 Descartes stated that he could prove that every even perfect number is given by Euclid's formula. By far the simplest proof is that published by the writer in 1910. Let $2^n q$ be an even perfect number, where q is odd. All the divisors of $2^n q$ are obtained by multiplying each of the divisors $2^n, 2^{n-1}, \ldots, 2, 1$ of 2^n by each of the divisors of q. Hence the sum of the divisors of $2^n q$ is ms, where $m=2^n+\ldots+2+1$ and s is the sum of the divisors of q. If we multiply m by $2-1$, we see that all but two terms of the product cancel, so that $m=2^{n+1}-1$. By definition, a perfect number equals the sum of all its divisors other than itself, whence

$$2^n q = ms - 2^n q, \qquad 2^{n+1} q = ms = (2^{n+1}-1)s\cdot$$

Dividing by $2^{n+1}-1$, we get $s=q+d$, where $d=q/(2^{n+1}-1)$. Thus the whole number $d=s-q$ is a divisor of q. Since the sum s of all the divisors of q reduces to $q+d$, q and d are the only divisors of q, so that $d=1$ and q is a prime. From $d=1$, we get $q=2^{n+1}-1$. Hence every even perfect number $2^n q$ is of Euclid's type.

Whether or not there exists an odd perfect number has never been decided. If one exists, it must be of the form ps^2, where p is a prime, as noted by Descartes in 1638. Frenicle observed in 1657 that p must be of the form $4n+1$. Sylvester proved in 1888 that no odd perfect number has fewer than six distinct prime factors, nor fewer than eight unless it be divisible by 3.

A multiply perfect number, like 120 or 30240, is one the sum $3\cdot120$ or $4\cdot30240$ of whose divisors equals an exact multiple of the number. Such numbers, mostly very large, were found by Mersenne, Fermat, Frenicle, and Descartes in the years 1631-1647.

To obtain an interesting generalization of both perfect and amicable numbers, let n_1 denote the sum of the divisors $< n$ of n, let n_2 denote the sum of the divisors $<n_1$ of n_1, etc. In case n is a perfect number, $n=n_1=n_2=$--, and conversely. If $n_2= n$, then n and n_1 are amicable numbers. If $n_k=n$, the chain of numbers $n, n_1, n_2,$ -- is said to be of period k. In 1913 the writer proved that there exists no chain of period 3, 4, 5 or 6 with $n<6233$, and verified for an extensive set of values of n that any non-periodic chain contains a prime, so that the next term is unity. By a more extended search, Poulet discovered in 1918 the following chain of period 5:

$$n=12496=2^4\cdot11\cdot71,\ n_1=2^4\cdot19\cdot47,\ n_2=2^4\cdot967,$$
$$n_3=2^3\cdot23\cdot79,\ n_4=2^3\cdot1783,\ n_5=n,$$

and noted that 14316 leads a chain of 28 terms.

The writer defined an amicable triple to be three numbers such that the sum of the aliquot divisors of each equals the sum of the remaining two numbers, and obtained the following two examples of amicable triples formed of distinct numbers:

$$3\cdot89b,\ 11\cdot29b,\ 359b \qquad (b=2^{14}\cdot5\cdot19\cdot31\cdot151);$$
$$293\cdot337c,\ 5\cdot16561c,\ 99371c\ (c=2^5\cdot3\cdot13).$$

Lionnet defined a perfect number of the second kind to be a number which equals the product of its aliquot divisors. But the only such numbers are p^3 and pq, where p and q are distinct primes, and the question is too simple to be amusing.

In 1657 Fermat challenged the English arithmeticians to find a cube (other than 1 and 7^3) which when increased by the sum of its aliquot divisors becomes a square. The least answer appears to be the cube of $2\cdot3\cdot5\cdot13\cdot41\cdot47$, the sum of whose divisors is the square of $2^7\cdot3^2\cdot5^2\cdot7\times 13\cdot17\cdot29$. He also demanded a square which when increased by the sum of its aliquot divisors becomes a cube; the simplest know answer is the square of $43098=2\cdot3\cdot11\cdot653$, the sum of whose divisors is the cube of $1729=7\cdot13\cdot19$. John Wallis found more complicated solutions of each problem by a very long computation.

For complete references to the literature on the present subjects see the writer's *History of the Theory of Numbers*, Carnegie Institution of Washington, Vol. I, 1919, pp. 1-58, 393-407.

CLIMATE AND HEALTH, WITH SPECIAL REFERENCE TO THE UNITED STATES[1]

By Professor ROBERT DeC. WARD
HARVARD UNIVERSITY

PRESENT VIEWS REGARDING THE RELATIONS OF CLIMATE AND HEALTH

THE modern view as to the part played by climate in relation to health is very different from that held in earlier days. The cause of most diseases was formerly sought directly in atmospheric conditions. These conditions, to state the present view very broadly, are now believed to be important in two ways. They may affect, more or less directly, the life, development and virulence of the micro-organisms which are the specific cause of disease, and they may strengthen or weaken the individual's power of resistance against the attacks of these organisms. The older views concerning the predominant and direct influence of climate have largely been replaced by the conviction that good hygiene is more important than climate alone, and that, in the matter of the influence of a change of climate as a preventive or restorative, a change of residence, habits, occupations, food, is usually of as much importance as, if not of more importance than, the actual change in atmospheric conditions. If pure air, good food, freedom from worry, time for rest, proper exercise, outdoor life and a congenial occupation are provided, many bodily and mental ailments yield to the treatment. Climate is by no means to be discarded as of no account. It affects our physical and mental condition and our bodily comfort. It may be dull, rainy and cheerless, or bright, sunny and exhilarating. It may tend to keep us indoors, or it may naturally tempt us to go out. Thus some climates are naturally avoided; others are sought out. The choice of a suitable climate must depend upon the disease to be dealt with and upon the individual concerned.

WHAT IS A GOOD CLIMATE?

What, then, is a "good climate?" This question can here be answered only in the most general way. The answer, in individual cases, must obviously depend upon a person's physical and mental condition; upon his own personal preferences, and upon the factors other than climate which should be taken into account in each special

[1]Part of a Presidential Address before the American Meteorological Society, Chicago, Ill., December 29, 1920. The writer is indebted to Dr. Guy Hinsdale, of Hot Springs, Va., for valued criticisms.

case. A "good climate" is naturally one which is favorable to the development of a sturdy race of men and women, physically strong and mentally alert. There is a pretty general agreement, among physicians, physiologists and climatologists, that, excepting those who are distinctly ill, the best climate for most people and most of the time is one which has frequent moderate weather changes; fairly marked annual and diurnal variations in temperature; a reasonable amount of cold during at least part of the year; a refreshing variety in the amount of cloudiness, and sufficient rainfall to provide enough moisture for the growth of grass and crops. Such a climate is an intermediate one. It is neither invariably hot nor permanently cold. It is neither monotonously arid and cloudless, nor always dull and rainy. It is between all extremes. The climates of much of the so-called "temperate zones" are of this general type. Their physiological effects are intermediate between those of the equatorial and those of the polar zones. They exercise the body's power of reaction and adaptation, keeping it physiologically active, and in good "working condition," without subjecting the different organs to too severe a strain.[2]

A climate which encourages people to spend the maximum possible amount of their time outdoors, in the open air, is, other things being equal, the best for the majority of men and women. Applying these general principles to the question of health, it may be stated that a health resort where a patient can find comfortable quarters, congenial company, plenty of diversion, and where favorable climatic conditions such as those above noted, with abundant sunshine, an absence of disagreeable winds and dust and of sudden marked weather changes, encourage outdoor life, is to be recommended. The climate does not necessarily and inevitably cure, but it is very often an important help in the treatment of disease. To quote Sir H. Weber, "for any given class of cases, that climate is a good one in which the qualities that would be disadvantageous are to a certain degree absent during the whole year, or at least part of the year, while the other qualities are present by the proper use of which the bodily strength is raised and the restoration of the affected organs and functions is facilitated."

Is There Any "Perfect" Climate?

In the foregoing quotation from one of the leading medical climatologists, emphasis is laid on one point concerning which there is a general and persistent misconception. "That climate is a good one," Sir H. Weber wrote, "in which the qualities that would be disadvantageous are to a certain degree absent during the whole year, or at least part of the year." In other words, a good climate has the fewest

[2]F. P. Weber and G. Hinsdale, "A System of Physiologic Therapeutics," Philadelphia, 1901, Vol. III, p. 18.

"outs," or is free from its "outs" during a portion of the year. It is often said that the climate of a certain place is "perfect" or "ideal." As a matter of fact, there is no such thing as a "perfect" climate, anywhere, or all the time. Every climate has some disagreeable features. Health resorts are never equally desirable at all seasons. It is probably safe to say that every climate has advantages of its own for some special purpose, but some climates have more, and some have fewer, disadvantages. A southern climate which has a mild and genial "winter," and therefore provides abundant opportunities for an outdoor life at that season, is likely to be too hot, or rainy, or dusty, in summer. A northern climate, which has the advantages of cool summers, is likely to be very cold and stormy and snowy in winter. A western seacoast in subtropical latitudes, with the attractions of equable temperatures, mild winters and cool summers, relatively small rainfall and few stormy days, may be too damp and too foggy for many invalids. Mountain resorts, often so useful in the treatment of lung diseases, may have the disadvantages of being too cool at night; too windy and dusty by day, or of having frequent severe local storms. "Perfect" climates, then, do not exist. In climatotherapy, which may be broadly defined as the use of climate for checking or preventing the development of disease, and for aiding the recovery of those who are ill or convalescent, the obvious course is to select a locality where the other necessary conditions, such as suitable accommodations, good food, expert medical attendance, and so on, are already provided, and where the climate has a maximum of the desired characteristics for the particular case concerned, and the minimum of undesirable features. The seeker after health whose physician orders a "change of climate" should go away expecting some conditions which are neither "perfect," nor perhaps even altogether agreeable. If a "perfect" climate is not anticipated, the inevitable lack of perfection will bring with it no disappointment. It should be remembered that any climate which is recommended by a competent physician doubtless has far more good qualities than bad ones. The utmost advantage can always be taken of the good; most of the temporary disagreeable ones can be escaped by staying indoors, and by maintaining a cheerful disposition which refuses to be overcome by an occurrence of so little importance as an occasional spell of bad weather.

No Climate is "The Only Climate" For Any Individual Case of Ill Health

In connection with this misconception regarding the existence of "perfect" climates, there is a widespread and persistent popular impression that certain climates have such special and peculiar properties of their own that there is some one particular climate which is the only one fitted for a special case of illness. If an invalid hits upon this climate, he believes that he will, beyond a doubt, regain his health.

In my own experience of a score of years I have had abundant and often very distressing opportunity to learn how widespread is this notion, and how nerve-racking, in many people's minds, the choice of this one climate becomes. I have received many letters, personal visits and even telephone calls, asking me to name that special place whose climate is the one needed in the individual case concerning which the inquiry is made. It is hardly necessary for me to say that under no circumstances do I attempt—nor should any climatologist attempt—to prescribe any climate for any specific disease. That is the responsibility of the physician. The most pathetic case which has ever come to my own attention was that described in a letter which I received a few years ago. The letter was from a physician in New York State, who had a son seriously ill with a complication of disorders. Leading specialists in New York had been consulted, but the youth was steadily growing worse, and there seemed little hope of saving his life. Evidently in depair, and as a last resort, the father, who was unknown to me even by name, wrote to me, giving me full details as to his son's illness and the previous treatment of the disease, and asked me to name the place to which the son could be taken in order to give him the benefit of whatever climate, in my judgment, would be the suitable one for that particular case. That letter revealed the whole story of the father's love for his boy; the tragedy of his despair of saving the boy's life; the grasping at a "last straw" in his writing to me as one of whom he had somehow or other heard and who might possibly give the advice which would save the son's life. What could I write in reply to that father's pathetic and despairing appeal? All I could do was to write a letter as full of human sympathy as it was possible to make it; to urge consultation with some physician who had made a specialty of climatotherapy; to point out the importance of selecting some place where every possible comfort and care could be found, and then to mention the general advantages of the winter climates of a considerable number of Southern resorts where relief from the winter cold and from the sudden and severe weather changes of New York State might be found. I need not say that I named no place as possessing the one climate which would be of most help in the curative process. The end of this story I do not know. No second letter ever came to me from that father.

This incident serves as a striking illustration of exactly what I am here trying to emphasize. Climate, as a recent writer has well put it, may "play an important part in the curative process, but the climate of certain localities does not possess any peculiar properties which act as a specific on certain diseases." Or, as another has put it, "the choice of a climate is not a nerve-racking decision the entire success of which depends upon hitting upon the one ideal climate in the whole world, but simply the selecting of one out of six or seven localities, any one of which will do all that climate can do to restore health" (Dr. Woods Hutchinson).

Local Versus General Climates

This belief that the climates of individual health resorts possess certain special local characteristics, of peculiar health-giving value, and differing essentially from the general climate of the surrounding country, is apparently largely based upon an exaggerated idea of the importance of local controls over climate. The subject of local as compared with general climates is a large one, and cannot here be adequately discussed. A few illustrations may, however, be given to indicate some typical cases.

As a whole, climates are more alike than unlike. In the Tropics, where cyclonic weather controls are characteristically absent (except in certain restricted areas and at certain special seasons), and where diurnal controls are dominant, a small district well enclosed by mountains probably comes as near to having a local climate as is possible on a land area. Here the general winds, which are the most effective agents in wiping out climatic boundaries, are excluded, and temperature, winds, cloudiness, humidity, rainfall and other elements are essentially influenced by local conditions. Over most of the "Temperate Zones," on the other hand, where cyclonic cloud and rain areas, and cyclonic winds, are the characteristic phenomena of the weather, and largely determine the character of the climates, local controls inevitably have far less influence. Examples of various degrees of local modifications of climate may be classified under three general heads: (1) extended, open, level plains, lacking bodies of water and forest cover; (2) coasts; (3) mountains. To these may perhaps be added (4) the subordinate and very local influences of forests. In the first-named districts, where the prevailing winds have free sweep, and where there are no local topographic, water or forest controls, local climates, in any real sense, cannot exist. In the second case (2), that of coasts, places on and near the seashore often have the advantage of a cooling sea-breeze on hot summer days. The effect of the water is noticed on a much larger scale, and to a far greater distance inland, when the prevailing winds, or the temporary cyclonic winds, happen to blow on-shore. The proximity of the ocean, or of large inland bodies of water like the Great Lakes, may have considerable effects not only upon temperature, but also upon cloudiness, humidity, rain and snowfall. Marine fogs are another local characteristic of some seacoasts. (3) Topography is one of the chief controls in modifying general climates. Elevated stations have certain distinguishing characteristics which, when well developed, give rise to the term "mountain climate." Altitude, as is well known, affects temperature. Mountain stations as a rule have lower temperatures than adjacent valleys and lowlands. On the other hand, on clear, quiet nights, especially in winter, "inversions of temperature" frequently give slopes and summits distinctly milder spells than those found at lower levels. Mountains and even low hills modify the direction of the winds. A range of mountains, or a single mountain, may protect places to leeward against strong winds. Cool, descending nocturnal breezes, following hot summer days, often provide comfortably refreshing nights where houses are favorably situated opposite the mouths of valleys. Proper choice of building sites, above the level of valley and lowland fogs, ensures drier air and more sunshine than are found lower down in the fog zone. Mountains offer opportunities for the development of diurnal cumulus clouds on fine summer days, and local showers and thunderstorms occur with greater frequency in mountainous country than over the surrounding lowlands. (4) Forests, although very subordinate controls of local climate, check wind velocity, serving as a protection against disagreeably strong, hot or cold winds; provide fresh, clean, pure air, very free of dust and of injurious micro-organisms; slightly lower the mean temperature and slightly increase the relative humidity. The air in pine forests has long been believed to have certain desirable soothing and healing properties, of benefit in affections of the nose, throat and lungs. It is upon such local characteristics as those here mentioned, and others like them, that many local weather prognostics and proverbs are based. Familiarity with such weather signs often gives local "weather-wise" people some advantage over an "official" forecaster at a great distance, who has only the general conditions shown on the weather map to guide him.

In these, and in other ways, general climates may locally be more or less modified. But the larger controls of the general climate persist. What are popularly believed to be special peculiar qualities of the local climates of well-known health resorts are usually in no way essentially different from the climates of hundreds or thousands of square miles of the surrounding country. The factors which are of most consequence in giving such resorts their reputation are not, therefore, the special and peculiar qualities of their *local* climates, although these may play a part, but the combination of many conditions which render these places safe, desirable and agreeable residences for invalids and for pleasure-seekers.

Factors Other Than Climate Which Determine the Popularity of Health Resorts

When, centuries ago, Hippocrates wrote "in chronic diseases it is advisable to go to another country" he doubtless had in mind the benefits to be derived not only from a change in climate but also from a change in the general environment, social, mental and physical. For it cannot be too strongly emphasized that climate is but one element in the treatment, albeit often a, or even the, most important element. In fact, so large a part do the other factors play that it is difficult, even impossible, to determine how much of the benefit of a health resort is derived from the climate, and how much from other conditions. Given a suitable climate for the particular illness in question, among the other important contributing factors are accessibility; comfortable and cheerful accommodations; an altered diet of good food; expert medical attendance and proper hygiene; a congenial social environment; outdoor attractions of beautiful scenery, opportunity for varied forms of exercise and diversion such as walks, drives, sea-bathing, outdoor sports, and the like. Rest; recreation; freedom from worry; mental and social change and relaxation, usually play an important part in the benefit derived from what is generally called merely a "change of climate," and as a rule accomplish better and quicker results than a more prolonged treatment at home. The use of suitable mineral waters, taken internally or used for bathing purposes, is another non-climatic element which, in the case of some resorts, is of predominant importance in the treatment.

The enumeration of these various non-climatic elements should by no means lead to the conclusion that climate is of no value, that there is no such thing as climatotherapy; that climatologists have no concern in this matter. Climate, it is true, is but one element in the treatment, but it is an element of great, and in most cases of paramount, importance. As has already been pointed out, atmospheric conditions are critical in that they affect the micro-organisms which are the specific causes of disease; they strengthen or weaken the individual's power of resistance; they encourage or they discourage rest and recreation out of doors, and outdoors is the best treatment of all.

The established health resorts of the United States, and of other countries, have gained their reputation because they combine, more or less completely, the complex series of factors just enumerated. They have what has well been termed "the momentum of an early start." Advertising has had, and always will have, a great deal to do with the popularity of all such resorts. So far as climate alone is concerned, there are enoromus vacant tracts in this country—in the Appalachians, in the Rocky Mountains and plateaus; on the Pacific slope—where health resorts without number could be developed with just as favorable climatic conditions as those which prevail at the resorts which are already established. But the latter now have the accommodations and the other advantages which are needed to make them popular, and therefore they have the "early start."

In what has thus far been said, the term health resorts has been exclusively used because the subject under discussion concerns itself primarily with the climatic treatment of disease. It is however, perfectly obvious that most of the so-called health resorts are also pleasure resorts, frequented by persons who are in no way ill, however much they may sometimes seek to give themselves, and others, the impression that they are so, but who are attracted by the many natural and artificial advantages which these so-called health resorts offer. There are, in reality, few places which are frequented solely by invalids. Those which belong in this group are sanitaria where special attention is paid to the treatment of certain special diseases, and where no one is admitted who is not in need of such treatment. Many places which began as health resorts have now become pleasure resorts, pure and simple. Others are rapidly going through the same change. It is, therefore, impracticable, in the present discussion at any rate, to draw any distinction between resorts which are devoted solely to health purposes, and those which are used partly or solely for pleasure.

The Health Resorts of the United States: General

Having now considered, in broad outline, the larger relations of climatotherapy, attention may next be directed more specifically to the health and pleasure resorts of the United States. This phase of the question is also treated in a very broad way. No attempt is here made to give a catalogue of the health resorts of the United States, or to include any numerical or statistical data. All such data can readily be secured from the regular publications of the United States Weather Bureau. All that is here intended is to give a systematic presentation of the larger climatic characteristics, in the form of broad generalization, in such a way that the essential facts may be properly coördinated. Furthermore, it does not fall within the scope of the present discussion to consider in detail the physiological reactions of the human body to varying meteorological conditions, nor to mention any but the most common and most familiarly known diseases.

In what follows, the places which are specifically mentioned by name are considered as types of the health and pleasure resorts which are already established in the same general regions, and may be taken also as representative of many others which may, in the future, be established in the same districts, and with similar advantages in so far as these concern the climate and the general physical environment.

The Climatic Provinces of the United States in Relation to Health

For purposes of systematic coördination it is necessary to group the health resorts of the United States in certain large and easily remembered climatic provinces. These are: (1) the Eastern Province, extending from the eastern base of the Rock Mountains to the Atlantic Ocean on the east and the Gulf of Mexico on the south; (2) the Rocky Mountain and Plateau Province, and (3) the Pacific Province.

THE EASTERN PROVINCE. GENERAL RELATIONS TO HEALTH

From the point of view of health, the most important climatic features of the Eastern Province are the great seasonal ranges of temperature, the severe cold of the winters over northern sections being followed by hot summers, and the suddenness, frequency and amount of the weather changes, especially in winter. Several short periods of extreme cold are to be looked for every winter, and the summers always bring spells of extreme heat. In such a region, where sudden severe and irregular weather changes are so characteristic, climatic averages can give little idea of the actual conditions which are experienced from day to day. Seasons often differ markedly in character from year to year. Weather changes are erratic and unexpected. It has become a popular saying that almost any kind of weather may be expected at any time of the year. The Appalachians are of too moderate an elevation to produce typical mountain climates, and the effect of the ocean is reduced to a minimum because the prevailing winds are off-shore. Lorin Blodget was not far wrong when he wrote: "We scarcely regard the Alleghenies as disturbers of any condition of climate except in the moderate degree produced by altitude alone."[3]

With decreasing latitude, the southern tier of States has distinctly milder winters, with less and less snowfall, somewhat warmer summers, and generally steadier and more "settled" weather.

The severe weather changes of the northern winters are usually borne without serious discomfort or harm if the body is in good health, and accustomed to adjusting itself quickly. Cold in itself, if not too severe and not too long continued, is beneficial to most people who were born and who have lived in the higher latitudes, for it necessitates increased bodily heat production and metabolism, and leads to a beneficial activity of many tissues and organs. On the other hand, these same sudden physiological readjustments may be too severe a strain on the aged and those who, because of illness or general physical disability, cannot react readily. Such meteorological conditions may then bring on various functional disturbances, and are especially harmful in the case of elderly people.

In damp air, evaporation from the internal surfaces of the body is decreased. When the air is at the same time cold, the lungs and respiratory passages not only lose a large number of heat units in the effort to heat the inspired air up to the body temperature, but also lose much moisture by evaporation, warm air having a greater capacity for water vapor than cold air. These physical processes, and the frequency of the sudden readjustments necessitated by the variable weather changes, are often followed by certain well recognized conditions of ill health. Diseases of the organs of respiration are prevalent in the

[3]Lorin Blodget: "Climatology of the United States," 1857.

winter months over the northern and northeastern sections, where the winter cold is often damp, and where temperature and humidity changes are most marked. Such diseases are "colds," influenza, bronchitis, catarrh, whooping cough, diphtheria, congestion of the lungs, pneumonia, and so on. The outdoor conditions tend to lower the vitality of the body which is not in good physical condition, and, when unusually severe or long continued, may react unfavorably on those who are otherwise in good health. Furthermore, the indoor life which so generally results from the prevalence of cold and of stormy weather, and the consequent lack of fresh air, naturally lead to a general lowering of the vitality, and to a diminished power of resistance against the attacks of disease germs. The greatest prevalence of most of the throat and lung diseases towards the end of the winter and in early spring depends upon the fact that the injurious effects of an indoor life, insufficient exercise in the open air, and inadequate ventilation, are at a maximum after several weeks or months of that highly artificial "hot-house" sort of life. Diseases of the nervous and circulatory systems, and rheumatism are also common in this type of winter climate. In summer hot spells, when both temperature and relative humidity are high, diarrhoeal disorders become frequent; sunstroke and heat prostrations occur. Hay fever is also a summer condition which affects large numbers of people who, on this account, seek places from which the irritating cause is absent.

The Health and Pleasure Resorts of the Eastern Province: General Classification

The simplest rough-and-ready grouping of the health and pleasure resorts of the eastern United States depends upon the fact that the northern winters are cold and stormy, and that the summer temperatures are high, especially in the south. It is thus to be expected that great numbers of invalids, and of others who are in a position to travel, should seek relief from the inclemency of the winter months by going south, and should go north, to cooler latitudes, during the hottest season. There is, therefore, a general group of I. *Southern winter resorts*, further roughly subdivisible into (a) mountain, (b) coast, and (c) intermediate. Likewise, there is a general group of II. *Northern summer resorts*, also subdivisible into (a) mountain, (b) coast, and (c) intermediate. No classification of this sort can be a hard and fast one. Many of the southern resorts which are frequented by Northerners who are trying to escape the cold in winter are used by Southerners who find these same places desirable resorts during the summer. Further, physicians are sending certain classes of cases to northern resorts, like the Adirondacks, in winter, and it is becoming more and more the habit of some of the younger and more robust members of the population of the northeastern cities to enjoy winter outings in the mountains of New England, and in the Adirondacks, where the deep snows give opportunity for winter sports, such as snowshoeing, skiing and tobogganing. Again, a good many readily accessible places in intermediate latitudes, such, e. g., as Atlantic City, N. J., are well filled at all seasons.

Southern Winter Resorts

Southern winter resorts have long been recommended by physicians who realize the advantage of a winter sojourn for many invalids and convalescents in climates where the conditions are less rigorous than those farther north, and are therefore also better suited to an open-air life. The best-known Southern health resorts are in Virginia, the Carolinas, Georgia and Florida. In mid and late winter and early spring a great exodus of health-seekers, bound south, sets in. Luxurious trains, equipped with every luxury and comfort, with through Pullman cars to all the Southern resorts, are then crowded to their utmost capacity. The development of this elaborate system of transportation, and of the great numbers of modern and highly luxurious southern hotels, is a natural response to the steepness of the winter poleward temperature gradient on the Atlantic coast.

The invalids who constitute a large element in this annual southern migration are sufferers from tuberculosis, asthma, bronchitis and other affections of the nose, throat, and lungs; from rheumatism; nervous and kidney troubles; insomnia; overwork. Convalescents from acute illnesses of many kinds make up a further considerable percentage of the total. But increasing numbers of those who "go South" in winter are really nothing but pleasure-seekers, afraid of the cold. They belong to the wealthy and semi-leisure classes, and are in search of a soft and comfortable life, with plenty of diversion and such outdoor occupations as golf, sea bathing and horseback riding. It is, perhaps, fortunate for the future race that so insignificant a part of the population as a whole can afford to bask in the warm sunshine of luxurious southern winter resorts.

Asheville, North Carolina, is probably the best known of the southern winter resorts of the mountain group (I, a). Far enough south to escape the extreme severity of the winter cold and storms, yet far enough north to have a moderately stimulating and invigorating climate, with many dry and sunny days; situated in the midst of a beautiful mountainous country, with excellent hotel accommodations and abundant opportunity for outdoor life and diversion, Asheville has become a resort for those afflicted with pulmonary and similar ailments; and for a large group of cases such as nervous disorders, for example, which are benefited by an intermediate climate. It is used by Northerners in winter and by Southerners in summer, the two chief seasons being February and March, and July and August.

The mountainous portions of Virginia, the Carolinas and Georgia offer essentially similar climatic advantages over enormous areas, and are certain to witness the development of many health and pleasure resorts in addition to those already established. A special class of stations in this same general region is that which has become known on account of its mineral springs, e. g., Hot Springs, Va., and White Sulphur Springs, W. Va. These places are chiefly resorted to because of the benefits to be derived from the use of the waters and from the expert medical practitioners whose services are there available, but they also have the advantages of a mild winter climate and excellent accommodations.

The southern coast resorts (I, b) may be considered to extend as far north as Virginia, and to include Florida and the Gulf coast on the south. The New Jersey coast is intermediate between the northern (II, b) and the southern (I, b) coasts, but here again no sharp line of demarkation by latitude can be drawn. Old Point Comfort, Newport News and Norfolk, Va., have long been winter and spring resorts for Northerners and have been used as summer resorts by people from the South. They combine the advantages of a mid-way location, accessibility, good hotels, and a climate moderated by ocean influences both in winter and in summer. The journey from the great northern cities to the far South being often somewhat trying to those in delicate health, these Virginia coast stations have proved convenient temporary stopping places, and also provide a gradual climatic transition between north and south.

Farther down the Atlantic seaboard, the advantages of the southern coast as a place for a winter sojourn naturally increase. Far to the south, at the extreme end of the Atlantic coast temperature-ladder, lies Florida, a deservedly famous winter playground and health resort whose popularity has grown very rapidly. The peninsula of Florida, lying between the warm waters of the Atlantic and the Gulf, enjoys an almost tropical climate, naturally attractive to those who come from the ice and snow of the northern states. The Florida "winters" are extraordinarily mild and equable, interrupted now and then by moderate cold spells which, on relatively infrequent occasions, are sufficiently severe to bring frost. Invalids should be prepared for these occasional cold spells, as well as for spells of enervating, even uncomfortable warmth, for there are many distinctly "hot" and relaxing days, especially in the late winter and spring. Abundant sunshine; a dry, sandy soil; relatively few rainy days; the absence of snow; a soft, balmy air; the beauties of the semi-tropical vegetation; every inducement to an outdoor life which natural conditions and the thought and ingenuity of man can devise; excellent train service; luxurious hotels and sea-bathing even in mid-winter—these are sufficient to ensure the popularity of Florida as a winter resort. Before the heat of later spring begins, a wholesale exodus of invalids and of pleasure-seekers takes place. The northbound trains are then crowded, hotels are closed, and Florida settles down to the quiet of its long summer.

This mild, relatively damp climate is soothing and relaxing. It is prophylactic, preventive. While not the best for certain cases and stages of tuberculosis, and not unlikely to aggravate certain anemic conditions, Florida winters have many excellent qualities for convalescents; for elderly persons; for those broken down nervously; for many patients with nose and throat troubles, and in certain diseases of the digestive organs. Too long a sojourn in such a climate may, however, lead to a marked toning-down of the system, to loss of appetite, and to digestive and nervous difficulties. Palm Beach, with its seashore life, is known the country over through persistent newspaper notoriety. Tampa, Miami, Jacksonville, St. Augustine, are familiar names.

The Gulf coast, from northwestern Florida to Texas, by reason of its mild winters and its summers tempered by the prevailing onshore winds, offers numerous resorts which, while not as generally frequented by Northerners as those of the Atlantic seaboard, are popular among Southerners, both in summer and in winter. New Orleans, about midway on the Gulf coast, attracts Northern visitors who are diverted by the life of this quaint and picturesque city.

Between the Appalachian Mountains on the west and the Atlantic seaboard on the east, and towards the southern portion of the Atlantic Slope, there is an intermediate group of stations (I, c) of considerable importance. These are mostly situated at a very moderate elevation above sea-level, in a belt of dry, sandy, porous soil covered with extensive pine forests; far enough south to have dry, mild and relatively sunny winters, without the sudden weather changes of the north, yet with a more bracing climate than that of Florida. Aiken and Camden, S. C., Pinehurst and Southern Pines, N. C., Thomasville and Augusta, Ga., and other places, with excellent hotels, good golf links, and abundant attractions for an outdoor life, are much resorted to by Northern invalids and pleasure-seekers. The pure soothing "balsamic" air of the pine forests is doubtless a health asset whose exact value has yet to be determined. Pinehurst and Southern Pines are attractive names, with good "advertising value."

Northern Summer Resorts

One of the great summer vacation grounds of the United States is in New England and in the Adirondack area of New York. From the hot and crowded cities, vast throngs of people surge northward every summer, by train, steamboat and automobile, to the mountains, the seashore and the country, to seek relief from the summer's heat; to find rest and relaxation in beautiful scenery, changed surroundings and pure air. This annual exodus is chiefly made up of the well-to-do classes, and consists proverbially mostly of women and children. The men are usually obliged to limit their vacations to "week-ends," or to short outings of a few weeks. The large majority of those who frequent these northeastern summer resorts are not invalids, in any true sense, but do want and need rest, an outdoor life and changed surroundings.

The mountain districts of the northeast—the White Mountains of New Hampshire, the Green Mountains of Vermont, the Berkshire Hills of Massachusetts, the Catskills and Adirondacks of New York (II, a)—have long been favorite summer pleasure resorts. The summer population is here many times greater than that of winter. Hotels, boarding houses, cottages, camps, are filled. These mountain regions have many attractions for the summer visitor. They abound in picturesque scenery. They offer innumerable varied excursions. Mountain climbing, camping, fishing, tennis, golf, appeal to thousands of people.

The specific climatic advantages of the mountains are found in their clean pure air, in their latitude, and in their elevation. There is relief from the more intense heat of the crowded cities farther south, the nights in the mountains being as a rule cool and refreshing. But during the general hot waves which prevail over large sections of the eastern United States at one time, and import heat from a distance in their southerly winds, the mountains are by no means exempt from high temperatures. Local topography often plays a considerable part in the special climatic peculiarities of any given mountain resort. A place may be freely exposed to the prevailing summer winds, or it may be shut off from them by a mountain barrier, or by forests. There are hot valleys, even in the White Mountains of New Hampshire. A favorable location with reference to cool mountain winds may make the difference between a hot and oppressive night and one which provides refreshing sleep. Such local differences are quite worth consideration in building a summer cottage.

From the point of view of health, many of these mountain districts are famous for their immunity from hay fever, and for the benefit which the open-air life gives in many cases of pulmonary and bronchial disorders, in general debility, and in cases of overwork and nervous exhaustion. The early autumn, with its exhilarating days, its crisp, cool, often frosty nights, and the wonderful coloring of its autumn foliage, is the most stimulating and in many ways the most attractive season, but it is a time when most of the summer visitors have already departed to their city homes.

It is unnecessary to enumerate the many well-known resorts of the White Mountains. Good advertising, luxurious accommodations, a 'catchy' name—these and other factors may at any time bring into prominence a new hotel, erected in what was before an abandoned forest.

The Catskills, close to New York City, are now almost overcrowded during the hotter months. "The gentle loveliness of a hill country" has made parts of the Berkshire Hills in Massachusetts a veritable garden of beautiful estates. The Green Mountains of Vermont, less rugged than their neighbors, the White Mountains of New Hampshire, are dotted over with peaceful villages, and attract a numerous summer population.

Of these northeastern mountain groups, the Adirondacks are the most widely known as a health resort, and this chiefly because of the remarkable success which has been accomplished in the altitude and open-air treatment of tuberculosis at the "Trudeau Sanatorium," founded by the late Dr. E. L. Trudeau, at Saranac Lake Village. It is the perfection of medical care and proper hygiene, and the open-air life, rather than any peculiar climatic quality, which has given the Trudeau Sanatorium its richly-deserved reputation. The Adirondack "wilderness" offers many attractions to summer vacationists, with its dense forests; its many sparkling lakes and ponds; its mountain peaks; its varied inducements to a healthy, active, outdoor life. The pure, dust-free air; the tempered summer heat; the comforts and luxuries of the hotels, the accessibility, combine to give the very name of the Adirondacks a suggestion of enjoyment and peace, and above all, of health. Lake Placid, Saranac Inn, Paul Smith's, are familiar names. The Adirondacks, like all other places, have their climatic drawbacks. Occasional hot spells; frequent summer afternoon showers and thunderstorms, and nocturnal fogs over and in the immediate vicinity of the lakes and in the valleys, are among these. Saranac Lake Village is an all-the-year health resort and, as has already been noted, there is an increasing use of the Adirondacks by those in search of winter outdoor sports. The winters are rough and hard; spells of extreme cold are frequent in the valleys; there are many storms, much cloudiness and abundant snowfall. But there are also many bright, crisp, exhilarating winter days.

The coast, as well as, and often to a greater degree than the mountains, gives relief from the summer's heat (II, b). The whole New England seaboard, from Mt. Desert on the north to the shores of Connecticut on the south, is a succession of summer resorts and of summer cottages. Long Island and then New Jersey extend this line still farther south. With its cool ocean waters; its picturesque and rugged shore-line; its numerous bays and rocky islands and good beaches, the New England coast attracts vacationists from many parts of the United States. The Maine coast has exceptionally cool summers, especially to the north. South of Maine follows the short strip of the New Hampshire coast, and then the "North Shore" of Massachusetts, with picturesque Cape Ann, Gloucester, Manchester and Beverly. A majority of the native population in this whole section gains the chief part of its livelihood from the summer visitors. The general trend of the coast line is such that the prevailing summer winds (S. W.) in many places are tempered by passing over the cool ocean water before they blow onto the land. The sea-breeze brings in pure, cool, refreshing ocean air during the noon hours of many summer days. Hence the coast often escapes the extreme heat of the interior and of more southern seashore resorts which have not the benefit of such cold offshore water as flows along the northern New England coast. The stimulating and bracing qualities of this cool summer climate have been recommended by the medical profession to many convalescents from chronic illnesses, and to patients suffering from general and nervous debility, anemia and in some cases of insomnia. But the frequency of chilling fogs and of damp easterly winds is disadvantageous in most throat and lung troubles, and the climate is too stimulating for many delicate persons who lack the vitality to react properly. These cases do better in a less bracing climate. For them, the "South Shore" of Massachusetts, and the seashore resorts reaching from southern Massachusetts to New Jersey, are generally more favorable. The Massachusetts "South Shore," with the Cape Cod and Buzzards Bay resorts, and its warm ocean waters, is warmer, more equable and more relaxing than the Maine coast. It is, therefore, better in most cases of insomnia, mental and nervous exhaustion, overwork, and convalescence. Its fogs and dampness are, however, a drawback. Martha's Vineyard and Nantucket, both of them islands to the south of Cape Cod, have even more equable conditions and smaller diurnal temperature ranges than those of the mainland. All their winds blow off the warm ocean water. Rhode Island has its Newport and its Narragansett Pier. Connecticut and Long Island offer many additional seashore residences. New Jersey may be taken as the southern limit of the "Northern Summer Seashore Resorts." The coast of New Jersey is practically one long line of health and pleasure resorts. The best known, and most consistently and widely advertised of these is Atlantic City, with a long and growing list of luxurious hotels; its famous "Board Walk," and its typically American seashore amusements. These attractions, combined with easy accessibility from New York, Boston, Philadelphia, and other large cities, and the excellent bathing facilities, ensure the popularity of Atlantic City. In summer hot spells, the sea breeze gives welcome relief. And even the offshore winds blow over a narrow stretch of salt water which separates the sand bars on which the city is built from the mainland. Atlantic City has also become a much-frequented winter resort, especially by invalids and by vacation-seekers from the neighboring cities. There is a general impression that its winter climate is quite different from that of the rest of this part of the country. This is a mistake. The New Jersey coast is still within the storm-control of the northeastern United States. It has winter rains and snow, and cold waves, and much cloudiness, and frequent temperature changes. Its easterly winds are damp and chilly. On the other hand, however, the very rapid poleward temperature-gradient along the Atlantic coast in winter (2.7° Fahr. in January per latitude degree) inevitably gives New Jersey the advantage of mean winter temperatures somewhat higher than those farther north. Owing to the latitude and the location immediately on the ocean, the snowfall is less than inland, or in higher latitudes. The sandy soil dries quickly and warms rapidly, so that the snow which falls does not remain long on the ground. Bright, fine winter days show a considerable degree of diurnal warming.

It should be remembered that a large part of the reputation of Atlantic City, and of many other places, rests upon artificial conditions. In the case of Atlantic City itself, most of the "Board Walk" is sheltered from the northwest winds. On cold or stormy days people stay indoors; shut themselves up in glass-enclosed sun-parlors; venture out on the Board Walk in covered wheel-chairs, or sit and walk in sheltered places. Being away from home, and having no duties which call them outdoors, no matter how inclement the weather, they are naturally more or less unconscious of what the weather is. Advantage is taken of being out and of enjoying the warm sunshine and tonic air on all fine days, and, as so often happens, the "change" which benefits is more the rest, freedom from worry, and new and, to most people, diverting surroundings, than any marked difference in climate. As a winter and early spring health resort, the New Jersey coast is recommended for those who are suffering from overwork, insomnia, throat troubles; for "convalescents from acute diseases"; for many elderly people and those whose vitality is lowered—for all of whom comfortable accommodations, good food, pleasant surroundings, and somewhat less strenuous physiological adjustments to severe weather changes are desirable. Lakewood, N. J., while not on the immediate coast, may also receive mention here. Situated on the dry sandy soil of the pine belt of New Jersey, with somewhat warmer and more genial winters than prevail farther north, with clean, dust-free air and with protection against the coldest winds, Lakewood was formerly a health resort, but has now become largely a winter pleasure resort.

The third group of northern summer resorts is in the interior, neither in the mountains nor on the seashore and may be classed as intermediate (II, c). Here come the Maine woods and Rangely and other Lakes in Maine and the Lake Champlain and Lake George districts. Beautiful and varied scenery; extended forests, relatively cool stimulating summers; the opportunity for camping and fishing and for living a simple outdoor life. have here brought to many thousands of mentally and physically tired city folk rest and relief and fitness for their winter's work. For sufferers from hay-fever, and for many persons for whom the northern sea coast is too damp and too stimulating, these intermediate stations have proved highly beneficial.

The Great Plains

The Great Plains constitute a natural and logical province from the viewpoint of climate alone, but on account of their broad expanse of remarkably uniform topography, the similarity and the disadvantages of some of their general climatic characteristics, and the lack of local scenic attractions, they have not developed any climatic health resorts in the strict sense of the term.

The Western Mountain and Plateau Region

The great mountain and plateau region of the West, extending from the eastern foothills of the Rocky Mountains to the Cascade—Sierra Nevada divide, has altitudes sufficiently great to give true "mountain climates", with their special features of strong sunshine, dry air, and strong diurnal ranges of temperature. Combined, as they are in the western United States, with a small annual rainfall, comparatively few general storms, and little cloud and fog, such climates have distinct advantages for many invalids. Furthermore, with a great variety of topography and of altitude—lofty mountains, elevated plateaus, deep valleys, low-lying deserts—this great western region embraces a wide variety of local climates. Colorado has become famous the world over for the success which has there resulted from the altitude treatment of pulmonary tuberculosis. As Dr. C. Theodore Williams expressed it, "the favorable results (of the climate) . . . may be seen in the large number of former consumptives whom it has rescued from the life of invalidism and converted into healthy and active workers."[4] The development of the muscles of the organs of respiration; the resulting expansion of chest and lungs; the improved circulation; increased heat production; better appetite, a general stimulation of various organic functions—these are among the effects of the altitude cure which are helpful in raising the vitality and in giving the body the power to overcome the ravages of the tubercle bacilli. There are, however, a good many classes of tubercular cases for whom considerable altitudes are too stimulating, or even distinctly injurious, and who do better nearer sea level, where the climate is less stimulat-

[4]C. T. Williams: "The High Altitudes of Colorado and Their Climates," Quart. Journ., Roy. Met. Soc., Vol. 19, 1893, pp, 65-82.

ing, and where there is less danger of overworking the heart and blood vessels. Such cases are those of elderly patients, those with diminished vital powers and those suffering from insomnia, cardiac and bronchial affections. The winters of Colorado are marked by an abundance of fine, crisp, sunny days and little snowfall except on the higher mountain slopes, where it accumulates to great depths. Lower down snow falls much less frequently, melts rapidly and offers no serious obstacle to an open-air life. The summers have warm days and cool nights, with frequent local showers and thunderstorms in the mountains. In the foothills region the high dusty winds of the warmer months are a distinct drawback. As compared with the northern tier of states, especially in the eastern part of the country, there are in Colorado few general storms, even in winter. The winter's cold and the heat of the summer days are much more easily borne in the dry mountain air than is the case with the same temperatures in the more humid east. The large diurnal ranges of temperature usually ensure refreshingly cool summer nights and relatively warm winter days. Invalids can as a rule be out of doors for several hours a day, even in midwinter, and need only light wraps in the strong sunshine. The western mountains are so far from the great eastern centers of population that they have not in the past attracted such great numbers of summer vacationists as frequent the mountains and seacoast of the northeastern sections. But those who are in search of an outdoor life in a rugged country of great scenic beauty are going to Colorado in larger numbers each year, and the regular "tourist travel" to the Yellowstone and Glacier National Parks, and to other favored districts of great natural wonder and beauty is increasing annually.

What has been called by the late Dr. S. E. Solly the "Invalid Belt" of Colorado varies in altitude from 4500 to 8000 ft., and extends from Middle and Estes Parks to Colorado Springs. The latter is perhaps the best known of all the Colorado health resorts, especially for those predisposed to or afflicted with tuberculosis of the lungs. A considerable part of the population of Denver has settled there for reasons of health. Manitou Springs is another health resort. The climate of the region which these cities represent is also favorable to other classes of cases which need an open-air life and not too great a stimulation of various bodily functions. At these, and other places in the "Invalid Belt," special attention is paid to the care of consumptives. Expert medical practitioners, who are skilled in the treatment of tuberculosis, are available. Excellent accommodations are provided. Everything has been done to aid the cure, for the accomplishment of which the high, dry, sunny climate of Colorado has proved to be so peculiarly well adapted.

The so-called "Parks" lie west of the Colorado Front Range. They are sheltered intermont basins or valleys, of 6000—8000 ft., altitude, with scattering pine-tree growth, of a park-like character which gives them their name. Some of these parks are well frequented summer resorts, but there is, as yet, insufficient provision for invalids.

South and southwest of Colorado come the mountains and plateaus and valleys of New Mexico and Arizona, and then, along the southern border of the United States, are the low lying deserts and irrigated valleys of the driest portion of the country. It is highly significant that well south of Colorado, in the highlands of New Mexico, at Fort Bayard and at Fort Stanton, the United States Government has established its consumptive sanatoria for the Army and Navy.[5] Of this general region Dr. W. A. Hammond, formerly Surgeon-General of the Army, wrote: "New Mexico is by far the most favorable residence in the United States for those predisposed to or afflicted with pthisis," and Dr. W. M. Yandell, of El Paso, has said that if a mild climate during the cold season is desired, New Mexico and Arizona, south of latitude 35°, furnish by far the best winter climate in the United States for consumptives[6]. Northern New Mexico and Arizona have very much the same climatic advantages as does Colorado for the altitude treatment of tuberculosis, but are even less subject to cyclonic weather changes by reason of their somewhat lower latitude. Their winters are also milder for the same reason, but occasional spells of extreme cold and snowstorms are to be expected at the higher levels. The early mornings and evenings are usually frosty; the noon hours are warm and bright. The tonic, invigorating quality of the dry sterile air; the enjoyment and encouragement which comes from an abundance of bright sunshine; the very small winter precipitation, with a minimum of rainy and cloudy days; the possibility of open-air treatment throughout the cold season; the wonderful and varied coloring of the mountains; the glories, the bigness and the appeal of the desert—these are among the attractions of the Great Southwest. The summers are long and hot, and too debilitating for many invalids. The mountains then have an advantage over the lowlands, owing to their more comfortable nights, due to the marked diurnal variation in temperature and, often, to the occurrence of cool, mountain breezes. On the desert lowlands of the south, the summer heat is more intense, and lasts longer. The dryness of the air however helps to make these very high temperatures endurable, and sunstrokes are traditionally unknown. A distinct drawback to a

[5]Since June 15, 1920, the hospital at Fort Bayard has been in charge of the U. S. Public Health Service, and is now known as "Hospital No. 55, Fort Bayard." The hospital at Fort Stanton is "U. S. Marine Hospital No. 9." There is also a U. S. Naval Hospital at Fort Lyon, Colo.

[6]Quoted by Solly, loc. cit., p. 276.

summer sojourn in most parts of the semi-arid Southwest, especially on the low-lying plains, is the frequency of high, dusty winds. In many places this dust is alkaline, and is very irritating to the mucous membranes. As health resorts, such localities are obviously undesirable, if not altogether impossible.

While fully recognizing the many remarkable cures which have been accomplished in the cases of thousands of tuberculous patients when such persons were sent out in time; were properly advised as to the best place of residence, and were financially able to make the best possible use of their opportunities, it is undeniable that many serious mistakes have been made by the medical profession in advising their invalids to go to the Southwest. Such mistakes arose largely from an inadequate knowledge of the actual climatic conditions. Patients have been sent out to the wrong places, and at the wrong seasons. Invalids, far advanced in the later stages of tuberculosis, have been advised to take the long journey when they were in no condition to stand the fatigue and could not afford the expense. Many have gone to the higher stations ill-prepared for the cold of winter, or to the southern towns during the intense heat of the summer. It is manifestly unfair to attribute the deaths of many unfortunate invalids to climate, when such persons came too late, and had improper care and surroundings. It is as true to-day as it was when Lorin Blodget stated it that "large numbers seek milder climates and perish there, whose cases should be set down to the country from which they came."[7] A difficulty in the present-day use of New Mexico and Arizona for health purposes lies in the fact that there are as yet comparatively few places in which adequate provision is made for invalids. As a health resort, the Southwest is by no means fully developed. Santa Fé, Las Vegas, Albuquerque, in New Mexico (5000—7000 ft.), are fairly typical and are used as all-the-year health resorts for certain classes of lung cases. In Arizona, Phoenix, at a low altitude, Prescott and Flagstaff at greater elevations, are representative stations. El Paso, in extreme western Texas, has similar conditions to those of southeastern New Mexico at the corresponding altitudes. It also offers a favorable climate for invalids in winter but is too hot in the long summers.

The Pacific Coast

For many centuries the Mediterranean climates of the Old World have been lauded in song and in story. For generations, the Riviera has been a favorite resort where invalids have sought health, and where an escape from the rigors of a cold and inclement winter has been found by those who have had the time and the means to leave their

[7] Loc. cit.

northern homes. The sub-tropical belt, which has its greatest extension in the classic Mediterranean region, combines many of the qualities which, taken together, probably make as nearly "ideal" a climate, for the majority of people, as can be found. Situated far enough from the equator to be spared continuously high and enervating temperatures, yet near enough to it to escape the extreme cold of higher latitudes, these transitional sub-tropical belts are highly favored. With prevailing fair skies and abundant sunshine during most of the year, equable temperatures and generally moderate winter rains, "Mediterranean climates," as they have come to be called, possess many advantages which fit them to be health resorts. The long list of European "resorts" stretching along the shores of the Mediterranean Sea, in Italy, France, Spain and Africa, bears abundant witness to this fact. In the United States, Southern California, with similar climatic controls and characteristics, ranks high in the estimation of the medical profession, and in the minds of countless thousands who, in good health, have there sought, and found, pleasure and relaxation.

The Pacific Slope, with its great latitudinal extension, its snow-capped mountains and its broad and fertile valleys, embraces a great variety of climates. It is, however, the southern coast of California which is the real health resort, and it is therefore to that district alone that this discussion relates. A conservative estimate would indicate that fully three-fourths of the Eastern visitors to Southern California find their attraction in its climate and in the outdoor life which that climate makes possible, in the midst of vineyards, and orange groves and gardens of roses. The luxurious hotels make every possible provision for visitors, and the social intercourse with people from all over the country is an added element in the attraction for many. The essential features of the climate from the standpoint of health are its mildness and equability, without enervating qualities; the relatively mild winters and cool summers; the short winter rainy season, without snowfall and with rare frosts; the absence of sudden and extreme weather changes. Even in the so-called "rainy season" of winter, the rains are light; they are not steady and continuous, usually lasting but two or three days at a time and separated by much longer spells of fine sunny weather. The mountain barrier of the great Sierra Nevada and Cascade Ranges keeps out the extremes of winter cold which are found over the interior districts to the east of the mountains. In the "dry season" of summer, mild and nearly continuously fine weather is the rule.

Southern California has an all-the-year round climate. It is frequented at all times. Winter and spring, however, are the favorite seasons. It is then that the attractions of outdoor life are most appealing, the vegetation is green and fresh, and the great throng of visitors from the northern and eastern parts of the country, escaping from the severe winters of the interior and Atlantic Slope, take the long overland journey in order to be warmed by the California sunshine, to enjoy sea-bathing, and to revel in a tempered climate where there is no snow and ice, and where fruits and flowers and green leaves replace the bare trees and frozen ground of the East. Even the most enthusiastic native of the Pacific Slope must be satisfied with Blodget's reference to "the elastic atmosphere and bracing effect" which "constitute a striking difference from those of the Eastern States." There is no climate on the Coast "which is not the reverse of enervating. . . All residents concur in pronouncing it more favorable to physical and mental activity than any other they have known, from whatever quarter they come."[8]

The health district of Southern California lies south of latitude 35° S., and is separated from the interior by mountains which border the coast. It is a country of fertile valley and plain. San Diego, Coronado Beach, Santa Barbara, Los Angeles, Pasadena, are names as familiar as San Remo, Nice, Mentone and Monte Carlo. Most of the resorts are on or close to the coast, and at a low altitude. They have advantages, and some disadvantages, on that account. The special topographic surroundings of each station contribute something towards giving it certain local characteristics, but in the main, the climatic conditions are everywhere similar. On the immediate coast, the special features are the fog, the dampness, and the prevalence of cool onshore breezes. The fogs are chiefly nocturnal, and spring and summer phenomena. The diurnal onshore breeze, from the cool Pacific waters, is of great help in tempering the heat of summer, but brings a chill which is trying to many delicate persons, and demands the protection of warmer clothing than the majority of visitors, unfamiliar with the details of the local climates, at first think necessary. The high relative humidity, resulting from the proximity to the sea, the fog and the onshore winds, is a factor not usually expected. It is a prevalent idea, even in the minds of many experienced medical practitioners, that the small annual rainfall which, so far as actual precipitation is concerned, ensures a "dry" climate, is necessarily accompanied by a low relative humidity. The late Dr. S. E. Solly expressed the following opinion, which may be taken as authoritative: "This Pacific coast climate is damp and presents its claims to sufferers on the grounds of equable temperatures and sunshine. It lacks the dry air and tonic, stimulating qualities of the elevated inland plains, but offers less shock to the system from rapid changes." If an invalid "needs the element of absolute dryness with low altitude and sunshine, he will hardly find them together except along the low plains of Arizona and New Mexico; that is while the barren inland country of California is

[8]Loc. cit.

dry, it lacks the conveniences of civilization which cannot be obtained short of the towns of Phoenix, Tucson or El Paso." And again, "it should be thoroughly understood by the Eastern visitor in search of health that if he seeks more days of sunshine and opportunities for outdoor life, with an equable temperature and an average humidity a little greater than that of New York or Boston, he can find what he desires at Santa Barbara or San Diego."[9]

The damp, cool night air on the coast, not infrequently combined with fog, is thus a climatic feature which is not to be ignored in the treatment of invalids. Such persons can, of course, to a certain extent escape this condition by remaining indoors at night.

In climatotherapy, Southern California has in the past been much used for tubercular cases; for many cardiac affections; for insomnia, nervous disorders and for persons of somewhat lowered vitality. For many invalids, especially those with throat and lung troubles, the "back country," among the hills, offers more suitable conditions than the damper, chillier, and more trying seacoast. Redlands, and Riverside are representative of the interior district, somewhat back from the coast and at higher elevations than the stations directly on the ocean.

Although mention has been made of certain of the least desirable climatic features of Southern California, it cannot be too emphatically stated that his region has, on the whole, a remarkably favorable combination of climatic conditions. It even possesses certain advantages over the climates of the most famous Mediterranean resorts of Europe. "Here", as the late Charles Dudley Warner wrote, "is our Mediterranean. Here is our Italy."[10] And here, it may be added, countless millions in the years to come will seek, and will find, health and strength and a wonderful exhilaration in the joy of living.

[9] S. E. Solly: Medical Climatology, p. 312.
[10] C. D. Warner: "Our Italy."

THE PROGRESS OF SCIENCE

HENRY ANDREWS BUMSTEAD

Professor Bumstead, of Yale University, whose admirable address on the History of Physics is printed in the present issue of the *Monthly*, died suddenly on the night of December 31, at the age of fifty years. He had been in attendance on the meetings of the Physical Society at Chicago, of which he was a past president, and active in numerous conferences and committee meetings held during convocation week. The writer of this note was in conference with him concerning the organization of the Science Service, endowed by Mr. Scripps, until midnight on Thursday and again through Friday afternoon. His clear judgment and wise council were in constant evidence, and he appeared to be in the best of health. On Friday evening he took the train for Washington; on the following morning he was found dead in his berth.

Bumstead was the chairman of the National Research Council for the present year, succeeding Dr. James Rowland Angell, who now assumes the presidency of Yale University, where Bumstead was professor of physics and director of the Sloane Physical Laboratory. He remarked at Chicago that he was ready to devote this year to the odd jobs of science, but that he planned at the end of it to return to the research work interrupted by the war. This work was concerned with radioactivity and the Röntgen rays. He was especially interested in photoelectric effects, delta rays and the theory of electrons.

In *Nature* for February 5 will be found an appreciation by Sir J. J. Thomson, with whom Bumstead worked at Cambridge and with whom, as president of the Royal Society, he was associated during the war period. Professor R. A. Millikan, with whom Bumstead had been closely associated both as a physicist and in the conduct of the National Research Council, writes in an article printed in the issue of *Science* for January 25:

"When in 1917 the important and difficult post of scientific attaché in London was created, Bumstead was the only man considered, for no scientist in this country had his tact, his judgment, his knowledge of England, and his ability to assist in bringing about what was then, and what is now, the most important need of the modern world, namely, the cooperation and mutual understanding of the two great branches of the Anglo-Saxon race. Bumstead's success in London was extraordinary. The British liked and trusted him. Admiral Sims and our own War Department placed large responsibilities upon him, and his office became the center of a very active and very important service. Young American officers who went abroad on scientific missions found him the center of their contacts and the prime source of their usefulness. They all became his devoted admirers. Not one or two but a dozen or more of both British and American officers who came to Washington during the war told me that they owed their success in their work in England and the continent primarily to Bumstead, and counted it the most valuable part of their experience that they had had an opportunity to become acquainted with him. One of these officers described him as the most influential American in England."

"He had a brilliant analytical mind, profound scholarship, exceptional critical capacity, excellent judgment, an extraordinary winsome personality, the finest culture, and a great heart. His personal scientific contributions were important, though they had been much interfered with by his none too rugged health. His effect upon American physics, however, was not limited to his own sci-

HENRY ANDREWS BUMSTEAD

entific papers, but he exerted a powerful influence upon his pupils and upon his fellow physicists. It is not merely American science, however, which can ill afford to lose him twenty years before his time. American life in all its aspects is sadly in need of men of Bumstead's type. The cause of sanity, of culture, of Anglo-Saxon solidarity, of scholarship, of science, of world civilization, all suffer irreparably through his death."

AWARD OF THE NOBEL PRIZE TO PROFESSOR AUGUST KROGH

In Stockholm on last December 10, Dr. August Krogh, professor of zoophysiology in Copenhagen University, received the Nobel Prize in Medicine for the year 1920. The address of presentation was made by Professor J. E. Johansson of the Karolinska Institute of Stockholm. The award was given Dr. Krogh in recognition of his studies on the "capillariomotor mechanism." Until recently the conception of capillary function generally held in medical science has been that the number of open capillaries in any tissue depends upon the blood pressure in the small arteries which connect with these capillaries. As the blood pressure increases, for example, due to physical exercise, more and more capillaries open up to receive blood supply and thus accommodate the increased circulation.

Dr. Krogh who, during the past few years has made noteworthy researches in the general field of the physiology of respiration, clearly saw that if the capillaries act in this way, opening only in response to the stimulus of blood pressure and in number according to the height of the blood pressure, then the different capillaries of any tissue must vary in their susceptibility to this stimulus. Consequently if the animal organism is resting or fairly quiet, the blood supply would tend to flow in certain fixed capillary channels, viz, those which have the slightest resistance, hence some of the body cells adjoining capillary walls would be well supplied with oxygen while others would be in constant danger of suffering from oxygen want. When studying the matter experimentally in living tissues, he observed that no one capillary or group of capillaries functioned continuously. The capillaries are constantly changing in caliber. After one opens and receives blood supply it tends to close, while others in neighboring parts of the tissue open and provide new channels for circulation. There is thus a rotation or sequence of functioning so that all the capillaries receive in time their supply of fresh oxygenated blood. Further experimentation by Dr. Krogh has shown conclusively that the dilatation of the capillaries is not primarily dependent upon the blood pressure. Direct mechanical, thermal or chemical stimulation may produce dilatation of both capillaries and arteries and when the stimulus is sufficiently strong, the effect spreads to an area greater than that stimulated. The experiments indicate that the natural condition of capillaries in healthy tissue is that of tonic contraction due to local reflex action in the capillary walls and that the blood carries some substance as yet unknown which acts as a stimulus to this contraction, hence when the capillary receives blood, it begins to contract and after the stimulating substance is exhausted, it dilates to receive a fresh supply. The identity of the substance responsible for the tonic action of the blood has not been proved, but Dr. Krogh has shown it cannot well be oxygen.

Many research workers throughout the preceding years have noted what to them seemed curious phenomena in connection with the dilatation and contraction of capillaries and have recorded these facts. This work of Dr. Krogh is outstanding in that he

DR. AUGUST KROGH

has independently observed what had previously been incidentally found, has discovered other related phenomena, and correlated these so as to prove the existence of a second mechanism controlling the circulation of the blood. The heart and arteries may be termed the first mechanism with the function of dividing and propelling the blood to the different body tissues; the "capillariomotor mechanism" finally distributes the blood throughout those minute parts of the tissue which have need for the different substances which it is carrying. The two mechanisms, although commonly functioning in harmony, are thought to be relatively independent of each other.

Dr. Krogh is scarcely forty-five years old. He received his educational and scientific training in Denmark and is a son of whom that country can well be proud. For a number of years after receiving his degree and serving as laboratory assistant to Professor Christian Bohr no suitable teaching or research position opened to him in Denmark. However, he refused to accept such a position in any other country. He made two expeditions to Greenland, the first to study the tension of carbon-dioxide in ocean water and the second to investigate the respiratory metabolism of the Eskimos. Thus, without any laboratory facilities, he literally plunged into research. A study on the expiration of free nitrogen from the body was recognized as so important so as to receive the Seegen Prize of the Imperial Academy of Sciences in Vienna. He was appointed a lecturer in physiology under the science faculty of the Copenhagen University in 1908 and was provided with a small laboratory in the fall of 1910. It is in this laboratory that most of his scientific work has been done. A visitor will gain the impression that his laboratory facilities are rather meager as regards both room and equipment and that he does not have adequate assistance. Certainly it would be a most worth while investment to provide such a man with all the assistance he can comfortably direct. His researches have covered a wide range and have been singularly concise and complete. He is a master technician, a scientific explorer by nature, a skilled interpreter and critic of scientific facts and he has much facility in writing. Most of his recent work is published in English. About his personality there is a quiet humility which strongly attracts advanced students and begets confidence in Dr. Krogh's scientific results. His mental attitude can well be illustrated by a sentence from a recent letter to an American colleague. "The Nobel award came as a perfect surprise to me and when it was first told me by a journalist, I declined to believe it because, in my opinion, my work on the capillaries was so far only a promising beginning."

INTERNATIONAL EUGENICS CONGRESS

In 1912 there was held in London, under the auspices of the Eugenics Education Society, an International Eugenics Congress. A second congress was planned to be held in New York City in 1915 but, on account of the war, plans for the congress were abandoned. In the autumn of 1919, at a meeting of the International Committee of Eugenics held in London, it was agreed to hold the second International Congress in New York City in 1921. A general committee to arrange for this congress was selected by the National Research Council in the spring of 1920, and it is now announced that the Second International Congress of Eugenics will be held in New York City, September 22-28, 1921.

Of this congress Dr. Alexander Graham Bell is honorary president; Dr. Henry Fairfield Osborn, president; Mr. Madison Grant, treasurer; Mrs. C. Neville Rolfe (Mrs. Sybil Gotto) honorary secretary; and Dr. C. C. Little, secretary-general. The vice-presidents include Dr. Cesare Arton, Cagliari Italy; Dr. Kristine Bonnevie, Institute for Heredity Investigation, University of Christiania, Norway; Major Leonard Darwin, London; Dr. V. Delfino, Buenos Aires; Dr. E. M. East, Harvard University; M. Gamio, Director Archeology and Anthropology, Mexico; Sir Auckland Campbell Geddes, British Ambassador to the United States; Dr. Corado Gini, Rome; Hon. Mr. Justice Frank E. Hodgins, Supreme Court of Ontario; Dr. Frédéric Houssay, Paris; Dr. H. S. Jennings, Johns Hopkins University; G. H. Knibbs, Melbourne; Dr. Herman Lundborg, Upsala; Dr. L. Manouvrier, Paris; M. L. March, Paris; Dr. Jon Alfred Möjen, Christiana; Dr. T. H. Morgan, Columbia University; Dr. R. Pearl, Johns Hopkins University; Dr. Edmond Perrier, Paris; Dr. Ernesto Pestalozza, Rome; Dr. V. Guiffrida, Ruggieri, Italy; Professor R. Vogt, University of Copenhagen; and Professor Wille, University of Christiania.

SCIENTIFIC ITEMS

We record with regret the death of Sherburne Wesley Burnham, professor of practical astronomy in the University of Chicago and astronomer of the Yerkes Observatory; of Charles Henry Fernald, emeritus professor of zoology at Amherst Agricultural College; of Wilhelm von Waldeyer, professor of anatomy at the University of Berlin, and of Alfred Gabriel Nathorst, the Swedish geologist.

Dr. James Rowland Angell has been elected president of Yale University to succeed Dr. Arthur Twining Hadley at the close of the present university year. Dr. Angell is a son of the late President Angell of the University of Michigan, and a graduate of that university of the class of 1890. He has been professor at the University of Minnesota, professor, dean and acting president of the University of Chicago, chairman of the National Research Council, and president of the Carnegie Corporation. Dr. Angell is a distinguished psychologist, having been president of the American Psychological Association and being a member of the National Academy of Sciences. The Yale Corporation announces that it has endeavored to choose for its head the ablest educational administrator available in the United States, irrespective of the college of his graduation or the place of his residence.

The Carnegie Corporation of New York has entered into an agreement with Leland Stanford Jr. University, by which a food research institute is to be established at the university for the intensive study of the problems of production, distribution and consumption of food. The corporation expressed hope that the new organization will in time be known as the Hoover Institute. The corporation will provide $700,000 for its support for ten years. Dr. C. L. Alsberg, Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, has been elected the first director.

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MAY, 1921

THE HISTORY OF MATHEMATICS*

By Professor ERNEST W. BROWN

YALE UNIVERSITY

THE earliest dawn of science is without doubt not different from that of intelligence. But the civilized man of to-day, far removed as he is from the lowest of existing human races, is probably as far again from the being whom one would not differentiate from the animals as far as mental powers are concerned. What this difference is, neither ethnologist nor psychologist can yet tell. Perhaps the nearest approach to a definition, at least from the point of view of this article, is contained in the distinction between unconscious and conscious observation. We are familiar with both sides even in ourselves: records can be impressed on the brain and remain there apparently dormant until some stimulus brings them to fruition, and again, record and stimulus can appear together so that a train of thought is immediately started.

The faculty of conscious observation is a fundamental requirement of a scientific training, and no development can take place until it has been acquired to some extent. Although this is only the first step, it was probably a long one in the history of the race, just as it is relatively long in the lives of the majority of individuals. Reasoning concerning the observation follows, but not much success can be attained until a considerable number of observations have been accumulated. We may indeed put two and two together to make four, but experience shows that with phenomena the answer is more often wrong than right: we need much more information in order to get a correct answer.

We expect, then, that the earlier stage of a science will be one not so much of discovery as of conscious observation of phenomena which are apparent as soon as attention is called to them. The habit once acquired, the search for the less obvious facts of nature begins, and

*A lecture delivered at Yale University, February 26, 1920, the first of a series on the History of Science under the auspices of the Gamma Alpha Graduate Scientific Fraternity.

in the search many unexpected secrets are found. Once a body of facts has been accumulated, correlation follows. The attempt is made to find something common to them all and it is at this stage that science, in the modern sense, may perhaps be said to have its birth. But this is only a beginning. The mind that can grasp correlation can soon proceed to go further and try to find a formula which will not only be a common property, but which will completely embrace the facts; that is, in modern parlance, a law which groups all the phenomena under one head.

The formula or law once discovered, consequences other than those known are sought, and the process of scientific discovery begins. Realms which could never have been opened up by observation alone are revealed to the mind which has the ability to predict results as consequences of the law, and thence is found the means by which the truth of the law is tested. If the further consequences are shown to be in agreement with what may be observed, the evidence is favorable. If the contrary, the law must be abandoned or changed so as to embrace the newly discovered phenomena. The process of trial and error, or of hypothesis and test, is a recurring one which embraces a large proportion of the scientific work of to-day.

Scientific development has two main aspects. One is the framing of laws in order to discover new phenomena and develop the subject forward so as to open out new roads into the vast forest of the secrets of nature. The other is the turning backward in order to discover the foundations on which the science rests. Just as no teacher would think it wise to start the young pupil in chemistry or physics by introducing him at the outset to the fundamental unit of matter or energy as it is known at the time, but will rather start in the middle of the subject with facts which are within the comprehension of his mind and the experience of his observation, science itself has been and must necessarily be developed in the same manner. We proceed down to the foundations as well as up to the phenomena.

This two-fold aspect of scientific research has had revolutionary results in the experience of the last half century. It has fundamentally changed the ideas of those who study the so-called laboratory subjects in which observation with artificially constructed materials goes hand in hand with the framing of laws and hypotheses, but it has changed the study of mathematics in an even more fundamental manner. In the past, geometry and arithmetic were suggested by observation and practical needs and the development of both with symbolic representation proceeded on lines which were dictated by the problems which arose. The methods of discovery in working forward were not essentially different from those of an observational science, except perhaps that the testing of a new law was unnecessary on account of the rules of reasoning which accompanied them and became embodied into a system of logic. It was, however, in proceeding backward to discover the foundations that the whole aspect of the subject changed. While many of the hypotheses were suggested by observation and were known by numerous tests to be applicable to the discussion of natural phenomena, it became evident that the actual hypotheses used were independent of the phenomena. The laws which are at the basis of geometrical reasoning are not necessarily natural laws: they can equally well be regarded as mere productions of the brain in the same sense as we might imagine a race of intelligent beings on another planet free from some of our limitations or restricted by limitations from which we are free. It is seen to be the same with the rules of symbolic reasoning which have gradually grown up. A geometry without Euclid's axiom of parallels has been constructed perfectly consistent in all its parts. This is built up of a set of axioms which constitute its foundation together with a code of reasoning by which we develop the consequences of the axioms. The same is true of geometries which involve space in more than three dimensions. It is somewhat easier to imagine symbolic developments which have their foundations different from those of our school and college algebras because there is no obvious connection between these rules and the phenomena of nature.

It may be asked what limitation is there in the development of mathematical theories if any set of axioms may be laid down. Theoretically there is none, except that if we retain our code of reasoning about them such axioms must not be inconsistent with one another. A certain sense of the fitness of things restrains mathematicians from a wild overturning of the law and order which have been established in the development of mathematics, just as it restrains democracies from trying experiments in government which overturn too much the existing order of affairs. Changes proceed in mathematics just as in politics by evolution rather than by revolution. The slowly built up structure of the past is not to be lightly overturned for the sake of novelty.

The developments traced above apply mainly to the subject of mathematics apart from its applications to the solution of problems presented by nature. Applied mathematics is a method of reasoning through symbols by which we can discover the consequences of the assumed laws of nature. The symbolism which we adopt and the rules we lay down with which to reason are immaterial, provided they are convenient for the objects we have in view. One feature must not be forgotten. We can never deduce the existence of phenomena through mathematical processes which were not implicitly contained in the laws of nature expressed at the outset in symbols. One cannot take out of the mathematical mill any product which was not present in the raw material fed into it. It is the purpose of the mill to work up the raw material and the better the machinery the more finished and more varied will be the product.

To write a connected story of mathematical development within the limits of a brief article on a consistent plan without making it a mere catalogue of names and results is a difficult, perhaps impossible, task and no attempt is made here to accomplish it. If we try to lay stress on the workers rather than on what they achieved, in one period we encounter schools which developed particular subjects, in another, outstanding figures with or without influence on contemporary development and in still another numerous investigators who contributed in varying degrees to the advances made in their age. On the other hand if the development of ideas be the basis, parallel developments followed independently by different schools sometimes occur, at another time general methods of treatment seem to pervade and again we may find some fundamental advance made, the effect of which is not felt for many years. Consequently the plan which seems to fit best any particular period has been adopted for that period. Another difficulty consists in assigning the relative values to either men or ideas, about which probably no two persons will agree. There is, however, one stumbling block which is peculiar to mathematics. The very names themselves of many important branches of pure mathematics convey no meaning to the majority of scientific readers who are not trained mathematicians and to whom alone this article is intended to appeal. An attempt at brief definition has sometimes been made, but it can at best only give a partial view of the subject even with concrete illustrations of its significations. In the general outline, the historical development has been followed, but the methods of carrying it forward have varied with different periods. When a choice of names mentioned has to be made, a rough guide has been furnished in the earlier periods by selecting those who have taken the step forward which has rendered the subject capable of expansion or application by others as judged in the light of present knowledge. In the nineteenth and present centuries to carry out this method has proved to be beyond the ability of the writer; consequently, in most cases personal mention has only been incidental and the names of many of those who have done great service are missing. Fortunately, the history of mathematics has received much attention in articles and separate volumes and to them the reader who is interested in obtaining fuller information is referred.

The earliest traces in the form of written records have come to us from the Babylonians, mainly in the form of clay tablets which appear to have been made at least 2000 years B. C. They show a knowledge of numbers which indicates that their civilization must have been far removed from the low stages in which many native tribes exist at the present day. Simple counting with the fingers of the two hands can be considered as the first stage, but beyond ten some new system must be devised. It appears that the Babylonians had learned the method of position, that is, that the first figure to the right shall represent the units, the next figure the tens and so on. They had even constructed numbers with 60 as the base of the system instead of ten. They could write numbers exceeding a million, one tablet giving a table of squares, and they also used fractions. Their geometry, however, was only in an elementary stage. But in astronomy they seem to have passed beyond the first stage of observation and to have been able to classify the results, for they possessed a knowledge of the Saros or period of 18, 2/3 years in which the eclipses of the sun and moon recur; this must have involved a long period of observation and record as well as the ability to classify the results and it may perhaps be regarded as the earliest recorded scientific deduction from observation.

Concurrently with this civilization was one of perhaps equal development in Egypt. The Ahmer Papyrus, which is usually dated some 2000 years B. C., shows that the Egyptians had not only already constructed an arithmetic but had started the solution of what we now call equations of the first degree with one unknown. There was no general method for solving the problems and no symbolism for the unknown, although symbols for addition, subtraction and equality occur. In geometry they were also somewhat in advance of the Babylonians, apparently on account of practical needs in land surveying. It is generally agreed that the pyramids show evidence of astronomical observation in their orientation with respect to the stars and they certainly show evidence of a knowledge of geometrical form. As these monuments appear to go back some 4000 years B. C., we have evidence of some considerable development much further back even than the times indicated by the Babylonian tablets or the Ahmer Papyrus.

But the first real evidence of the scientific spirit comes from Greece. While they probably inherited some of the accumulated knowledge of both Babylonia and Egypt, they transformed much of the raw material thus acquired into a finished product which has survived to our own times. Much the most remarkable of all that we inherit from them in science, is the change which they effected in the study of geometry. The love and knowledge of form which is so strikingly exhibited in their buildings and statuary was also applied to geometrical figures. Development of logic and a real desire to know the sources of all things, was applied to the same study. Thus Greek geometry was not only a consideration of the properties of straight lines and circles, but much more, a development of those properties by processes of thought from axioms laid down as a basis. If the modern mathematician can see defects of logic in much that has been handed down, he still follows Greece in the method of thought by which he deduces one result from another. Those same methods, indeed, are used to criticize the defects of the early work and that he is able to do so is chiefly due to the extended range of ideas which the developments of all forms of science have been able to give him. Some of the great names of antiquity in what we now term the humanities, are also great names in the history of science; Plato and Aristotle played no small part in the early developments.

The Greek school appears to have started about the seventh century before Christ, and it lasted nearly a thousand years, coming to an end finally after a long struggle against the stifling effect of the Roman conquest. For the first three hundred years Greece, a free nation, or at least under the government of its own citizens, found leisure to devote to intellectual pursuits, as a host of great names testifies. The invasion and repulse of Asia in the fifth century B. C. seems to have quickened rather than retarded the development of literature, science and the arts, perhaps under the spur of the construction of a single nation with democratic ideals from numerous small states. The conquest of Greece by Alexander in 330 B. C. transferred the sceptre nominally to Egypt through the enlightened policy of the Ptolemys who founded and encouraged schools of learning in Alexandria. But those who taught and worked there were all under Greek inspiration, and most of the advances were made by those of Greek origin. Apparently the foreign soil and alien patronage, however, gave only a temporary lease of life, for a decline started soon after and was accentuated in the first century B. C. when the Romans conquered Egypt and gained command of the whole civilized world. They themselves contributed little. The Fall of the Roman Empire through the incursion of the northern tribes, the rise and spread of Mohammed's followers, who, it is true, brought in other sources of knowledge from the eastern world but contributed little themselves, the domination and repression of free thought by ecclesiastics, left no opportunity for schools of science to grow. But few names appear in this period and those who sought to study the problems of nature had little opportunity to extend the borders of knowledge.

The first signs of awakening appeared towards the end of the fifteenth century. Revolts against ecclesiastical authority in England by the reigning sovereign, and later in Germany by Luther, the great geographical enterprises which soon resulted in a knowledge of the principal land areas of the earth, the curbing of royal ambitions by the defeat of the Spanish Armada, and the brief interlude of a commonwealth in England, had their counterpart in the invention of printing and the appearance of scholars advancing knowledge in almost all the civilized countries of the western world. The tremendous steps taken in the course of two centuries, culminating in Newton and Leibnitz, finally placed scientific investigation on a plane where it became largely indifferent to what was going on in the political world, and where it was able to pursue its own course, hampered it is true, by wars and revolutions, but never without great names which will live as long as the history of scientific development is remembered.

This rapid sketch may serve to assist in seeing how the progress of scientific thought has been related to the development of civilization. We are all apt to regard our own concerns as independent developments and too often the history of science is treated in the same way. But in looking at the subject over long periods of time, we should treat scientific development as one of the phenomena which will illustrate progress or decline. The attitude of mind which leads to a search for the secrets of nature is simply one manifestation of a common desire for progress and if so, we should see signs of this desire in many directions. The ultimate causes which underlie the changes which have taken place—which produce periods of activity and inactivity in a whole people or group of peoples—are unknown and will probably only be finally found in the laboratories of the biologist and the physicist. All we can do now is to correlate the facts as far as possible and record them for future use.

Let us return to the Greeks and examine a little more in detail their contributions. In doing so we are at once faced by the difficulty that most of our knowledge comes to us second hand and in the form of treatises which gathered together past achievements. But few names survive and it is not always easy to apportion the credit. It sometimes appears that a name represents a school rather than an individual. This is certainly true to some degree of Pythagoras, to whom is usually credited the theorem that the sum of the squares on the sides of a right-angled triangle is equal to that on the hypotenuse. He certainly formed schools, but these were conducted as secret societies, the members of which might not divulge the knowledge they attained. Their continued existence for a long period of years was probably much assisted by the custom or rule of attributing all discoveries made by the members to their founder, thus avoiding much heartburning and jealousy. Nevertheless Pythagoras seems to have been responsible for placing geometry on a scientific basis by investigating the theorems abstractly. Briefly stated, it may be said that up to the middle of the fifth century B. C., shortly after the battle of Salamis, the Greeks had discovered the chief properties of areas in a plane and most of the regular solids.

Their clumsy notation for numbers handicapped them in arithmetic, but they knew such properties as that the difference of the squares of two consecutive numbers is always an odd number, they defined progressions of different kinds, and they had some acquaintance with irrational numbers. This was perhaps the first school which devoted itself to investigation for its own sake without any special reference to possible applications to physical problems.

Then followed the golden age of Greece with Hippocrates of Chios, Euclid, Archimedes, Appolonius, Hipparchus, and a number of others less well known. Plato and Aristotle must also be included for their contributions to the forms of logical reasoning which should be adopted, and Plato in particular contributed in this respect to an extent which has lasted until our own times. Euclid, whose personality is decidedly nebulous, wrote a text book on the geometry of the line and circle by which most mathematicians for the next two thousand years were introduced to the subject: it is indeed only during the last few decades that it has been replaced by modern texts. Appolonius did much the same thing for the curves of the second degree—the ellipse, parabola and hyperbola. While we know little of Euclid's own contributions as a discoverer, it is fairly certain that Appolonius had not only mastered all that was previously known, but greatly extended that knowledge himself. But of all those who lived up to the time of Isaac Newton, there can be little doubt that Archimedes is the chief. He is recognized as the founder of mechanics, theoretical and practical. His work on the lever alone entitles him to fame: "give me a fulcrum and I will move the world." He initiated the sound study of hydrostatics, advanced geometry by discovering how to find the area of a sphere and that cut off from a parabola by a straight line. He also discussed spiral curves, finding many of their properties. In arithmetic he seems to have had methods for dealing with very great numbers similar to those we now use by the index of the power of ten which can represent the number. These brief statements are only smbolic of what he achieved. His activities were very extended, and he preferred the modern custom of writing essays, or memoirs as we now call them, rather than treatises or text books. The tradition runs that he was killed at the fall of Syracuse to the Romans because, absorbed in a geometrical diagram, he insulted the Roman soldier who was spoiling it.

Hipparchus was mainly an astronomer, and indeed one of the founders of the art, and it was in the course of his work that he initiated Trigonometry as an aid when angles had to be measured as well as lines.

During the following centuries up to the Fall of Rome in A. D. 476, there were no great advances, the principal name of the period being that of Diophantus, whose main contribution was a study of indeterminate equations. Algebra seems to have been developing very slowly and naturally, first by abbreviation of the words of a statement, next by a typical word (heap) and later by a symbol to represent the unknown, and finally by the adoption of symbols for common operations, like those of addition, equality, and so on. Diophantus took a great step in this direction, and he may be regarded as the father of Algebra in the main stream of the development of mathematics, in the sense that he placed it on a basis which rendered it capable of development. However, his work received no recognition at the time and was not revived for more than a thousand years.

We must now say something about some of the tributaries which paralleled the main Grecian stream and connected with it through the Moorish invasion of Europe during the 7th and 8th centuries. During the time of their dominance the Romans, if they contributed little, at least allowed development to continue in the centers of civilization. The Arabs, however, following the example set by the theologians, who by this time were beginning to come into power, had little use for scientific works and investigation, and between them they destroyed completely the greatest library and museum of antiquity, that of Alexandria, so that most of the written learning of that and of previous ages was lost for all time. They did however form a valuable connection with the Hindu mathematics of their time and appeared not only to have brought it to Europe, but to have assimilated it themselves to some considerable extent.

The origin of Hindu mathematics seems very uncertain. Apparently some centuries before our era, they had developed arithmetic further than the Grecians of the same period, but we do not know to what extent the Persian conquest might have been responsible for introducing early Greek learning into India. It is however true, that from whatever source they started, they developed arithmetic and geometry from the mensuration point of view further than the Greeks who had considered geometry from an abstract standpoint. In illustration of this, it may be mentioned that they had found good approximations to $\sqrt{2}$ and to π. But their greatest contribution is our present number system, which came to Europe through the Arabs and hence got its name. From the seventh century it does not appear that they formed an independent school. Hindu mathematics seems to have been largely improved by the needs of astronomy. Their greatest exponents were Brahmagupta, who lived in the seventh century A. D., and Bhaskara, some five centuries later. Their work, again, is chiefly arithmetical. While the so-called arabic numbers were probably used by the former, the latter was the first who is known to have given a systematic treatment of the decimal system. Although the Arabs dispersed the western schools, they set up schools of their own which developed mainly on algebraical lines. One name stands out prominently, that of Alkarismi —who may be regarded perhaps as the founder of modern algebra— the name of the subject itself comes from him. But he used no complete symbolism, and he and his successors developed it mainly from the arithmetical point of view. In this school the modern names of the trigonometrical functions appeared although little was done in the way of development.

Chinese science seems to have started about the same time as that of Greece, but to have had little or no connection with our western science until the sixteenth century. Whatever mathematics the Japanese had probably came from China. It would appear at first sight that the earliest developments arose independently in all civilized nations about the same time, speaking broadly, but our knowledge is so scanty that we can only say that the records nearly all date back to similar periods in each case. Whether there is anything significant in this fact must be left to conjecture.

With this brief sketch this era may be thought of as closed in so far as the development of science and particularly mathematical science is concerned. It witnesses a real beginning in the study of geometry and algebra, and to a much less extent, of physical principles. A system of logical reasoning was discovered which, in its main outlines, still forms the basis of all deduction at the present day. The properties of the simpler geometrical figures had been studied and committed to writing. The advance of arithmetic was hindered by a poor numerical notation, but the foundations were laid for future development by the introduction of the Hindu symbolism. Algebra had started to emerge from the rhetorical form of discussion into the more terse abbreviations which we now use. Astronomy never failed to have exponents, though many who doubtless desired to increase their knowledge were restrained by the superstition of the age and by ecclesiastical authority, which attempted to dictate the thoughts as well as the actions of men. In mechanics, Archimedes seems to have stood almost alone, largely, perhaps, because no scientific method in dealing with the fundamental problems of nature had yet become current amongst the learned men.

It is difficult to sum up in a phrase the reasons for the scientific hiatus which occurred during the following three or four centuries. The revival of learning which sprang up towards the close of the eighth century was almost barren of progress in mathematics. The schools established by Charlemagne, while teaching mathematics, developed interest in other directions. Reverence for authority appears to be the basis of nearly all the learning of the age and there is no more stifling attitude of mind for progressive evolution of ideas. We may attribute this to a variety of causes any one of which may seem sufficient to explain it, but in reality, not one of them explains anything. It may perhaps be best likened to one of those pauses which nature seems to demand and in which breath is sought before taking the next forward step.

The first sign of activity found expression in the Crusades undertaken to free Jerusalem from Mohammedan control. Soon after this time, that is, at the beginning of the twelfth century, several of the modern universities were founded, partly as gatherings of students to learn and discuss, and partly as developments of schools which had been under the charge of the monasteries. The old Greek works on mathematics were revived and the learning transmitted by the Arabs began to be assimilated and taught. Systematic instruction and the writing of treatises for the transmission of knowledge were begun. These were mingled with courses on astrology, alchemy, and magic, perhaps, we may conjecture, because the learned man had little chance to earn his living except through supplying what was in common demand, and perhaps also because the ancient learning gave little enough scope for cultivation of the imagination.

A century later Roger Bacon appears on the scene. It is difficult to overestimate the man who, travelling over Europe and studying in Paris and doubtless absorbing the learning of his time, becoming a Doctor in Theology and probably a monk, could break away from his training and absolutely reject the ideas and methods of his age. One who could write that in order to learn the secrets of nature we must first observe, that in order to predict the future we must know the past, must certainly have had unusual clarity of vision. He taught too that mathematics was the basis of all science, but he clearly recognized that it could not replace experiment and knowledge of phenomena, but could be used to great advantage in deducing results when the phenomena had once been observed: the point of view is thoroughly modern. But his three great works failed to have much influence on his times and seem to have been forgotten for several hundred years. Like many of his predecessors and followers in science, he suffered for his opinions.

The real start of modern science opens, as has been mentioned earlier, in the middle of the fifteenth century, and from this time on there is no break in the sequence of scientific discovery. We have also less need to relate its progress to that of the social order. While there have been periods in which wars have seriously disturbed the ability of nations to produce and to foster learning, there has been no time in the period in which the whole of the civilized world was so far involved in struggles that intellectual progress came to a stop everywhere. Moreover, all attempts since 1450 to enslave the world, either physically or spiritually, have ended in failure. It is true that five hundred years is comparable with the periods of Greek, Roman, and Mohammedan supremacy, but in each of these civilizations we see signs of decline in a far shorter period. At present there appears to be no indication that the crest of the wave of scientific progress has been reached. The world war just concluded, in its essence a struggle for liberty of thought and action, was far too short to submerge the knowledge of the existing generation and prevent it from being handed on to the next.

The period can be roughly divided into two parts, the two centuries until the time of Newton forming the first of these. It is chiefly characterised by a sustained effort to lay solid foundations for all those sciences in which mathematics is needed for development, and success very nearly complete was attained at the end of the seventeenth century. In Astronomy and mechanics, Copernicus placed the sun in the center of our solar system. Kepler, building on the observations of Tycho Brahe, gave the laws of the planetary motions. Galileo laid foundations for the study of mechanics and proved the rotation of the earth about its axis, besides making a host of astronomical discoveries with his telescope. In mathematics, the arabic numerals came into full use and were applied to the needs of daily life. The symbolism of algebra was completed in nearly the modern form used in elementary mathematics: much of the work done by Vieta, Cardan and Tartaglia involved the solution of equations of the third and fourth degrees. Trigonometry, needed by the astronomer, the map-maker, and the navigator, was developed so far that Rheticus calculated a table of natural sines to every 10 seconds of arc and to 15 places of decimals. Logarithms were invented by Napier, and seem to have been adopted universally almost immediately. Descartes invented analytical geometry and thus gave to the investigators of space-forms a new weapon of immense power, while Desargues laid the foundation of projective geometry. Fermat, an amateur and perhaps as able as any of his contemporaries, laid down many of the laws of numbers and founded the calculus of probabilities.

The brevity of this summary is not a measure of the achievements of these two centuries- For this we must look to those which followed. While judged by modern standards, the actual progress seems small, it was far beyond that which had been achieved in all the previous ages. The only earlier contribution which has stood the test of time is perhaps the geometry of the Greeks, for the work of Archimedes, especially in mechanics, seems to have remained almost unknown up to the time of Galileo. The period showed not only a sound laying of foundations, but in its development of ideas, often only dimly expressed, showed that the germination of the seeds of future knowledge had already begun. Progress was frequently hampered by an unfortunate form of rivalry in which a discovery was kept back so that its possessor could propose problems to confute the claims for knowledge of his contemporaries. On the other hand, the circulation of knowledge was greatly increased by the possibility of printing old and new work. Books became regular articles of merchandise and could even be picked up in out of the way places.

The era of Newton is so important in the history of both pure and applied mathematics that no excuse is necessary for dwelling on what was achieved. If an attempt be made to characterize its results in a single sentence, it may be perhaps best emphasized as the epoch of the discovery of the fundamental laws of continuously varying magnitudes. Before this time such solutions of dynamical problems as had been obtained were isolated. Newton's formulation of the laws of motion and proof of the law of gravitation were found in his hands and in those of his successors sufficient to deal with all the problems of physics which were then and later under consideration. Little progress, however, could have been made without the necessary complement, the calculus, which permitted of the study of varying quantities by symbolic methods. Rates of change, when uniform, presented little difficulty; the real problem was to deal with them when they were variable, as, for example, in the motion of a pendulum or the vibrations of a string. To a limited degree, the geometry of the straight line and the circle can deal with these questions as Newton showed in the classic translation into geometry of his results for the motions of the moon. But his manuscripts indicate that he failed beyond a certain point to give geometrical proofs of other results obtained by means of the calculus.

But as I have emphasized before we must not only look to the applications, the chief question in Newton's time, but also point out that varying magnitudes have been studied for their own properties so extensively that they form the larger part of mathematical developments up to the present day. If we except the science of discrete numbers, it is only in comparatively modern times that discontinuous magnitudes have received any extended study and even these have been advanced in many cases through developments of the calculus.

Isaac Newton seems to have been one of those very rare cases of genius breaking out without any very obvious stimulus from a particular teacher or school. His first introduction to mathematics was accidental: a book in astrology picked up at a fair in 1661 containing geometry and trigonometry induced him to study Euclid and then to continue by reading such text books as were available. His discovery of the calculus or "fluxions" as he called it, was made within three years and a half, the binominal theorem was formulated about the same time, and a year later he began his first attempts to prove the gravitation law. He was elected Professor of Mathematics in 1669, eight years after his entry into Cambridge as an undergraduate. At this time his chief subjects for lectures and investigation were optics and algebra, the former of which involved him in much controversy. In fact all through his active period of work in mathematics, he seems to have suffered from the difficulties of having his great advances understood and accepted, although there never seems to have been much question amongst his contemporaries as to his wonderful powers. In 1679 he discovered the law of areas and showed that a conic would be described by a particle moving round a center of force under an attraction which varied inversely as the square of the distance. But it was not until 1684 that he began to work seriously at gravitation problems, his first step being to show that a uniform sphere exerts the same attraction as a particle of the same mass placed at its center. From this time on progress was rapid. Within two years the manuscript of the Principia was finished and the following year printed.

The Principia, like most of the works of the time consists partly of results previously known, but by far the larger part of it is Newton's own work. It begins with definitions, the formulation of the three laws of motion and the principal properties which can be deduced from them, with some examples, forming an introduction to the first book which contains his main work on gravitation. The second book is chiefly devoted to hydrodynamics and motion in a resisting medium and the third to various applications of the first book to bodies and motions in the solar system. As stated earlier, the proofs are cast into a geometrical form and freed from all traces of the method of fluxions which Newton had used to reach many of his results.

This great effort seems to have nearly exhausted his great powers for he produced little after its completion. In 1695 he accepted an appointment at the Mint and six years later resigned his chair at Cambridge. He was only forty-five when the Principia was published and he lived for thirty-eight years afterwards.

The half-century which followed the publication of the Principia seems to have been mainly occupied in understanding and digesting the advances made. On the continent, where Leibnitz' notation for the calculus was mainly adopted, a firm foundation was laid for the progress which began in the middle of the eighteenth century. In England the reverence for Newton was so great and separation from the continent so effective, that his methods dominated all the work for nearly a century and a half. This was perhaps mainly due to the translation of the Principia into geometry which ensured its early acceptance but must have fostered a distrust of all results which could not be proved in the same way. And further, Newton's notation for fluxions, which did not bring out their essential properties, had great influence in preventing advances as against that invented by Leibnitz. Nevertheless there are certain names in the English school which have lived to the present day. Brook Taylor who was born in 1685 gave the fundamental series for the expansion of a function which is known by his name, followed a little later by Colin Maclaurin with the particular case which is named after him. The latter also determined the attraction of an ellipsoid and introduced the idea of equi-potential surfaces. De Moivre, of French ancestry but English birth and training, introduced the use of the imaginary into Trigonometry and thus prepared the way for the great development of the theory of functions of a complex variable which took place in the nineteenth century. Roger Cotes must also be mentioned if only for the high opinion Newton had of his abilities: he was only thirty-four years old when he died.

On the continent the Bernouilli brothers, friends and admirers of Leibnitz, were largely responsible for realising the power of the calculus and making it known. They applied it to many physical problems but perhaps their greatest influence came through their teaching abilities. Most of those in this period who achieved distinction were their pupils and several of their descendents were well known as mathematicians during the eighteenth century. But the most able men of this period were undoubtedly Clairaut and d'Alembert. The former produced the first theory of the motion of the moon developed from the differential equations of motion: in it he showed that the theoretical motion of its perigee, which in the Principia was obtained to only half the observed value, agreed with observation when we proceed to a higher approximation. There was an interesting development in this connection. Clairaut at first thought that it would be necessary to make an addition to the Newtonian law in order to produce agreement and it was only when he carried his work further that he saw such an addition to be unneccessary. A similar addition was examined by Newcomb and others as a possibility which might explain the deviation of the perihelion of Mercury from its observed value, and it is only within the last five years that such an addition has been deduced from the relativity theory by Einstein. Clairaut also obtained the well known formula for the variation of gravity due to the shape of the earth.

D'Alembert is best known by his work on dynamics in which he showed how the equations of motion of a rigid body could be written down: the principle is still known by his name. He also reached the well known wave-equation, a partial differential one of the second order, in several physical investigations and showed how a solution may be obtained. This was pioneer work but its further development was not carried forward to any extent by him.

The great period of continental activity which began in the middle of the eighteenth century and contained the names of Euler, Lagrange, Laplace, and many others of whom a brief mention only can be made, was characterised also by social ferment which has profoundly changed the basis of society. The French revolution with all its far reaching consequences took place in the middle of the time of greatest mathematical activity, and the Napoleonic wars, carried into almost every country of Europe, served to stir up intercourse between the nations to a degree which must have had much effect on all forms of scientific activity. At the same time, the American revolution produced a new body of political thought which has had its development in the formation of a great and powerful nation. In England, comparatively free from invasion or social disturbance, little was produced of permanent value, the influence of Maclaurin being directed to the retention of published Newtonian methods. With the single exception of the Italian Lagrange, the great names of the period belong to France and Switzerland.

Those who have had the most far reaching influence, judged by modern standards, besides Euler, Lagrange, and Laplace, are Legendre, Fourier, Poisson, Monge, and Poncelet. I omit those whose chief labors were more closely associated with experimental work. The means for publication in this period were becoming more extensive and it is less easy to discover what each man owed to personal meetings with his contemporaries. The principal academies of Europe were starting or had started their volumes of transactions, extended treatises could be published and circulated, and the scientific men had new opportunities to meet and discuss, even to some extent with those of other countries, especially on the continent. The more enlightened courts sought the services of the ablest scientific men and, when the latter did not mingle too much in politics, on the whole treated them well. Fortunately, at least for the leaders, their teaching was usually confined to small bodies of earnest students and they appear to have been little hampered by demands on their time and energy for administrative duties. It is interesting to note that in a time of political disturbance which was perhaps comparable to that produced by the great war, the main foundations of modern mathematics, both pure and applied mathematics, were firmly laid.

Leonard Euler, born in 1707 at Basle in Switzerland and educated in mathematics by Bernouilli, was perhaps the most industrious of all his contemporaries and it is difficult to say whether his services to mathematics are to be judged best by his excellent treatises on analysis, including the calculus, or by his original memoirs on applied mathematics. In the former, he followed up all that was known at the time, recasting proofs and setting the whole in logical order. In the latter, he is best known for his formulation of the equations of motion of a rigid body, for a similar service in the equations of motion of a fluid and for his work on the theory of the moon's motion. With respect to the last it may be said that every modern method of treatment can be found to have started with Euler. He continued his work to the end of his life in 1783 in spite of losing his sight some fourteen years earlier and his papers by a fire in 1777.

J. L. Lagrange was born at Turin in 1736 and was, like Newton, practically self-educated as far as his mathematical studies were concerned. It gives some insight into the comparatively small body of mathematical literature at the time he was seventeen years old and his own great ability, that an accident directed his taste for mathematics and that after two years work he was able to solve a problem in the calculus of variations which had been under discussion for half a century. At the age of twenty-five his published work showed that in ability he had no rival. Before his death, at the age of seventy-seven, he had left his influence on almost every department of pure and applied mathematics. His generalizations of the equations of mechanics have proved to be fundamental in all modern investigations and his applications to dynamical theory of the principle of virtual work and of the calculus of variations are now even more important than at any time in the past. The latter is applied not only to particles and rigid bodies, but also to fluids. To celestial mechanics he contributed several new methods in both the theoretical and practical sides of the subject in which such topics as the general problem of three bodies, stability of a planetary system, mechanical quadratures and interpolation are developed. In pure mathematics his lectures on the theory of analytic functions, afterwards expanded in treatises, form the basis on which later writers built. He also founded the science of differential equations by considering them as a whole rather than a treatment of such special equations as might arise in particular problems. And he contributed some important memoirs on the theory of numbers. His influence was undoubtedly much increased by a remarkable gift of exposition both in lecturing and writing: those who have read his Mécanique Analytique in which his most important dynamical contributions were placed will appreciate this fact. And this may be said independently of the simpler problem before him than has the modern mathematician with the enormous mass of past work which he has to consider and the selection which must necessarily be made.

P. S. Laplace, whose mathematical ability is unquestioned, was essentially an applied mathematician in that he devoted himself almost entirely to the solution of the problems of nature by mathematical methods. In general, he was not particular about mathematical proofs or logic, provided he could obtain results: in many respects he may be said to be the founder of the more modern schools of mathematical physicists. His most enduring work has proved to be in the theory of attraction, especially gravitational, and its application to the solar system. He made potential a real and valuable instrument of analysis and discovery, working out many of its properties and applying it in various directions. The famous second order differential equation $\nabla^2 V = 0$, which is satisfied by every gravitational arrangement of matter, has been used as a substitute for the simpler expression of the Newtonian law of attraction and is especially interesting at the present time, since it may be regarded as the Newtonian analogue of the Einstein law. Laplace was the first to attempt a complete explanation of the motions of the bodies of the solar system or at least to formulate methods which could be applied for this purpose and his *Mécanique Céleste* remained the standard work of reference in this subject for a century. The theory of the development of the solar system from a primeval nebula which goes by his name and which was independently set forth somewhat earlier by Kant, has never been entirely rejected, although its supporters have often changed it almost beyond recognition while retaining his name in connection with their work. Its fundamental idea consists of the contraction of matter under gravitational attraction, but few now believe that the matter can produce planets and satellites by the throwing off of concentric rings as he supposed. What he did for celestial mechanics, he also achieved for the subject of probability, his *Théorie Analytique des Probabilités* being the classic treatise in which the whole is put on a sound basis and developed in various directions. It must be added that he gave many theorems and results in pure analysis but in most cases these were invented to solve physical problems.

Of the remaining names in this period, Legendre was essentially an analyst, his work being mainly in the theory of numbers, which few mathematicians of this time altogether left alone, in integral calculus and ellipitic functions, his treatises on these subjects being still consulted. Monge and Poncelet may be regarded as the founders of modern descriptive and projective geometry respectively. Fourier in his *Théorie Analytique de la Chaleur* enunciated the theorem for the expansion of a function in a periodic form which has had such immense value in the discussion of all periodic phenomena, and has now a literature of its own. Poisson's work in attraction is on similar lines to that of Laplace, whose natural successor he seems to be.

It is conventient to view the progress made in the nineteenth and twentieth centuries from two points of view: one, the development of the three great branches of mathematics, geometry, analysis and their applications to other studies; the other, the development of new ideas which have applications in many branches of mathematics. While it may be said that the former is more particularly characteristic of the first half of the nineteenth century and the latter of the succeeding period, it would give a false idea of the method of progress to regard these as anything more than general tendencies. But the difficulty (mentioned earlier,) of conveying an understanding of the advances made in pure mathematics, even by one much more familiar with them than the writer, occurs in an exaggerated form in attempting a chronicle of the work of the past century. The task is far easier in applied mathematics because most of us have some acquaintance with the problems, and the ideas to be conveyed are not so far away from our every day experience. Consequently, in the former, I can do little more than point to a sign post here and there, occasionally indicate the course of the road which has been followed, or describe by an analogy or an example a result which has been obtained.

The older geometry which consisted in the investigation of figures which could be generated under some simple descriptive definition like lines, circles, or conic sections, was greatly extended by Descartes' invention of analytical geometry. In the latter an algebraic statement of the properties gave rise to various classes of curves which could be ordered according to the forms of algebraic statement. Their properties could be investigated with much greater ease. The way was opened also for the consideration of the different kinds of curves or surfaces which possessed some definite general property; the properties common to a given class of curves or surfaces; the relations which may exist between theorems in analysis and geometry; and so on. When the methods of the calculus were added, the range of investigation was again widely extended through its facility for dealing with the properties of tangents and curvature. The new results obtained were undoubtedly instrumental in stimulating investigation from the more purely geometrical point of view. The names of Desargues, Monge, and Poncelet have been already mentioned as the creators of the subject of projective geometry; their work was continued and, during the third decade of the ninetenth century, developed into a separate branch by Moebius, Plücker, Steiner and a host of writers who have followed them. Simple illustrations of the idea involved, are that of map-making in which we represent portions of the spherical surface of the earth on a plane, or that of the shadow of a figure cast by a ray of light. These simple ideas have been generalised by considering the common properties of figures which are projected according to some given law and more generally by correspondences between two or more figures. Another development is that of transformations which leave properties unchanged. It will be seen at once that measurements of actual lengths of lines or metric properties, as they are called, are not those which would ordinarily be unchanged by projection, but this difficulty was overcome by Laguerre, Cayley and their successors.

Differential geometry is in its essence a study of the properties of geometrical figures by investigating the properties of small elements of those figures. Such properties as curvature of a single curve or surface, and those which depend on classes, such as the envelope of a systems of curves, the surfaces which cut systems of surfaces at right angles are the natural subjects of investigation under this head. In 1828 Gauss published a memoir which immensely extended the range of this subject, by introducing new ideas which have been applied to such topics as the deformation of surfaces under given conditions and more particularly to those properties which remained unchanged by deformation. The subject is closely allied to many problems in physics.

Many futile attempts to deduce the axioms of parallels from the other axioms laid down by Euclid led Lobatchewski and Bolyai to see what would happen if a geometry free from this axiom were constructed. The results showed that it could be made quite consistent in all its theorems, that some of the Euclidean theorems would still hold while others would be changed or generalised. Their chief successor was Riemann who showed that all previous geometries were special cases of a more general system. In our own time the subject has been developed in the direction of finding the properties which are possessed by the different geometries and also by investigation of the different sets of axioms which can be used as a basis for constructing different classes of geometries. In the applications to physics the most important has been perhaps the recognition that our own space is not necessarily Euclidean and that we can only find out its nature by examining properties which we are able to observe and measure.

The new developments have not prevented further research on the older lines. Geometry is still much used as a convenient language for the development and expression of analytical results. As seen below, the plane is the home of the complex variable, but in the theory of functions of this variable, it has become many-storied with ladders reaching from one story to another. Most of our physical problems, however, demand the use of three dimensional space and here the complex variable is not sufficient because with our ordinary algebraic rules, there are only two different kinds of numbers, the real and the imaginary, which are used to deal with two different directions in a plane. Hence the theory of vectors which deals with straight lines in any number of dimensions and particularly three has been evolved and is coming more and more into use on account of its brevity and compactness. It requires, however, a new notation to be learnt and a certain degree of familiarity with the operations which are possible.

The older theory of numbers in general dealt with integers and to a less extent with fractions, square roots, etc., that is, numbers which could be formed out of the integers by the ordinary operations of arithmetic. Gauss opened the way to a more extended idea of the meaning which might be attached to numbers by introducing those which are the solutions of an ordinary algebraic equation of any degree, whose coefficients are rational; such numbers are called algebraic. They naturally introduced complex numbers and have properties such as divisibility more extended than those which play a large part in our ordinary number system. This soon demanded a theory of congruences which, in their simplest form are numbers which, when divided by a given factor (called the modulus), always leave the same remainder (a residue). The theory of forms was another development which arose. Since Gauss' time the ideas have been greatly extended to many other kinds of numbers in which special classes have special properties, and these classes are the main subjects of investigation.

The extensive development of the theory of functions of a complex variable is perhaps the most significant achievement of the last hundred years. The imaginary was always arising in such questions as the solutions of quadratic equations and in the new branches. The next step was to give a geometric interpretation of a complex number by showing that it could represent in a single symbol the two co-ordinates of a point in a plane. A function of a complex variable was therefore a function which could take values over an area as against one of a real variable which could only take values along a line. The majority of functions become infinite for one or more values of the variable and these infinities play the major part in the development of the theory. To Cauchy belongs the honor of starting the work in the third decade of the nineteenth century, examining such questions as the possibility of developing such functions in series, their integrals, and the actual existence of functions of different kinds. Closely following him, Weierstrass and Riemann developed Cauchy's ideas, the former by basing his arguments on a special form—a series of powers of the variable—and the latter by using geometrical and even physical ideas for progress. Their successors have merged these different modes of development and have continued to investigate with success the representation of a function under given conditions, and the limitations of a given function. At the same time special functions, particularly those known as elliptic, were being developed by Abel and Jacobi, and the latter extended them in a very general manner. We have now many groups of such functions, some of which have become of sufficient importance to have whole treatises devoted to them.

The study of functions of real variables during the past half century has been largely due to the critical spirit which has compelled mathematicians to examine thoroughly the foundations of the calculus. It consists of "all those finer and deeper questions relating to the number system, the study of the curve, surface and other geometrical notions, the peculiarities that functions present with reference to discontinuity, oscillation, differentiation and integration, as well as a very extensive class of investigations whose object is the greatest possible extension of the processes, concepts, and results of the calculus." (J. Pierpont, Bull, Amer, Math. Soc., 1904, p. 147).

Ever since the invention of the calculus, the relations between two or more variables which contained also their derivatives and known as differential equations, have been continually brought before the eyes of the mathematician by the physicist, owing to the fact that the simplest symbolic statement of nearly all physical problems has been in the form of one or more differential equations. For finding the derivatives or integrals which arose in his work, definite rules were generally available even if they demanded much calculation. But he failed to find such rules for most of his differential equations, and in fact they do not exist. The pure mathematicians, led by Cauchy, took up the question from other points of view asking, in particular, the nature of the function which is defined by a differential equation. This is naturally an extension of the theory of functions and the methods of the latter opened the way. But the questions are so difficult that only a particular form, known as the linear, has made any considerable progress; this form, however, does embrace a large number of the functions whose properties had been examined. In our own generation the subject has been extended by the consideration of equations in which integrals also occur; these again are necessary in certain physical problems.

Most of the progress which has been made in applied mathematics will be treated in the article on Physics, but in addition to the remarks at the close of this article some few words may be said of those branches in the development of which mathematics plays the larger part. The chief of these is the dynamics of a system of particles and rigid bodies. W. R. Hamilton and C. G. J. Jacobi, in the second quarter of the century, put the equations of motion of all such systems into forms which not only permitted of remarkable generalisation, but indicated new methods of integration which opened out research into the general properties of such systems. The later work has been mainly developments and applications of these methods. The particular branch of this subject known as celestial mechanics has been continued on the practical side by extended theories of the motions of the planets and the moon and on the theoretical side by investigations into the general problem of three or more bodies. In the former numerous writers have continued with increasing accuracy the work of the eighteenth century: for the latter new foundations were laid by Poincaré some thirty years ago.

Hydrodynamics has had less success in its applications. The prediction of the tides, chiefly from the work of G. H. Darwin, and the relative equilibrium of liquids in rotation by him and Poincaré have advanced in a satisfactory manner, but the knowledge of the motions of bodies in actual fluids is still in an elementary condition, especially when an attempt is made to apply it to under-sea and air craft. This, of course, refers, not to the experimental side, but to developments from the equations of motion. An interesting, but now almost neglected subject is that of vortex rings in a perfect fluid, the main features of which were given by Helmholtz and Lord Kelvin, giving rise to a hypothesis, now abandoned, that the fundamental atoms of matter consisted of such rings. The motions of our atmosphere have so far defied attempts at explanation on any general plan. The theory of sound, on the other hand, in the hands of Helmholtz and Lord Rayleigh, has been well developed. The theory of elasticity is almost entirely a creation of the present century and has found many applications.

Many of the ideas which are now fundamental in mathematics have had their origin in an attempt to advance some particular branch. Development has proceeded to a certain stage by means of known methods and then stops, owing perhaps to mathematical difficulties or to a failure of those methods to cast further light on it. A new method of attack has then been evolved, showing new roads by which it may be explored, after a time leading to openings which enable the investigator to continue on the earlier lines. These new methods have then been seen to be applicable to various other branches, thus forming connecting links and shedding new light. Indeed, one not infrequently meets with a statement that all mathematics can be based on some one of these ideas. This may be true, but progress demands that the subject be cross cut in many ways: a new country may be opened out by one great highway, but it is only well developed by several main roads in different directions with numerous connecting branches. I shall take up certain of these ideas and try to indicate briefly their bearing on various mathematical topics.

Some illustrations have already been given of the effect which a critical examination of the logical processes used in mathematics has produced. In geometry, the examination of Euclid's axioms has led to the discovery of ideas of space other than those which were current in earlier times. In analysis, algebras have been constructed in which some of the familiar rules have been dropped or changed. The way was thus opened to the examination of the foundations on which mathematics rests. Here the work gets close to a consideration of the mode in which the human brain can think. But without going into this question it is possible to indicate the general method followed at the present time. At the outset a set of statements, usually called axioms or postulates (there is a difference of opinion as to the exact meaning to be attached to these words), is made. These statements may be redundant but must not be contradictory: a complete system is one which contains all the statements necessary for the object in view but which has nothing unnecessary or redundant so that no statement or combination of statements can result in another of the set. To connect and deduce, a system of reasoning is also required. From this it will be seen that mathematical science has no necessary relation to natural phenomena, but that it can be regarded as solely a product of the brain and that its results are simply consequences which may be deduced from ideas without external assistance. The last half century has seen great progress made in clarifying our ideas and in the introduction of rigorous methods of argument. It has now extended to the phenomena of nature, particularly in the direction of a reconsideration of our ideas of time and space and in an examination of our powers of observation, as will be illustrated below.

The idea of invariants has permeated every branch of pure and applied mathematics. In its elementary forms it is not difficult to understand. Natural processes are subject to change but we can nearly always find certain features of them which seem to remain the same in the conditions under which we observe them, as for instance, mass and energy. In geometry, the ratio of the circumference of a circle to its diameter is constant, the ratio of the sections of any system of straight lines cut by three parallel lines is the same, certain properties of a system of curves remain unchanged under given conditions of deformation, and so on. In analysis, one of the commonest modes of investigation is to find out what expressions remain unchanged when a specified change is made in the symbols. It has been said that all physical investigations are fundamentally a search for the invariants of nature. The various terms which occur in modern algebra, such as discriminant, Jacobian, covariant, are special forms of the same fundamental idea.

The idea of permutations and combinations which few of us fail to meet with in our every day experience, was chiefly developed in earlier times from the point of view of the number of arrangements which could be made of a set of objects under certain specified conditions. The modern theory of groups is the natural successor of this subject, but as has so often happened, the point of view and its development have changed. If we have a set of symbols and replace one by another according to a specified law, we can consider what changes will leave unchanged certain combinations of those symbols, as well as the number of such changes which can be made. In doing this we naturally make a connection with the theory of invariants. Such a set of changes is called a group. But a more fruitful idea has been obtained by considering what combinations amongst the symbols, using a specified law of combination, will always produce another of the symbols, and will produce nothing else. As a simple and familiar example, take the series of numbers 0,1,2, . . . with the law of addition. If we add any two of these numbers we always get another of the same series and we never get any other kind of number. The whole of the series is called a group from this point of view. The even numbers form a sub-group under this definition but the odd numbers do not because the sum of two odd numbers is not an odd number. If we use the same series, omitting the zero, with the law of multiplication instead of that of addition, we again have a group, but now the odd numbers form a sub-group. Again we may consider the operation of turning a straight line through 60° in a plane about one end of the line. There are obviously six positions of the line and in whatever one of the six positions we start, a turn through 60° will always give one of the other positions. The whole set constitutes a group.

The idea of a group of substitutions enabled Gabois and Abel, about the middle of the nineteenth century, to open up the way to treat algebraic equations of a degree higher than the fourth and in fact to show that the methods used to solve equations of the second, third and fourth degrees could not in general be applied to those of the fifth and higher degrees. The quintic had long been a puzzle to mathematicians, all attempts to give a general solution in terms of radicals having failed. Later on, Sophus Lie applied the idea of groups to the solution of differential equations and was able to indicate the nature of the solutions in certain general classes. Before his time the methods for finding them had been disconnected and apparently without any common property. Another form of the group theory has been applied with success to the investigation of curves and surfaces and it is not too much to say that the idea has been one of the most fruitful in producing progress. "When a problem has been exhibited in group phraseology, the possibility of a solution of a certain character or the exact nature of its inherent difficulties is exhibited by a study of the group of the problem."[1]

One of the most useful efforts of the nineteenth century mathematicians has been in the direction of proving the possibility or impossibility of performing certain operations or of solving certain problems, that is, in the investigation of existence theroems, as they are often called. The squaring of the circle or the trisection of an angle are two of the oldest of them and later arose the obtaining of a finite numerical expression for the number *e* which is the base of the Napierian system of logarithms and which arises in numerous mathematical and physical investigations. The failure of attempts to solve these problems finally led mathematicians to consider whether they could not be proved to be insoluble under the conditions laid down. Complete success has rewarded them. We now know that with the use of the ruler and compasses alone, it is not possible to find a square which shall be exactly equal in area to that of a given circle, nor given any angle is it possible to construct the lines which shall divide it into three equal parts. The number e too cannot be exactly expressed by fractions or square roots or any other such simple numerical representations, though it can be approximated to as closely as we wish by decimals or in other ways. The labor of useless effort on the part of the mathematician is thus avoided, though we shall still probably continue to hear of those who claim to have performed the impossible. In our time it is quite usual as a part of an investigation to find included in the construction of some new function or in a new representation of a known function, a proof of its existence; especially in those cases where the possibility may be called into question. In celestial mechanics an important part of Poincaré's work consisted in proofs of the existence or non-existence of different kinds of motion and of different kinds of integrals. Indeed we have a considerable class of literature which consists solely in demonstrating the existence of functions or curves with little indication of the methods by which they may be constructed. The stimulating value of such researches in suggesting problems is often forgotten by those who, with some justice, complain of their dullness.

It is strange in connection with existence theorems that some of the problems, most simple in statement, are still unproved. Long ago Fermat stated that there are no whole numbers which will satisfy the statement that the sum of the n^{th} powers of two whole numbers is equal to the n^{th} power of a third whole number, except when n is equal to 2. This impossibility has been proved for all values of n up to 100 and for a few beyond, but no general proof has yet been given that it is universally true. Again, there is no general method which will enable us to pick out the prime numbers, that is, those which are not divisible by any other number except unity. In geometry we have the famous four-color problem in which it is desired to prove that a map consisting of countries of any shape and arrangement can always be painted with four colors so that no two adjoining countries will receive the same color. In these and similar cases, no exceptions to the statements have been found and there exist no complete demonstrations of their possibility or impossibility. It is of course assumed that if they are true

[1]L. E. Dickson, Paris International Congress, Vol. 2, p. 225.

a proof can be constructed without a change of our axioms concerning number or space.

It will be seen from the sketchy remarks of the last few paragraphs that at least one outstanding feature of pure mathematics during the last century has been its emancipation from the trammels imposed by any necessity for application to physical problems. It is, nevertheless, necessary to say a few words about these applications, although the major part of the story naturally comes under the history of physics. Under the general term "applied mathematics," are included at least three methods of study. In the first and simplest, we translate the physical problems into symbols and deduce the consequences we desire by mathematical methods. The work consists, therefore, of little more than an argument on lines laid down by the mathematician. In the second, a study of the formulae and relations which have arisen from physical problems is made, without any special desire to apply them to the phenomena: as indicated above, much of the pure mathematics arose in this way, even before it was recognized that such study was a quite legitimate intellectual exercise. In the third, the mathematical processes used by the applied mathematician are studied in order to find out their limitations, the extent of their validity, what extensions they will admit, how more general methods may be obtained, the best manner of treatment, and so on. This is not by any means an infertile source of progress, as may be illustrated by Poincaré's work on the divergent series which are used to calculate the places of the moon and planets.

The most fundamental change in the attitude of applied mathematicians has been in the recognition and working out of the consequences of simple fundamental principles or laws. Foremost amongst the latter is that known as the conservation of energy, brought into prominence in the middle of the nineteenth century by the labors of Helmholtz and Kelvin. It is now regarded as the chief invariant of the universe and has been applied to every branch of physics. Owing to the various forms which energy can take and to the fact that we are practically compelled, in applying mathematics to a physical problem, to deal only with some partial phase of it rather than with the whole, we cannot always assume that the principle holds in a particular problem. But in the majority of such cases the energy which is lost or changed from the particular form which we are considering is small so that this loss may be neglected or allowed for. When the loss is zero, the differential equations of the problem admit of an integral which expresses this fact. Newtonian mechanics lead to two forms of energy, kinetic (that due to motion) and potential (that due to position) and the development of the mathematics of all material systems has been mainly based on this separation.

The principle of Least Action, enunciated by Maupertius in 1744 but first put into correct mathematical form by W. R. Hamilton a century later, is essentially one which demands mathematical treatment. The Action of a system is a certain function depending on the velocities and relations of its parts which takes a minimum value whenever the system moves under natural laws. The process of discovery of this minimum leads to the differential equations of motion of the system and thus includes a complete statement of the problem. Since the initial form of the function is an integral, its mathematical treatment consists in finding the least value of this integral and thus becomes a problem in the calculus of variations to which considerable attention has been given by pure mathematicians, especially during the last two or three decades. While the physical consequences of the principle have been less developed than those of energy, there appears to be a growing feeling as to its fundamental importance and the aid of the mathematician in solving the problems which it raises, will become increasingly necessary.

The study of the properties of a system containing a large number of particles not fixed relatively to one another, now generally studied under the term, statistical mechanics, has penetrated into several branches. It is to be understood here that the question is not one of finding the separate motions of the various particles but to try and find out such properties of the system as can be deduced from averages. It is probable that as long as we cannot observe the motions of the separate particles, we should be able to deduce in this way most if not all the properties of the system that we are able to observe. Maxwell and Boltzmann founded the subject from this point of view, applying it to the kinetic theory of gases, while J. W. Gibbs was largely responsible for its application to thermodynamics. In astronomy the present century has seen it applied to the motions and positions of the stars, thus opening the way to a knowledge of the outlines of the construction of the stellar universe. Mathematically these questions are obviously very similar to those parts of probability which deal with errors of observation and thus form a continuation of the development of that subject.

The mathematics of continuous media has received very complete development during the century and, besides the earlier investigations into the motions of fluids and elastic solids, has been applied to the so-called luminiferous ether and finally by Maxwell to the whole electric field. In all this work the continuity of the medium is a fundamental axiom involving the hypothesis that no action can take place without its presence. Further, the Newtonian laws of motion were assumed as fundamental and time and length were regarded as unchangeable separate entities. The classic experiment of Michelson and

Morley which showed that the velocity of light was apparently independent of the velocity of the medium in which it travelled, and observations on the motions of certain particles with very high velocities, started a reconstruction of ideas. It was possible to explain the results on the assumption that the length of a body depended on its velocity. It was then that Einstein sought to generalize Newton's equations of motion by making them entirely relative, not only for uniform velocity, but also for accelerated motion. By adding the assumption that the laws of nature should refer to all such systems of reference and by making the velocity of light a fundamental constant of nature, he was finally able to generalize the whole subject. Matter appears simply as a form of energy. Gravitation can be exhibited as due to a warping of space without the introduction of force, but if this is so, the Newtonian law requires a minute correction. The motion of the perihelion of Mercury and the bending of a light ray as it passes near the sun have given remarkable confirmation of this theory. His work crosscuts several subjects which previously had an interest only for the pure mathematician, in particular the theory of extensible vectors (tensors) and the theory of invariants. His differential equations for the gravitational field should supply mathematicians with problems of great difficulty and interest for some time to come. Those for the electric field are unchanged. A further interesting product of this work on relativity lies in the question of what we can or cannot observe and in what may be deduced from observation without the assumption of hypotheses. This is, of course, fundamental in all experiments, but it has received little attention as an exact science. Given that we can only observe certain properties of a function, what limitations is it possible to make in the construction of the function?

Finally the quantum theory of Planck, according to which energy is not infinitely divisible but is always received or emitted in exact multiples of a fundamental unit, is bringing forward the necessity for a calculus allied to that of finite differences as against the differential and integral calculus which depends in general on continuity. It is even suggested that not only energy, but also space and time have ultimate parts which cannot be divided. At present the mechanics of this theory is in a very nebulous state but as a statement of the results of observation it has had very considerable success. The construction of the atom is now generally exhibited as a kind of minute solar system, but there is as yet no indication how such a system can only permit of the limited number of motions required by the quantum hypothesis. It may perhaps be due to fundamental instabilities for we know little of the ultimate stability of most of the motions in the problems of even three particles. In any case, the field of work has approached one of the oldest of mechanical problems and the reaction of celestial mechanics on that of the atom should prove stimulating to both.

DEMOCRATS AND ARISTOCRATS IN SCIENTIFIC RESEARCH

By Dr. ESMOND R. LONG
UNIVERSITY OF CHICAGO

MOTIVES, methods, and enthusiasm in approaching and conducting scientific research certainly are as widely different as those in any other form of public endeavor. This is perhaps obvious enough to those accustomed to think in research terms. The public at large, it may be said, does not think in such terms, and has an indistinct notion as to what scientific research is. And this is not to be wondered at, for the public at large is not in the habit, not to mention the mood, of following scientific publications and so is largely dependent for its information upon a daily press, out of its depth entirely where science and exact truths are concerned. Much of the press knows a great scholar and gentleman, William Osler, chiefly, if not solely, for a chance, half-chaffing remark on longevity. In guileless simplicity it hails an untried adventurer sailing for southern seas in search of the "missing link" as a new Darwin, and it will continue in sublime ignorance of the stupendous amount of scientific material submitted to a critical world by that retiring but superhumanly able observer, to regard the distinguished biologist as the one original "monkey man" of all time.

Yet a public so educated, even with the movie scientist as the prototype of the species, dimly classifies research men into two groups. The one, alert to the present, includes the physician driving with all the power of his trained mind toward the achievement of a "cure" for one of mankind's maladies, and the engineer or botanist contriving methods which will make the desert blossom as a rose. In the other, we find an irresponsible person, perhaps damned with faint praise as an intellectual, given to investigating minute details of unimportant subjects, fussy and irritable if disturbed in his meditations or laboratory procedures, and prone to have beautiful if undeserved daughters, popular and addicted to the habit of staying out late nights. And after all, with some modifications, the classification holds, if one deserts the movies and views the latter creature on his own plane. It is this group, the science-for its-own-sake and knowledge-as-its-own-reward crowd, that we may designate as the aristocrats of science, in contradistinction to that other class, impatient, often as closely altruistic as it is given to man to be, who from their ardent endeavors in the direction of popular demand and rigid dependence on the wishes of the *people*, may be labeled with the over used and much abused word democrat.

In the passing of William Osler and Emil Fischer of Berlin, science has in the past year lost two of the foremost minds of the century. Widely different in their fields of scientific endeavor as well as in their manner of cultivating them they may serve to illustrate anew the distinction drawn above.

Osler spent his life among people, giving to the full of his own strength and skill in the personal effort at the bedside, and outside as a great organizer. He was a member of innumerable societies and committees with the avowed purpose of promoting human welfare in one form or another. His objects are understandable to all. To heal the sick, to prevent suffering, to teach others to do the same, these are things that come within the range of common experience. He was a profound student of tuberculosis and every one knows what tuberculosis is, of typhoid fever, and diseases of the heart. A layman picking up his papers of twenty years ago on cancer of the stomach could see at a glance what he was driving at, might recognize the cuts, and with a little effort understand something of the pathology. His great textbook which went through many editions, has traveled far, being often seen on the "Science Shelf" in the smallest of village libraries. His name is familiar consequently to some of the most superficial of readers and because of the nature of his subject he is a person to them, where to the same individuals Fischer would be "a book."

The enthusiasm he aroused in his students is characteristic of the man. His own life-long student's attitude-that same spirit which used to lead him to say, "And now let us see where we made our mistakes," as he marched into the old autopsy room at Montreal-kept him on earth as far as his pupils were concerned and made him approachable to all. There was a very human touch to his work that belonged not merely to its nature but perhaps much more to his treatment of it. It must have been a primal urge, something essential in the man, which led him to devote himself to the people in such a way. His campaign must have been for end results, however interesting the preceding discoveries were of themselves. If he studied typhoid fever, in the last analysis it must have been with the object of preventing typhoid fever and making it unnecessary to study it, not for the mere acquisition of knowledge of typhoid fever for its own sake. Twenty years ago, commenting on the waste of life from this disease due to ignorance and neglect, he said, "Very different from death which comes with friendly care to the aged, to the chronic invalid, or the sufferer with some incurable malady, is that from typhoid fever. A keen sense of personal defeat in a closely contested battle, the heart searching dread lest something had been left undone, the pitifulness of the loss, so needless—

and as a rule in the 'morn and liquid dew of youth'—the poignant grief of parents and friends, worn by the strain of anxious days and still more anxious nights—these make us feel a death from typhoid fever to be indeed a Delian sacrifice. For fifty years the profession has uttered its solemn protest as I do this day; we have done more—we have shown how the sacrifice may be avoided and the victims saved." The marked decline in the incidence of typhoid fever in late years, due to the combined efforts of medical men, sanitary engineers, and public health officials, must have given Osler untold satisfaction.

But if William Osler was a public personage whose life played a part, great or tiny, in that of every one of us who has known what it is to be sick, what shall we say of the incomparable Emil Fischer, perhaps the greatest organic chemist who ever lived, whose place in the history of his science will be secure when Osler's in the development of his, is centuries forgotten? How many have heard of Emil Fisher? In his own group, chemists and biologists, he has for a generation sat on the highest tier of the seats of the mighty, and yet his place has been quite without the public ken. A supreme investigator who undertook the most fundamental and most difficult problems of his science, he carried on a labor which by its very nature has been inexplicable to the average man. To be sure the average man would not wish it explained to him, would resent it deeply if forced to listen to such dry stuff. But he is safe. No newspaper in the country would be competent to discuss it for him. The pathetic attempts of the daily press to keep up on the relatively simple subject of poison gas in the late war and the rude caricatures of chemical nomenclature which finally found their way to the proof reader and past him, merely serve to emphasize this point.

Let us see if, without being too technical, we can show how it was that Emil Fischer came to stand so high above the crowd. Forty-five years ago Fischer discovered phenyl hydrazine, an accomplishment which alone would have sufficed to give him some fame, but in the hands of its discoverer phenyl hydrazine became a tremendous weapon, a 42 centimeter gun, a whole park of them in fact, for a war on the ultimate nature of the carbohydrates. These last substances are of immeasurable importance, making up as they do the bulk of matter in the vegetable world, including the sugars, starches, wood and various intermediary bodies. With the different sugars, scores in number, into which all of these substances can be ultimately resolved, phenyl hydrazine yields characteristic crystalline precipitates, permitting relatively easy identification. Be it said, once and for all, however, that Fischer did not pack up his phenyl hydrazine and his polariscope and enter the sugar business, nor did his altruism lead him to desert theoretical fields and apply his trained mind to the production of cheap sugar for the people. What Fischer was interested in was the composition, the structure of sugars, and to few men has it been given to penetrate the subject so deeply. Molecules of the sugars, like those of all substances, are composed of atoms which stand to each other in definite relations in space. The molecules, that is to say, the essential units of a certain group of sugars, all contain six atoms of carbon, twelve of hydrogen and six of oxygen, and yet the group includes several distinct substances because the arrangement of these atoms in space is different. For instance, one possible difference in arrangement is that in which the atoms of two molecules are so disposed that the three dimensional molecule of one is the mirror image of the other. When the likeness is so close the properties are identical, except for one feature. A ray of light which has been "polarized" by passing through a Nicol prism is bent to the right by one form, by the other to the left. With greater variation in the arrangement greater differences in chemical properties are noted. Abstruse matter this, and all theory, for no piling up of lenses has ever been sufficient to enable man to gain a faint glimpse of one of these hypothetical molecules. Yet the theory stands, and by virtue of the enormous number of predictions made upon its basis which were later realized by experiment. And to Fischer, using the sugars, is due much of the credit for the establishment of this, the so called Van't Hoff and LeBel hypothesis.

The study of sugars led him to the substances that in nature act upon them, the enzymes or ferments, substances like the diastase which acts upon starch converting it into glucose. That enzymes are specific in their action had long been known, but it remained for Fischer to demonstrate how high that degree of specificity is. To one of a pair of extremely closely related substances, differing only in a slight variation in the arrangement of their atoms in space, a given enzyme is neutral, while acting readily upon the other. A slight change in the latter renders it, too, insusceptible. The proof of this led Fischer to the conclusion that enzymes act upon their substrates through exact spacial approximations, his famous key and lock analogy.

So much to show the nature of Fischer's work, to indicate the type of mind of the man. It was by no means the only, or even the largest, problem this brilliant and versatile chemist undertook. In another class of compounds, the proteins, was a chaos which seemed of inconceivable complexity until Fischer pointed the way through. Proteins are peculiarly biological; without them there would be no life, and differences in protein are probably ultimately responsible for differences in living forms, inasmuch as protein must carry the hereditary characteristics. They are found in greatest bulk in the animal kingdom, though not confined to it, and include such well known substances as egg white, the casein of milk, and flesh of all forms. In the analysis of these proteins, involving breaking them down and identifying the products, Fischer played a great part, his greatest contribution being the development of a method which enabled others to expedite the solution of the colossal problem. Difficult as the analysis has been Fischer was at the time of his death in a fair way of accomplishing the reverse, the synthesis or reconstruction of a highly complex protein from its split products, a tremendous conquest of the world of the unknown.

One more glimpse and we shall leave the subject of Fischer's work and place our label on the man. Combined with certain proteins in that mysterious portion of the living cell which apparently governs the latter in its chief actions, the nucleus, is a substance called nucleic acid, characterized in part by the presence of certain bases, the purines. The familiar uric acid is a member of this group. Fischer, working on uric acid and the related substance, caffeine, synthesized both, and not only them but all other members of the group. It was a work of prime importance chemically and brings up for our consideration a special point. Fischer commercialized his artificial synthesis of caffeine, that substance both praised and reviled, and made many thousands of dollars. The emphasis placed upon this associated his name in many minds, especially those of medical men, with the substance caffeine, and in superficial biographical treatment it has been customary to list its synthesis along with his other great accomplishments and on the same plane. As a matter of fact it must be thought of as purely by the way. Beyond question what really counted in Fischer's mind was not the synthesis of this isolated substance but the unshrouding of the relations of that whole group of compounds of which caffeine was but an ordinary member, making the previously confused subject as clear as the light of day.

Fischer was an aristocrat in scientific work if there ever was one. No man can explain this devotion to his science. We can perhaps say that the ability created the desire, but most men work for rewards, and what was Fischer's? Fischer made money, but no sum of money could be adequate pay for the superhuman accomplishments of the man, nor did he make a tithe of what he might have made had he tried. He saw himself in the front rank of scientific men, but the contemplation of that spectacle must have palled upon his cold judgment. The only thing that remains is the thing itself. Pushing back the horizon of knowledge was its own reward.

Scores of other pairs might be cited to illustrate the grouping over and over again. A fascinating book might be written by plagiarizing a method from Plutarch and setting down side by side the biographies of great scientific men, laboring on similar lines, devoted to different points of view. We could thus pair off contemporaries, and going closer, warm friends, and sometimes master and pupil. What could be more characteristic than the distinction in the attitude of Darwin and his brilliant spokesman, Huxley? On the one hand, we have the quiet naturalist of Down turning over in his mind for twenty years observations made on the voyage of the Beagle, and the culmination of that reflection in the scientific torpedo of the nineteenth century, *The Origin of Species.* And on the other, stands the rugged Huxley, self-appointed champion for truth, the most lucid scientific writer of the day, meeting all comers in defense of the theory of evolution, nay, going much further, carrying war into the enemy's country, extending his campaign beyond the field of biology and evolution and, through the medium of the public press, hammering into public consciousness the scientific method in general. In Darwin's own words in his autobiography we have this; "I think I can say with truth, though I cared in the highest degree for the approbation of such men as Lyell and Hooker, who were my friends, I did not care much about the general public. I do not mean to say that a favorable review or a large sale of my books did not please me greatly, but the pleasure was a fleeting one, and I am sure that I have never turned one inch out of my way to gain fame." He must have been regardless of public approbation who spent eight weary years on the Cirripedia, describing all known living species, and publishing two quartos on the extinct species, and who passed from the *Origin of Species* to a book on the "Fertilization of Orchids." But Huxley was different. Brilliant investigator that he was himself in the field of pure science, he cared more for something else. The education of the masses was the supreme thing. He fought to give the people the truth at a time when they did not want it, and how he came up from the bottom is appreciated by few of the succeeding generation who take his victory for granted.

We might confuse the issue a little and pair off Sir Humphry Davy and his pupil, the immortal Faraday, perhaps the most lovable man science has ever produced, and, if we except Pasteur, the favorite of all biographers, Faraday, who never knew what it was to have a decent income, and presented to the world a set of scientific experiments the cash value of which to mankind was estimated by Brailsford Robertson some years ago at seventy five billions of dollars. For to Faraday we owe the motor and the dynamo.

Which was Faraday? The aristocrat surely, we say when we recall that he repeatedly dropped his investigations when they neared the point of marketable value. But he never lost sight of the latter. "I had rather," he said, "been desirous of discovering new facts and new relations dependent on magneto-electric induction than of exalting the force of those already obtained, being assured that the latter would find their full development hereafter." And when asked of the possible utility of some of his discoveries he was wont to reply in the words of Franklin, "What is the use of a baby?" And it is on record too that in dispute over the priority of certain scientific discoveries he stood resolutely on his rights on more than one occasion.

And Davy, baronet and pet of society, aristocrat in the common acceptance of the term—which was he? "A philosopher" he was in the old terminology, and the "philosophers" were mostly aristocrats in science. His fame rests chiefly on his discoveries in electro-chemistry, but we can not forget the ten years of lecturing in the cause of agriculture and his own experiments for its promotion. And there is the deliberate and successful attempt to produce a safety lamp for miners, followed by the presentation to him of a set of plate worth two thousand pounds by the coal owners of the Tyne and Wear in testimony of their appreciation of the benefit thus conferred. And we know that his last great scientific endeavor was an effort based on exact deduction from the laws of electro-chemistry to protect the copper sheating of vessels from the corrosive action of sea water. Vain and selfish he may have been, but he must have had the interest of the people at heart, and so we can place that to his credit against his oft cited jealousy and ill treatment of his rising, more brilliant pupil, Faraday.

Probably the greatest scientific democrat in history is Louis Pasteur. No more patent testimony of public affection for a scientific man has ever been given than that expressed in the recent French plebiscite on the greatest man of the nation, which went easily to Pasteur with Sadi-Carnot and the great Corsican running second and third. And yet, as we have defined the term, Pasteur began his researches as one of the aristocrats; it was his brilliant success in a field of pure science which laid the foundation and directed the way for his later, more famous, investigations on the etiology of disease. It was in the course of his highly technical work on the optical rotation of the salts of tartaric acid that he discovered the fact that of its isomers one form is destroyed by fermentation, and the other not. These isomers, like the sugars described above, differ from each other simply in the arrangement of the same atoms in space. He thus anticipated by many years Fischer's classic work on enzymes. But in their application of the facts thus secured is strikingly emphasized the wide divergence in the point of view of the two men. Fischer's work on ferments constantly led back to the theory of sugar structure. With Pasteur's successful solution of his problem he turned the page and with new interest in fermenting bacteria entered upon that lifelong endeavor to thwart the action of pernicious microorganisms that has made him one of the greatest benefactors of mankind.

How he passed first to the relief of stricken industry, adopting means, based on his discoveries in bacteriology, for the cure of "diseases" of beer and wine, and of the fatal silkworm disease, and thence to the extermination of those plagues, fowl cholera and anthrax, which were wiping out the flocks and herds of France, saving to the country in a matter of months the equivalent of the Franco-Prussian war debt, and thence to preventive vaccination in man, has been the theme of a score of biographies and many an inspiring address. The life of this non-medical man is held up as a shining example by the most intolerant of professions for the guidance of its students and future fellow physicians.

Commenting on aims in scientific research the famous British chemist, Roscoe, chose a text from Pasteur to bear him out in his contention that although it would be foolish and short-sighted to decry the pursuit of any form of scientific study because it was as yet far removed from practical application to the wants of man, yet discoveries which tend to diminish the ills that flesh of man or beast is heir to, deservedly create a more general interest than those having no direct bearing on the welfare of the race. In the French hero's simple words, "There is no greater charm than to make new discoveries, but the pleasure of the investigator is more than doubled when he sees they find direct application in practical life."

The same year that Pasteur graduated from the Ecole Normale in Paris a young German physician, but a few months older, read, before the physical society of Berlin, one of the two epoch-making scientific contributions of the century, "Ueber die Erhaltung der Kraft" rivaled only by the *Origin of Species* in its effect upon thought. The notion of the Conservation of Energy may not have originated in the precocious intellect of Helmholtz, for Newton, DesCartes, Leibnitz, Lavoisier, Mayer, Colding and Joule had more than touched it, but it surely crystallized there. It remained for a physician to desert his chosen field for a theoretical one and establish the fact that energy, although it may be transformed in kind, is indestructible, and the total quantity in the universe is constant. The physiologist was also a mathematician of the first order.

Perhaps the most frequently cited achievement of Helmholtz is his invention of the ophthalmoscope, that familiar combination of mirror and lenses used in examination of the interior of the eye. How did he come to devise it? As a matter of fact it took its origin in a simple desire to exhibit a physiological phenomenon to his students. It had long been known that light could be reflected from the back of an animal's eye, but no one had yet been able to put his own eye in such a position as to have reflected directly back to it light from the illuminated eye in concentrated form. Helmholtz, by the proper disposition of mirrors, involving a knowledge of optics and the anatomy of the eye, accomplished this for the first time, and, eight days after he conceived the desire to show it to his students, he was the first to see the living human retina.

While following the invention of the ophthalmoscope, Helmholtz was occupied for some years with physiological optics, it can not be said that it "set" his career as it might have done with another man, as for instance his invention of the stethoscope did with Laennec. The latter putting a paper cylinder to a consumptive girl's chest discovered that through it he could hear the sounds of moisture vastly better than by direct application of the ear. Here was a method, and the young clinician devoted the rest of his own all too short consumptive's life to diseases of the chest. Helmholtz turned the so called practical application of his ophthalmoscope over to the clinicians and busied himself with the discovery of new facts and explanation of old, quite regardless of their direct application to the ills of man. The physics was the more attractive field than the pathology, and to the end of his life he gravitated more and more from the latter toward the former, until the boy of twenty-eight, who started out as a professor of physiology and pathology at Königsberg, became at fifty the dominating figure of the time in physical science as professor of physics in Berlin. While he was one of the masters of medicine, his contributions were toward theory and not practise, his name being associated in the science chiefly with the explanation of vision and hearing and the theory of color and tone. That immeasurable practical use of his discoveries is being made goes without saying. But it is indeed a fortunate thing for mankind that the superb intellect of Helmholtz was not turned into the superficial channels of practical usage but was left free to explore the unknown depths below.

In later years his trend of thought took him more into the field of dynamics and electro-dynamics, bringing him back to the direct course on which he started forty years before with his immortal essay on the Conservation of Energy. His intellectual goal was never a democratic one. He felt it his duty as a disciple of science to ascertain truth for its own sake, and no man more strongly decried the pursuit of science merely for the practical results. His clear exposition of the principles of the transformation of energy furnishes the index of his character, and, whatever the practical applications of the principles thus enunciated may be, we can not avoid the impression of something essentially aristocratic in a young man of twenty-six killing for all time with one blow, the idea of a machine for perpetual motion.

Obviously the points of view of Pasteur and Helmholtz were fairly far apart. This does not mean that the one was consistently democratic and the other at all times aristocratic in the sense defined above, throughout their long lives of scientific research. Many times the rôles were reversed. Helmholtz contributed a practical remedy for nasal catarrh, and Pasteur evolved a theory of the essential nature of fermentation. But the dominant note of each was as given above. Pasteur burnt himself out in the effort to bring relief to a mankind patently suffering before his eyes. Helmholtz consumed his candle more slowly, pursuing the even tenor of his way without committing himself on his sympathies.

Undoubtedly the distinction is but vaguely general, and perspective may be needed to bring it out. Undoubtedly there are no pure types. Scientific men, goaded by poverty or other considerations, may and often do change the direction of their researches, like the rubber synthesist of "Marriage." The war brought out many a quiet man from purely academic life to construct a poison gas, or detect a submarine, or relieve a starving people. But most of these men have gone back. The will of the people was temporarily irresistible. But characters were not changed much. A certain group are altruistic from the start, and do not need to explain their motives. The other group are exclusive and do not try to explain theirs, except to each other. They isolate their intellectual lives to a certain extent, in all the pride of an aristocracy based on achievement rather than accident. The achievement is the increase of knowledge, and that is both goal and prize.

THE CONDUCTION OF RESEARCH

By F. H. NORTON

CHIEF PHYSICIST, NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH may be defined as the process of intentionally looking for something new; the value of some physical constant, a new material, or a method of performing some operation. According to its purpose, research can logically be divided into two classes; the first is pure research which includes the study of the properties of natural objects, such as the determination of atomic weights, the distance of a star, or the development of plants and animals, while the second may be termed industrial research which includes the development of a material having commercially useful properties, or the refinement of a process so as to increase its output or decrease its cost. Such a division can not of course be strictly held to, for the two classes intermingle at times, as there are a great many cases where an investigation, starting as pure research, later developed industrial possibilities. In fact there are very few pieces of pure research that do not sooner or later offer valuable contributions to the industries.

A very large portion of the modern development in science is due to systematic research. While it may be true that some highly interesting facts are stumbled upon in the realm of science, it is the thorough, painstaking investigations conducted at our government, university and industrial laboratories that in the last twenty years have given us such a remarkable insight into the structure of matter and the universe.

Engineering, which has in the past, clung to cut and try methods, is beginning to realize the value of trained men and well-equipped laboratories in solving its problems. Perhaps no division of engineering has advanced as rapidly in this respect as aeronautics, comparatively a very new subject, and yet, because of its exacting demands, has caused the development of methods so advanced that they may well be borrowed by the older branches. Commercial enterprises of all types are developing research by organizing their own laboratories or by financing the research laboratories of the universities. Many concerns are devoting five to ten per cent. of their profits to research, and some have laboratories employing scores of trained men. The industrial research laboratory is past the experimental stage and is recognized as a sound financial asset.

Research may also be divided according as it is definite or indefinite, that is, whether or not it is known beforehand what is being searched for. An example of the first class would be the determination of the melting point of an element, while the development of a machine for making bricks belongs to the second. The first class is the more straightforward, so that the program can be planned in advance with the possibility of only minor changes, and the final result will be uncertain only in its degree of accuracy. A research of the second class is more difficult, as it is a process of trial and error, the most hopeful ideas being tried out until by the knowledge gained from previous failures, a successful result is obtained. But, unfortunately, in this class of research a successful result can not be guaranteed in advance, and consolation must sometimes be obtained by the knowledge that a well tried failure is a step ahead.

Perhaps the first thing to do when commencing a piece of research is to make a thorough study of the available literature on the subject; first, to get new ideas, and, second, to prevent the repetition of methods that have been found unworkable. On the contrary, there are certain types of original thinkers who claim that they do not wish to know what any one else has done on the subject, as they believe that this knowledge will hamper the freedom and originality of their work. This manner of working certainly leads to much needless duplication and is not to be recommended except for very special cases. It is unfortunately true that many statements appearing in print are in error, due to poor experimentation, wrong conclusions and arithmetical blunders, and it is strange how long these erroneous statements are accepted. There are many instances where results of this type have been quoted several times by other authors before their absurdity has been made evident. It is, therefore, advisable to take all information on trial, and to take no one's statements for granted without giving them a thorough examination.

After all the important information has been reviewed and carefully analyzed, a plan, or several alternative plans, can be laid out for the most promising manner of attacking the given problem. Although the plan will undoubtedly have to be revised or even completely changed during the progress of the investigation, it is much better to have a definite program to start with than to work along in a haphazard manner, principally because of the training gained by the experimenters in an orderly procedure. It is foresight and anticipation of difficulties at this time that saves endless complications later on, and the value of a research director depends on his ability to keep his men from getting into trouble, or, if this is impossible, to get them out as quickly as possible. The more experience one has had in research the more clearly can he visualize the subsequent procedure, and the final results.

If the research being undertaken is of a simple character the only apparatus needed will be of a standard type that can be readily obtained, but in most cases it will be necessary to build special apparatus. There are two ways to design research apparatus; the first, is to lay out an expensive and elaborate design on the drafting board without experimental trial of any of its parts, the second, is to carry on the experimental work as far as possible with inexpensive, temporary means, until the soundness of the method is assured, and then designing the apparatus from the knowledge gained in this manner. The first method may work out satisfactorily but more often it does not, and an expensive instrument or machine must be greatly altered or scrapped. The second is not as rapid nor as convenient, but it is safe and sure and should certainly be used unless there is a large fund of past experience to draw from in regard to that particular subject.

After the general type of apparatus is decided upon, there is its detailed construction to consider. If it is to be used for only a short time, there is no need to go into elaborate design, or neat finish; the main points to think of are cheapness and quickness of construction and ample opportunities for making alterations. It is always best to rebuild a standard type of machine if possible, and it is surprising how a little ingenuity will make a working device out of the most common parts. It is natural that an experimenter should desire to have an original and neat piece of apparatus, but first it should be determined whether the increased efficiency in operation will warrant the necessary expense. However, it is often the case that a little extra expense if applied efficiently to finishing a piece of apparatus will effect a saving in the end by preserving it from the attacks of moisture or chemical fumes. At the same time a well finished job, even though it will not actually give more accurate results, takes it out of the home made class, and gives to the report illustrated by its photographs, a workmanlike tone that is of the greatest value in raising the standard of that particular investigation. Although an expensive and well finished instrument does not assure excellence in the experimental work, yet the person reading the report is unconsciously affected by the appearance of the apparatus, crude apparatus being associated with uncertain results. On the other hand, there is undoubtedly a tremendous amount of money spent each year on unnecessarily elaborate machines and instruments, but the waste is usually due more to the fact that the complete design is unworkable, than that the elaboration is unnecessary.

There are other types of research that extend indefinitely into the future, using principally the same apparatus in all the tests. Examples of this are tests of material strength, or model testing is towing basins or wind tunnels. In these cases the conditions are far different from the isolated investigation, and it is simply a question of how far it will be advisable to go, in using automatic and recording devices to reduce the personnel required in the testing. For example let us consider a wind tunnel balance for measuring three forces and three moments on an airplane model. Ordinarily two men operate the balance, reading two of the required quantities at a time. If it were a question of time, the balance might be arranged to use six observers who would read the six quantities simultaneously, but this would increase the operating expenses. The next improvement would be an automatic balancing arrangement so that one observer could record all six quantities, but this would require a much more expensive balance. If it was desired to reduce the labor still further, the work of several draftsmen could be dispensed with by making the balance record and plot all six quantities, a process that is actually quite simple to do, but which would require still more additions to the balance. The elaborateness of a piece of apparatus, then, will depend largely on how much it will be used, for there would obviously be no use in building an expensive and labor saving machine for a few experiments, nor would it be economical to use a cheap and inconvenient machine for an extended series of investigations.

Another particular that should be kept in mind when designing apparatus is a construction that will make the calculation of results simple and convenient. It very often happens that a small change in an otherwise excellent instrument will save days, and perhaps weeks of computation. As an example of the importance of this, it may be stated that in a certain investigation on an airplane in free flight, the data was collected in less than ten hours of flying, but required the time of three men for four months to work up the final results, and there are other experiments where the ratio is even greater than this.

The economy of having a well equipped research laboratory is soon demonstrated by the saving in time and expense in setting up for an experiment, and the older a laboratory is the more apparatus there is accumulated from which to select. In any experimental work a large junk pile is invaluable, and until this is collected, the true experimenter cannot work efficiently. The laboratory should have a shop of its own, or immediate access to one, equipped to do the class of work desired, as the ability to easily get small parts constructed or alterations made is of the greatest importance in the efficient conduction of research. Nearly all classes of research require in some way the application of photographic methods, so that a dark room is a valuable, sometimes a necessary adjunct to the laboratory.

With the construction of the apparatus completed, we come to the actual carrying out of the research. The first thing to do is to set up and try out the apparatus and to determine with what accuracy the results may be depended upon. It is good policy, especially in extended experiments, to take plenty of time in the beginning to get all parts in reliable operation, or much time and accuracy will be lost later on by breakdowns. Often times a slipshod arrangement is allowed to stand with the hope that it will hold together during the test, but nothing can be more discouraging than to find at the completion of a long run that some little thing had gone wrong and rendered the results useless.

Perhaps it would not be out of place at this time to touch on the subject of precision of measurements. It is believed that a lack of understanding of this subject leads to a large amount of extra work being done, and accuracy sacrificed, in many branches of research. There is obviously no use in obtaining data, or of computing results, to a much higher degree of accuracy than the least precise component, and it is the neglect to find the precision measure of this component that leads to much needless computation. On the other hand, it sometimes happens that if the least precise component were recognized it could be obtained with greater precision, thus increasing the accuracy of the whole experiment. It often happens, too, that certain factors having only a slight influence on the results, are either recorded when their effect is smaller than the errors in the other factors, or they are neglected when that effect is larger than the errors introduced from all other sources. For this reason, every condition that can in any way effect the final results, should be carefully analyzed, not only to determine whether it can safely be neglected, but to find out how closely it need be measured if it can not be neglected.

The successful carrying out of an experiment requires the constant checking up of the data obtained, in order to detect an error before it has invalidated a long series of runs. It is only by constant vigilance that errors can be excluded from the work, and it is the ability to detect irregularites that will cause future errors, or to detect the errors themselves before they can cause trouble, that distinguishes the true experimenter. For example, let us consider a certain test to determine the effect of varying the aspect ratio of a model airplane wing in the wind tunnel. The procedure consisted in making a test, then cutting off a small length of the wing, and repeating the test, continuing the process until the span of the wing was reduced to a small amount. It would be extremely unwise in an investigation of this kind to collect all of the values without working up the data and constantly comparing it with the preceeding results each time before cutting off the wing. Otherwise, it might be found that one or more of the runs did not agree with the rest, due to a lack of alignment or to some other type of error that is apt to creep into any experimentation. After the wing had been cut down, however, it would be too late to make a check run and the whole test would be invalidated or at least made to appear of doubtful value.

Before beginning an experiment care should be taken that everything is functioning properly, and that all disturbing factors have been taken into account. Never take a chance, as every research man should realize that not only his reputation, but that of the organization with which he is connected, is endangered by his mistakes, and he should under no conditions allow results to come from him, unless he is very sure of their correctness.

It might seem unnecessary to bring up the subject of honesty in research, for there would seem to be very little reason to give results deliberately in error. It has often happened, however, that an experimenter has shaded the values of his readings to make them come closer to what he supposed was the true value, but he often finds later, that he has gone in the wrong direction, and readings taken in this way will give neither the true mean nor the probable error. Sometimes this squeezing of results up or down is done quite unconsciously, and for this reason when it is desired to make a check run, the results of the first run should never be in sight, or it will not be a true check, even though the recorder is not in any way intentionally dishonest.

When it is desired to determine the accuracy of certain data, or to be assured that it lies within the permissible limits of accuracy, it is customary to make two or more runs under identical conditions, the difference between the values obtained in each being an indication of the accuracy that may be expected. This does not, however, tell the whole story, as it does not take into account those errors in the design or setting up of the apparatus, or the individualities of the experimenters. For this reason, it is always well when making a check run to reset the apparatus or, better, to use a different piece of apparatus and different observers, in which case the results may be considered to give a true indication of the probable error from all sources. It often happens that a certain set of facts are not obtainable in a direct or simple manner, nor is the best method that can be devised entirely satisfactory. In such cases it is always best to obtain the results in several different ways, and, although none of them may be satisfactory, yet, if the several results show an agreement, it may be concluded with certainty that they are correct. Even in the more straightforward investigations, wherever possible, the results should be checked up by an alternative method, as this is an excellent way to make others have confidence in the data.

Next to accuracy, the most important consideration in research is efficiency, that is, the obtaining of the largest amount of results for the least expenditure of time and money. Efficiency can only be attained by the careful laying out of the work, the careful determination of what is necessary to do to get the required accuracy, and, most important, to have a smooth running organization. The laying out of the work consists in ordering materials, having apparatus designed and constructed and deciding on the methods to be used. The laying out of the work in a manner to promote efficiency depends largely on the foresight and experience of the experimenter or research director. For this reason, it is false economy to employ low grade or inexperienced research men, as the saving in the pay roll is more than offset by the decreased value of the results and the increased cost of the investigation.

As time is usually as important an item in efficiency as cost, the ordering of necessary supplies should be accomplished as early as possible, and when big delays are impossible to avoid because of the lack of some material, it may become necessary to alter the experimental methods in order to be able to proceed within a reasonable time. It is very costly to have everything set for performing an experiment, and then to find that some small but vital thing has been forgotten which will take weeks to procure. All phases of the preliminary work should be constantly checked over and the most delaying items followed up vigorously.

The previous discussion of efficiency has been confined to a single piece of research, but usually a number of investigations are going on together in one laboratory, perhaps a separate group of men working on each research, or a group alternating between several types of work as conditions permit. In this case it is the duty of the research director to arrange the work not only so that every one will be kept busy, but so that each man will be working to the best advantage. Every one is more or less of a specialist, and it is of considerable advantage to have each person kept as far as possible on one type of work. This can not, of course, always be done, but by carefully laying out the work ahead in this respect, it will be possible to have the men working in their most efficient positions a large part of the time. The same thing applies to pieces of standard apparatus such as balances, testing machines, etc., so that the work should be planned to use the equipment as efficiently as possible.

In regard to the selection and training of the research personnel, it will be best to first discuss the types of men available, exclusive of their particular training. In the first place men may be divided rather sharply into two classes, the first we will call practical, and the second, theoretical. The first class have mainly gained their knowledge from experience, are mechanically inclined and know how to use their hands, while the second class have obtained their knowledge almost exclusively from books and have very little commonsense in regard to mechanical matters. For example, one of the theoretical class may be able to make a complex computation of the stresses in a certain small bolt, and yet when screwing in the same bolt he will calmly twist its head off, simply because he has no mechanical sense. The latter are a type that are of great value in mathematical work, computations and the writing of reports, but when it is attempted to use them on purely experimental work, their efficiency is greatly reduced. It is far easier to teach one of the practical class to work efficiently on theoretical problems, than is to teach one of the theoretical class to work efficiently with their hands. It is quite necessary to have experimenters who can be trusted with delicate apparatus without having constantly to fear for its safety.

Some men are naturally hustlers and possess initiative enough to make themselves of value with very little supervision, and some go so far in this direction as to require constant restraint to keep them from getting beyond their depth, but this quality is on the whole a good one, and should be directed rather than discouraged. On the other hand, there are men who will take no responsibility and need constant pushing to keep them working efficiently, but wherever possible it is better to lead than to force. If a person is really interested in his work, and by interested, I mean the ability to derive pleasure from thinking of the problems evolved outside as well as inside of working hours, he requires no pushing and very little directing, so that the whole problem of successful administration lies in getting the staff interested in the problem on which they are working.

As far as possible it is best to give to each man a definite job, and make him responsible for it; giving him the credit when it is successfully completed. This stimulates interest and originality, and is much better than a constant supervision down to the smallest details, a method that is likely to produce ill feeling and retard the development of the experimenter. Of course, an inexperienced man can not be efficiently put on to a new subject without considerable supervision, but this supervision should be instructive rather than destructive, and as soon as he shows himself capable of handling the work he should be left to carry on alone. When, as is often the case, a number of men are working on one problem each one should be encouraged to acquaint themselves with the work of the others in order to obtain a more general view point.

It often happens in research work that certain portions of it, such as computations, are exceedingly monotonous and it would certainly be an injustice to give all of this portion to one man, so that it is always best to distribute this kind of work among the investigators, unless, of course, some of the men are especially hired for this, and have no experience fitting them for other work. There are some types of research that can be most efficiently carried out by a single person working exclusively on that job, but in the majority of cases it is better to concentrate a number of men on the problem, not only to finish it up and get it out of the way quickly, but because a man is apt to get into a rut when working alone. There are some experiments that require a high degree of manipulative skill and to these should be assigned the type of man who is naturally handy with his hands. Conversely there are problems of a mathematical nature that would be exceedingly irksome to the preceding type, whereas the theoretical type could handle them efficiently. It is the problem, then, of the research director to so arrange the work that each man of his staff will be working to the greatest advantage.

Undoubtedly the most important quality that any experimenter can have is persistence. There are many problems that require months and perhaps years of hard, discouraging work before the first ray of success can be discerned, and in such cases it requires the utmost faith in the ultimate result to enable one to keep up his interest. It is only by the careful, systematic elimination of each obstacle as it comes up and the direction of the work continually into new and more promising channels that will make successful what to the less determined experimenter would be a failure.

Perhaps it will not be out of place to say a few words about the presentation of results. In the first place, the data should be given, wherever possible, in graphical form. There are some instances where the accuracy of the results is greater than can be represented by a plot, in which case the data must be also given in tabular form, but in most cases a curve is sufficient and the tables may be omitted. When plotting curves, no points should be used except those directly computed from the experimental results, as the practice of some very reputable laboratories of taking points from a faired curve as the basis of plotting is very misleading as to the regularity of the results. On the other hand, no experimental curve should be shown without including the actual points, otherwise the results can not help but be regarded with suspicion. It is always better to present a few well checked results than a multitude of irregular ones.

One of the secrets of experimentation is to know when to stop, for it is a natural tendency to carry the work further than the value of the additional results will warrant, and it is inefficient to allow a nearly finished piece of research to drag along. There is of course, no definite point where a piece of work can be considered finished, and often times one feels that he is in a position to efficiently commence the work only when the allotted time or money is exhausted. For this reason one of the most important functions of an investigation should be the paving of the way for more extended work. Therefore every report should contain an account of the difficulties encountered, and most important the recommendations of the experimenter for the conduction of further research, for every difficulty, and every failure, should be made of value by preventing others from encountering the same obstacles.

It is urged that every investigation that produces results of interest or value be published or in some way be made available to those who are interested. It now happens, especially in the industrial laboratories, that much work is done which is never known outside, and there is generally no reason why the results should not be published after the particular organization has received its benefit. Because of this practice a great deal of money is spent in duplicating work that has been already accomplished, and, while a certain amount of duplication is valuable as a check, it is in general very uneconomical. In the same way, it sometimes happens that similar investigations are undertaken simultaneously, and, although their results are later published, it means an unnecessary duplication. In this particular it would be of great value to have a research clearing house where all the work in preparation could be gathered together for general information.

It may be stated in conclusion that the carrying out of a piece of research will comprise in general the following procedure: First, the similar work of others is studied, especially their difficulties and failures, and from this information a plan of operation is laid out. And if there is any doubt, and there usually is, as to the practicability of the proposed methods, preliminary experiments should be conducted, from which data are obtained for use in designing apparatus and for more completely planning the subsequent procedure. In carrying out the actual work, the first consideration should be accuracy and the second, efficiency, both depending on suitable equipment and on an interested and well-organized staff. Lastly, the experimenter must organize his results, and deduce from them conclusions that will be of value in joining them with similar work and in advancing the theory and practice of the subject. Briefly, successful conduction of research depends on the foresight and vision of the experimenter in laying out the work, his accuracy, persistence and manipulative skill in carrying it out, and, lastly, his analytical ability in deducing conclusions from the results.

A BIOLOGICAL EXAMINATION OF LAKE GEORGE, N. Y.

By Professor JAMES G. NEEDHAM
CORNELL UNIVERSITY

DURING the summer of 1920, the New York State Conservation Commission maintained a field laboratory on Juanita Island in Lake George. The writer was placed in charge. Dr. Chancey Juday of the University of Wisconsin, was at the laboratory in August studying temperatures, plankton, and dissolved gases of the lake at different depths. Dr. Emmeline Moore, of the Commission, was detailed to assist in the work of studying the food of fishes and of tracing it back to its sources in the lake vegetation of the shores and of the plankton. State Fish Culturist, Mr. John W. Titcomb, of the Commission, was also present during August studying fishes. Messrs. Charles K. Sibley, of Kingston, N. Y., and William R. Needham, of Ithaca, were regular assistants at the laboratory during the whole of the season. Visiting naturalists who participated to some extent in the work of the laboratory at times during the summer were Mr. S. C. Bishop, New York State Zoologist, of Albany; Professor C. R. Crosby and Dr. M. D. Leonard, entomologists of Cornell University; Miss Sue J. Reid, secretary of the Chicago Nature Study Society, and Miss Jay R. Traver Supervisor of Nature Study at Wilmington, Delaware. The object of this laboratory was to determine conditions in the lake affecting the life of food and game fishes. A report has been made to the commission on fish cultural matters. And at its completion it has seemed to the writer that a number of observations made in the course of this work that are of a more general scientific sort might be helpful to other field naturalists and ought to be placed on record: hence, this paper.

The water of Lake George is "soft"; and the dominant plants and lesser animals are quite different from those of the lakes in Central New York. Doubtless the most abundant plant in the lake—the one that bulks largest—is the stonewort *Nitella opaca*. It occurs at depths between 18 and 45 feet and covers scores if not hundreds of acres of the lake bed between these depths. It forms great meadow-like beds of erect or recumbent, soft, translucent bright green stems often three or four feet long. These beds (called "grass" by the local fishermen) furnish shelter and support for a large population of sessile algae; for case-inhabiting insects, such as caddis worms and midge larvae; for free-living animals such as mayflies, snails and scuds, and for sessile hydras and rotifers. About these beds most still fishing is done by the initiated.

Other stoneworts observed by us were all found in quite shoal water—less than 10 feet—and the most interesting of them was the extremely delicate and remarkably pretty *Nitella batrachosperma* that occurred at 5 feet, on beds of yellow ripple-marked sand, and swayed in passing waves with all the aspect of a bright green frog-spittle This occurred sparingly but was found by us in places as wide apart as the head of Northwest Bay, the south shore of Juanita Island and the outlet channel below Baldwin. Two species of Chara also were found in the shoals.

In the lake bed below the level of the Nitella zone there grow two peculiar and characteristic green algae. One is a "Siphon alga" *Dichotomosiphon* that at 40 to 50 feet in depth is so abundant as to be a nuisance to the lake trout fishermen: the lead bob of their trolling apparatus gathers the tangled and matted threads of this plant about it and brings them to the surface in slimy dripping handfuls. This is what the fishermen know as "moss." Dr. Moore is publishing elsewhere an account of this species. The other alga, a species of *Cladophora* invades the depths where hardly any light penetrates. Its minute branching sprays usually about a fourth of an inch long and of very bright green color may be found sparingly, lying amid the bottom sediment at almost any depth in the lake below the shoals.

The most abundant filamentous alga of the shore is a species of Tolypothrix which fairly covers submerged stones and timbers with its little tufts of brownish-green swaying threads, always and everywhere interspersed with masses of gelatinous palmelloid forms. Among the coarser waterweeds hornwort and elodea are quite scarce and the fine tall-growing *Potamogeton praelongus* is conspicuous, forming some of the most beautiful weed beds of the lake. These weed beds occur mainly at depths of 10 to 15 feet. They shelter forms similar to those of the Nitella beds and many additional, including two interesting waterfleas, *Acantholeberis curvirostris* and *Eurycercus lamellatus*. The latter is abundant enough and large enough to form an important item in the diet of some of the adult game fishes of the lake.

In the plankton of the lake, diatoms of four genera were probably the most important food gatherers. Asterionella, Cylotella, Tabellaria and Fragillaria. Other algae less constant but occasionally abundant were Anabaena, Aphanizomenon, Aphanocapsa, Botryococcus, and Staurastrum. Among the cladocerans, which all season through were far more abundant than copepods, Bosmina was rather common throughout the season, Polyphemus became abundant for a time in

July, Holopedium attained an extraordinary dominance the latter part of July and two species of Daphnia replaced it in late August. On July 14th a net of No. 6 silk drawn for a few minutes in the lake gathered a solid pailful of Holopedium in a nearly pure culture. A few Leptodoras and a few Daphnias were present besides.

We found some good collecting grounds for aquatic plants and animals; and it may benefit some future naturalist who is visiting Lake George for the first time if I mention a few of them. First of all, Juanita Island itself, our headquarters, has most interesting shores. On the west the rocks rise vertically out of the water; on the north they run down in gently sloping serried low ridges of solid rock, smooth and bare as far as the breaker line; on the northeast is a broad smooth sandy beach in a sheltered bay (here was our bathing beach); on the south is a shore line of broken rocks and at the east this merges into a narrow beach of ripple-marked sand. Eastward of the Island is a deep current-swept channel, and northward is a more sheltered cross channel in which the "grass" and "moss" of the fishermen are found. There are scattering growths of Potamogeton, Ceratophyllum and Heterantheria below the breaker line (which occurs here at about 5 feet below the surface) and just above it grow Valisneria, Eriocaluon, and Lobelia.

There is a very interesting admixture of small plants growing in the rippled sand about the dock and at the edges of the beach within the bay. The most abundant plant present is one of the least conspicuous, *Myriophyllum tenellum*, a true sand-binder of the shore, whose tufted, slender interlaced stems lie buried in the sand, and whose many leafless red branches rise erect but an inch or so above the surface, and, draped with tufts of filamentous algae, are most inconspicuous. More in evidence is the little creeping *Elatine americana*, that formed close-growing patches the size of a silver dollar on the surface of the sand, and that is fairly covered in August with minute blossoms. Intermixed with it, and likewise persistently blossoming is the curious little cruciferous quillwort, *Subularia aquatilis*, which grows erect to a height of perhaps an inch above the surface of the sand. Another pygmy component of this inch-high vegetation is the slender creeping spearwort, *Ranunculus flammula filiformis* which here spreads by stolons about an inch long in single lines of progression over the sand. Another is an undetermined closely tufted spike-rush, whose roots bear numerous slender little brownish tubers.

There are also scattering plants of taller stature here; bushy little sprays of *Nais flexilis*, pinnate sprays of *Potamogeton perfoliatus* and *P. heterophyllus*, the latter having when grown two or three oblong leaves that reach the surface. There are small tufts of eelgrass, *Valisneria spiralis*, in the more exposed places on tufts of two species-of quillwort, *Isoetes* and *I. tuckermann macrocarpa* in the edges: there are also similar tufts of *Sagittaria graminea* with only the stubby basal leaves developed. But where there is sufficient shelter to avoid burial of its tuft-forming leaves by the sand, the pipe wort, *Eriocaulon articulatum,* comes in and forms a complete ground cover. About the edges of the mats of pipe wort are always a few water lobelias, *Lobelia dortmanni,* and the slender white stems of the former and the purple stems of the latter shoot upward together to the surface at flowering time in August.

At the west and about the charming little Boquet Island large fresh-water mussels abound wherever there is enough soil accumulated among the rocks to give them footing; and a little farther away to the southward the clay bottom about the Ranger Pool is fairly covered with a little translucent white clam, *Sphaerium tenue,* having siphons of a charming rose-pink color.

Shelving Rock Bay on the eastern shore of the lake a mile south of Pearl Point is a very fine collecting ground, having in close proximity a large variety of aquatic situations. A charming mountain brook, spring fed and full of trout, enters the head of the bay. A storm-wave reef across the head encloses a marsh of a few acres mostly overgrown with sweet-bay, but having small areas of open water, where pike and bullheads spawn. So great is the abundance and variety of marsh life found here that I can hardly specify particulars. I will only mention the abundance of desmids among the algae, and of the clusters of the bryozoan, *Lophophus crystallinus,* about the bases of emergent sweet-bay stems.

The bay itself has a broad quietly-sloping wave-swept sandy beach, one of the finest on the lake for a bathing beach. Further out toward Iroquois Island, in 35 feet of water are fine beds of *Nitella opaca* and just beyond that Island the bottom drops away to nearly 200 feet. Northward behind Log Bay Island is a sheltered harbor, and on the way into it are some fine mussel beds and then broad shoals densely covered with pipewort.

At the head of Northwest Bay on the west side of the lake, where another mountain stream enters through marshy lowlands there is another rich collecting ground. Here young fishes and minnows are exceedingly abundant, and everything that is needed to fed them is here also. Submerged logs in the stream are plastered over with colonies of the bryozoan, *Pectinatella magnifica.*

At the foot of Black Mountain on the eastern shore is *Chives Rock,* so called from a species of chives (Allium) that is said to grow in the narrow crevices that traverse its broad face. It presents a broad flat surface to the waves and rises directly out of rather deep water. We found this an especially good place to get a line on the lotic insects of the lake. Many of these, which are not easily collected from the lake, climb up the flat surface of this rock to transform and leave their cast skins clinging there, most of them within reach from a boat anchored at the foot of the vertical cliff. In an hour's collecting I gathered a great number and variety of those belonging to two species of stone-flies, several species of Heptagenine mayflies, three species of dragon-flies, and I noted scores of adult orl-flies, *Sialis infumata*, entangled in the spiders' webs that clung to the face of the rock. The most unexpected find here was four skins of the fine Corduline dragonfly, *Neurocordulia obsoleta*.

Doubtless there are other good collecting grounds on the lake: these are the ones we know about. A single season was not time enough for a very wide acquaintance. The clustered bays about the southeast corner of the lake, where occur the most extensive beds of shore vegetation, and where we did several days' collecting, are doubtless rich fields also.

It seems a bit strange that a body of water that is so easily accessible and that is visited annually by so many thousands of people, should be so little known biologically. Apparently not even a list of its fishes is anywhere available. Yet the islands are mostly state-owned and are offered freely for camping sites. Three passenger boats each way daily with frequent stops make any part of the lake easy of access. A grocer's boat making a circuit of the camps several times a week helps to solve the forage problem; and it would seem that these things should bring more naturalists to this, one of the most beautiful and one of the cleanest of American Lakes.

THE HISTORY OF SCIENCE AS AN ERROR BREEDER

By Professor G. A. MILLER
UNIVERSITY OF ILLINOIS

WHILE the rôle of the history of science as an error exterminator is much more significant than its rôle as an error breeder, it is necessary to consider it in both of these lights in order to understand its bearings completely. If a comparatively harmless pest destroys pests which are more harmful than itself, it is desirable to consider the injuries which it inflicts as well as the services which it renders. The services that the history of science renders as an error exterminator have received much attention, especially in recent years, but its mischievous rôle as an error breeder seems to have received only little public notice, hence it may be profitable to consider here some striking evidences of this rôle.

In these days of great specialization in science, it is scarcely necessary to emphasize Sir W. Hamilton's dictum "the greater the extension the smaller the intension." All scientists are aware of the fact that it is a very difficult matter to secure a deep and satisfactory intellectual penetration even in a comparatively small domain of science. If one desires to obtain a comprehensive view of the fundamental developments in a larger domain, such as chemistry or mathematics, one has to take much for granted that has been said by others but has not been fully verified by oneself. This method of procedure has to be followed still more by those who strive to secure comprehensive views as regards the fundamental developments in science as a whole.

The highly commendable attitude of mind which seeks to understand the broad lessons taught by science as a whole and to secure a comprehensive view not only of the scientific work now being done in various countries but also of the work done during the preceding ages presents a great contrast when compared with that actuating the extreme specialist when working in a field which he has made his own. It is true that the historian of science is not always actuated by the former attitude of mind. He, too, has his special problems and ponders profoundly over some of the elements in his work. As regards these particular elements he stands on a par with the specialists in other fields.

The historian of science is compelled, however, when he is called upon to treat science as a whole, or even a large domain thereof, to take much for granted which he cannot verify on account of lack of time. It is here where the breeding of errors makes its appearance. The historian is greatly tempted to state interesting and striking facts. He finds that many such facts have been emphasized by the specialists, but he naturally fails at times in his efforts to interpret the language of the specialists. The next historian who tries to interpret the words of this earlier historian frequently misses the correct interpretaion still more, and hence statements conveying an entirely false notion tend to creep into the general histories of science.

As pure mathematics is the most exact science it may perhaps be assumed that the history of this subject is the most accurate among the histories of the various sciences. At any rate, it seems desirable to illustrate some of the preceding observations by examples of such an elementary type that they can be easily understood by all. The history of mathematics furnishes many such examples since some of its early permanent developments belong to a period when the mathematical specialists dealt with questions which all could easily understand. These specialists had not then raised themselves to great intellectual heights by standing on the shoulders of other specialists, who, in turn, stood on the shoulders of earlier specialists in almost endless succession.

To furnish a striking but somewhat extreme illustration of the fact that the mathematical historian is apt to repeat statements which he does not fully understand, it may be noted here that on page 165 of the third edition of Cantor's well-known *Vorlesungen über Geschichte der Mathematik*, 1907, it is stated that the Greeks used the term *epimorion* to denote the ratio $n/(n+1)$, and that "Archytas had already stated and proved the theorem that if an epimorion, α/β is reduced to its lowest terms, which may be called μ/ν, then $\nu=\mu+1$. It is evident that this remark is practically meaningless, for if α/β is an epimorion then it is obviously already in its lowest terms according to the definition of the term epimorion just noted, which seems itself to be incorrect. Notwithstanding this obvious lack of clearness, the statement appears again on page 53 of the second edition of Cajori's *History of Mathematics*, 1919, in spite of the fact that G. Eneström had in the meantime directed attention to its inaccuracy in volume 8 of the *Bibliotheca Mathematica*, 1917-1918, page 174.

An important feature of the history of science is that many statements made therein are intended to be true only in a general way, while others are supposed to be exact, and the reader has frequently to decide for himself to which of these two classes a particular statement is supposed to belong. For instance, one can usually not determine accurately who was the founder of a large subject since steps towards its development were commonly taken by a number of different men. On the other hand, such statements as "Newton and Leibniz were the founders of the calculus" have an important historical significance. One might almost say that such incomplete assertions constitute the meat of a general history of science. When it is remembered that they are supposed to represent only first approximations to the truth they can not be regarded in the light of actual error breeders, even if they are apt to have this effect temporarily, especially on beginners.

The significance of many statements in the history of science grows with the growth of the reader's breadth of knowledge relating to the subject involved. Statements which at one period of his scientific development would have appeared satisfactory may not appear so at a later period. It is, of course, impossible for an author of a general history of science to provide for these various stages of development, but there are instances where such authors have failed to provide a satisfactory account for any of their readers irrespective of the stage of their scientific development. While such instances are comparatively rare and do not necessarily impair seriously the works in which they appear they may serve to illustrate the general topic under consideration and are unusually interesting in themselves. Hence we give here one such instance relating to mathematics during medieval times.

On page 314 of Hankel's *Geschichte der Mathematik*, 1874, it is stated that "the first mathematical paper of the Middle Ages which deserves this name is a letter of Gerbert to Adelbold, bishop of Utrecht." In view of the fact that we are now living in an age of numerous scientific papers, this remark by Hankel should be of great interest at the present time. Such interest is reflected in the fact that F. Cajori quotes this remark in the two editions of his *History of Mathematics*, 1894 and 1919, respectively, as well as in the two editions of his *History of Elementary Mathematics*, 1896 and 1917, respectively. Hence the American reader of the history of science is seriously exposed to the danger of assuming that the said remark by Hankel represents a well-established historical fact.

Such an assumption does not imply that the said letter by Gerbert, who died as Pope Sylvester II in 1003, contained any new mathematical results, since there are now expository mathematical papers as well as research papers. It does not imply that the letter in question was long, since there are now many brief mathematical papers as well as long ones. It does, however, imply that this letter was superior to the many other mathematical writings which had appeared during the four or five centuries which had then elapsed since the beginning of the Middle Ages.

It is true that such a superiority even in so long a period of years does not imply very much, since this particular period was unusually barren as regards mathematical developments. Notwithstanding this comparative barrenness, it includes a few noteworthy oases created especially by the Arabs in algebra and in trigonometry. In particular, the work from which our modern term algebra is derived was composed during this period, and the work of several well-known Hindu writers appeared therein. Hence the reader seems justified for having somewhat high expectations as regards the mathematical importance of Gerbert's letter if it actually deserves being called "the first mathematical paper of the Middle Ages." In fact, the non-mathematical reader might be inclined to fear that the mathematical merits of this letter were too great to lie within the limits of his comprehension.

These expectations and fears are apt to be enhanced by the reading of the accounts of Gerbert's letter in some of our most popular histories of mathematics, including the ones already noted. Not only is it stated here that this letter contained a *correct* explanation for the difference of the results obtained by using two different formulas for the determination of the area of an equilateral triangle, but some of the other statements relating to this letter are sufficiently obscure and misleading to arouse the suspicion that the subject treated therein might possibly be difficult. In various instances the obscurity is increased by the fact that figures of triangles which are not equilateral are given, while the text relates to an equilateral triangle. This is done, for instance, on page 249 of Günther's, *Geschichte der Mathematik*, 1908, as well as in the three editions of volume I of Cantor's well known *Vorlesungen über Geschichte der Mathematik*, pages 744, 815 and 866, respectively.

From the preceding remarks the reader will naturally conclude that the present writer does not believe that the letter in question merits to be called "the first mathematical paper of the Middle Ages which deserves this name," notwithstanding the fact that this epithet has been applied to it by eminent authoritities. In fact, the present writer believes not only that the letter does not merit this epithet but that it is of so little mathematical importance as to make it appear ridiculous to make such a claim for it. Moreover, he believes that other statements made about this letter in well-known mathematical histories are strikingly inaccurate. In order to establish the correctness of this point of view, it is necessary to state just what is found in the part of this letter which has been preserved, upon which our view of its merits must be based.

In view of the great claims made for this letter, the reader will naturally be surprised to find that it deals with the very elementary question of finding the area of an equilateral triangle, a question which had been completely solved many centuries before. Gerbert gives here the rule that the altitude of such a triangle can be found by subtracting one-seventh from its side, which is a sufficiently close approximation for many purposes, since the altitude is $^{a}/_{2}\sqrt{3}$, where a is the side. He then states, in substances, that the area of an equilateral triangle is one-half of the product of the base and the altitude thus obtained, and he calls this the "geometric rule" for finding such an area.

Thus far there is nothing surprising in this letter, and no one seems to have claimed much credit for this part, but Gerbert then makes some very inaccurate and foolish remarks about finding the area of such a triangle by another rule, called the "arithmetic rule," and it is just upon these remarks which exhibit a great lack of geometric insight that the high claims of this letter have been based. The inaccuracy of these remarks had been noted by M. Chasles in his well and favorably known *Aperçu Historique*, 1875, page 506, but notwithstanding this fact various later mathematical authors, including all those noted above, have called them correct in their general histories.

In order to appreciate the crudeness of this "arithmetic rule," which is equivalent to the formula $\frac{1}{2}a(a+1)$, it may be noted that in the work of the Egyptian Ahmes, written about 1700 B. C., the area of an isosceles triangle seems to have been found by multiplying one-half the base by a side instead of by the altitude. This method has been regarded as remarkable on account of its crudity, but when we are told that more than two thousand years later the Roman surveyors were taught to find the area of such a triangle by finding the product of one-half of the numerical measure of the base and a number which is even larger than the numerical measure of another side, there seems to be sufficient ground for surprise even in a scientific matter.

It must be admitted that the instances cited above are insufficient to establish the fact that a general history of science is an unusually favorable ground for the breeding and the propagation of scientific errors. In fact, all that has been attempted here is to advance a few reasons why one might suspect danger here, and to support these reasons by illustrations which were assumed to be also of interest to the reader on account of their unusual intrinsic features. Perhaps a more conclusive argument in support of the thesis in question is furnished by the fact that G. Eneström noted more than two thousand desirable changes relating to the general history of mathematics by M. Cantor, to which reference was made.

THE BIOLOGY OF DEATH. III—THE CHANCES OF DEATH[1]

By Professor RAYMOND PEARL
THE JOHNS HOPKINS UNIVERSITY

1. The Life Table

UP to this point in our discussion of death and longevity we have, for the most part, dealt with general and qualitative matters, and have not made any particular examination as to the quantitative aspects of the problem of longevity. To this phase attention may now be directed. For one organism, and one organism only, do we know much about the quantitative aspects of longevity. I refer, of course, to man, and the abundant records which exist as to the duration of his life under various conditions and circumstances. In 1532 there began in London the first definitely known compilation of weekly "Bills of Mortality." Seven years later the official registration of baptisms, marriages and deaths was begun in France, and shortly after the opening of the seventeenth century similar registration was begun in Sweden. In 1662 was published the first edition of a remarkable book, a book which marks the beginning of the subject which we now know as "vital statistics." I refer to "Natural and Political Observations Mentioned in the Following Index, and made upon the Bills of Mortality" by Captain John Graunt, Citizen of London. From that day to this, in an ever widening portion of the inhabited globe we have had more or less continuous published records about the duration of life in man. The amount of such material which has accumulated is enormous. We are only at the beginning, however, of its proper mathematical and biological analysis. If biologists had been furnished with data of anything like the same quantity and quality for any other organism than man one feels sure that a vastly greater amount of attention would have been devoted to it than ever has been given to vital statistics, so-called, and there would have been as a result many fundamental advances in biological knowledge now lacking, because material of this sort so generally seems to the professional biologist to be something about which he is in no way concerned.

Let us examine some of the general facts about the normal duration of life in man. We may put the matter in this way: Suppose we started out at a given instant of time with a hundred thousand infants.

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 30.

equally distributed as to sex, and all born at the same instant of time. How many of these individuals would die in each succeeding year, and what would be the general picture of the changes in this cohort with the passage of time? The facts on this point for the Registration Area of the United States in 1910 are exhibited in Figure 1, which is based on Glover's United States Life Tables.

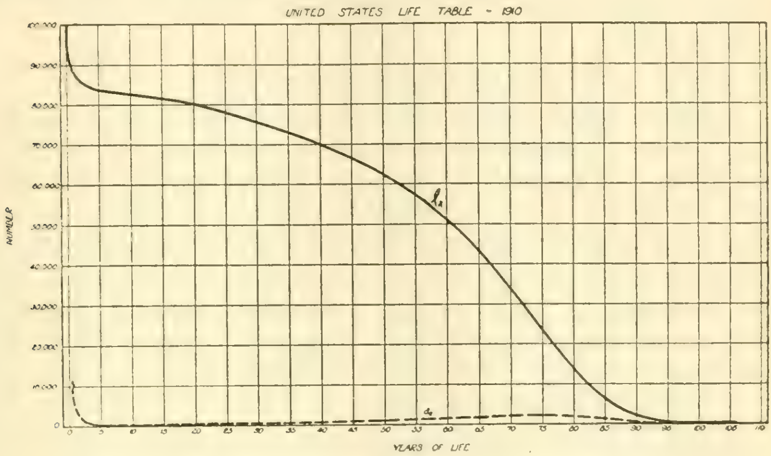

FIG. 1. LIFE TABLE DIAGRAM. FOR EXPLANATION SEE TEXT

In this table are seen two curved lines, one marked l_x and the other d_x. The l_x line indicates the number of individuals, out of the original 100,000 starting together at birth, who survived at the beginning of each year of the life span, indicated along the bottom of the diagram. The d_x line shows the number dying within each year of the life span. In other words, if we subtract the number dying within each year from the number surviving at the beginning of that year we shall get the series of figures plotted as the l_x line. We note that in the very first year of life the original hundred thousand lose over one-tenth of their number, there being only 88,538 surviving at the beginning of the second year of life. In the next year 2,446 drop out, and in the year following that 1,062. Then the line of survivors drops off more slowly between the period of youth and early adult life. At 40 years of age, almost exactly 30,000 of the original 100,000 have passed away, and from that point on the l_x line descends with ever increasing rapidity, until about age 80, when it once more begins to drop more slowly, and the last few survivors pass out gradually, a few each year until something over the century mark is reached, when the last of the 100,000 who started so blithely across the bridge of life together will have ended his journey.

This diagram is a graphic representation of that important type of document known as a life or mortality table. It puts the facts of mortality and longevity in their best form for comparative purposes. The first such table actually to be computed in anything like the modern fashion was made by the astronomer, Dr. E. Halley, and was published in 1693. Since that time a great number of such tables have been calculated. Dawson fills a stout octavo volume with a collection of the more important of such tables computed for different countries and different groups of the population. Now they have become such a commonplace that elementary classes in vital statistics are required to compute them.

2. Changes in Expectation in Life

I wish to pass in graphic review some of these life tables in order to bring to your attention in vivid form a very important fact about the duration of human life. In order to bring out the point with which we are here concerned it will be necessary to make use of another function of the mortality table than either the l_x or d_x lines which you have seen. I wish to discuss expectation of life at each age. The expectation of life at any age is defined in actuarial science as the mean or average number of years of survival of persons alive at the stated age. It is got by dividing the total survivor-years of after life by the number surviving at the stated age.

In each of the series of diagrams which follow there is plotted the approximate value of the expectation of life for some group of people at some period in the more or less remote past, and for comparison the expectation of life either from Glover's table, for the population of the United States Registration Area in 1910—the expectation of life of our people now, in short—or equivalent figures for a modern English population.

Because of the considerable interest of the matter, and the fact that the data are not easily available to biologists, Table 1 is inserted giving the expectations of life from which the diagrams have been plotted.

TABLE I.

Changes in expectation of life from the seventeenth century to the present time.

Age	Average length of life remaining to each one alive at beginning of age interval.			Age	Average length of life remaining to each one alive at beginning of age interval.		
	Breslau, 17th century.	Carlisle, 18th century.	U. S. 1910		Breslau, 17th century.	Carlisle, 18th century.	U. S. 1910
0 - 1	33.50	38.72	51.49	50-51	16.81	21.11	20.98
1 - 2	38.10	44.67	57.11	51-52	16.36	20.39	20.28
2 - 3	39.78	47.55	57.72	52-53	15.92	19.68	19.58
3 - 4	40.75	49.81	57.44	53-54	15.48	18.97	18.89
4 - 5	41.25	50.76	56.89	54-55	14.99	18.27	18.21
5 - 6	41.55	51.24	56.21	55-56	14.51	17.58	17.55
6 - 7	41.62	51.16	55.47	56-57	14.02	16.89	16.90
7 - 8	41.16	50.79	54.69	57-58	13.54	16.21	16.26
8 - 9	40.95	50.24	53.87	58-59	13.06	15.55	15.64
9 -10	40.50	49.57	53.02	59-60	12.57	14.92	15.03
10-11	39.99	48.82	52.15	60-61	12.09	14.34	14.42
11-12	39.43	48.04	51.26	61-62	11.62	13.82	13.83
12-13	38.79	47.27	50.37	62-63	11.14	13.31	13.26
13-14	38.16	46.50	49.49	63-64	10.67	12.81	12.69
14-15	37.51	45.74	48.60	64-65	10.20	12.30	12.14
15-16	36.86	44.99	47.73	65-66	9.73	11.79	11.60
16-17	36.22	44.27	46.86	66-67	9.27	11.27	11.08
17-18	35.57	43.57	46.01	67-68	8.81	10.75	10.57
18-19	34.92	42.87	45.17	68-69	8.36	10.23	10.07
19-20	34.26	42.16	44.34	69-70	7.91	9.70	9.58
20-21	33.61	41.46	43.53	70-71	7.53	9.17	9.11
21-22	32.95	40.75	42.73	71-72	7.17	8.65	8.66
22-23	32.34	40.03	41.94	72-73	6.85	8.16	8.22
23-24	31.67	39.31	41.16	73-74	6.56	7.72	7.79
24-25	31.00	38.58	40.38	74-75	6.25	7.33	7.38
25-26	30.38	37.86	39.60	75-76	5.99	7.00	6.99
26-27	29.76	37.13	38.81	76-77	5.79	6.69	6.61
27-28	29.14	36.40	38.03	77-78	5.71	6.40	6.25
28-29	28.51	35.68	37.25	78-79	5.66	6.11	5.90
29-30	27.93	34.99	36.48	79-80	5.67	5.80	5.56
30-31	27.35	34.34	35.70	80-81	5.74	5.51	5.25
31-32	26.76	33.68	34.93	81-82	5.86	5.20	4.96
32-33	26.18	33.02	34.17	82-83	6.02	4.93	4.70
33-34	25.59	32.36	33.41	83-84	5.85	4.65	4.45
34-35	25.05	31.68	32.66	84-85		4.39	4.22
35-36	24.51	31.00	31.90	85-86		4.12	4.00
36-37	23.97	30.32	31.16	86-87		3.90	3.79
37-38	23.43	29.63	30.42	87-88		3.71	3.58
38-39	22.88	28.95	29.68	88-89		3.59	3.39
39-40	22.33	28.27	28.94	89-90		3.47	3.20
40-41	21.78	27.61	28.20	90-91		3.28	3.03
41-42	21.23	26.97	27.46	91-92		3.26	2.87
42-43	20.73	26.33	26.73	92-93		3.37	2.73
43-44	20.23	25.71	25.99	93-94		3.48	2.59
44-45	19.72	25.08	25.26	94-95		3.53	2.47
45-46	19.22	24.45	24.54	95-96		3.53	2.35
46-47	18.72	23.81	23.82	96-97		3.46	2.24
47-48	18.21	23.16	23.10	97-98		3.28	2.14
48-49	17.71	22.50	22.39	98-99		3.07	2.04
49-50	17.25	21.81	21.69	99-100		2.77	1.95

Figure 2 gives the results from Halley's table, based upon the mortality experience in the City of Breslau, in Silesia, during the years 1687 to 1691. This gives us a picture of the forces of mortality towards

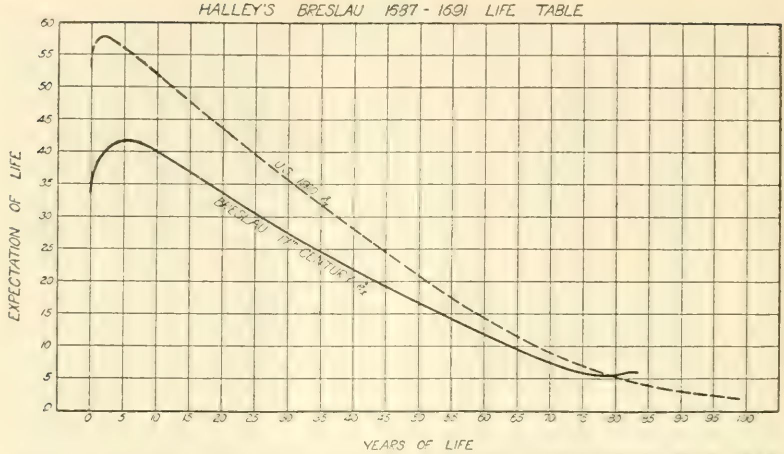

FIG. 2. COMPARING THE EXPECTATION OF LIFE IN THE 17TH CENTURY WITH THAT OF THE PRESENT TIME

the end of the seventeenth century. From this diagram it appears that at birth the expectation of life of an individual born in Breslau in the seventeenth century was very much lower than that of an individual born in the United States in 1910. The difference amounts to approximately 18 years! At 10 years of age, however, this difference in expectation of life had been reduced to just over 12 years; at age 20, to a little less than 10 years; at age 30 to 7-1/3 years; at age 50 to just over 4 years; at age 70 to 1-1/2 years. At age 80 the lines have crossed. The individual 80 years old in Breslau could expect to live on the average a half year *longer* than the individual of the same age in the United States in 1910. At age 83, the last year covered by Halley's table, the 17th century individual could expect on the average to live approximately a year and a half longer than his twentieth century brother. So then what the diagram shows is that the expectation of life at early ages was vastly inferior in the seventeenth century to what it is now, while at advanced ages the chances of living were distinctly better—*relatively* enormously better—then than they are now. Let us defer the further discussion of the meaning and explanation of this curious fact until we have examined some further data.

Figure 3 compares the expectation of life in England at the middle of the eighteenth century, or about a century later than the last, with present conditions in the United States. Again we see that the expectation at birth was greatly inferior then to what it is now, but the difference is not so great as it was a century earlier, amounting to but 12-3/4 years instead of the 18 we found before. Further it is seen that, just as before, the expectations come closer together with advancing age. By the time age 45—middle life—is reached the expectation of life was substantially the same in the eighteenth century as it is now. At age 47 the eighteenth century line crosses that for the twentieth century,

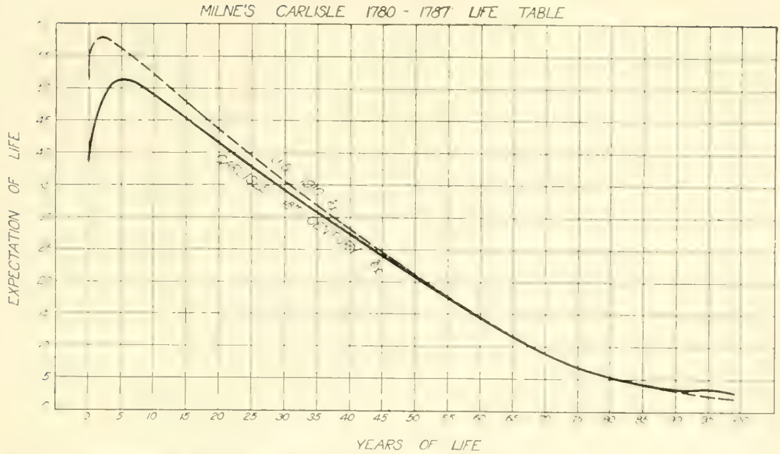

FIG. 3. COMPARING THE EXPECTATION OF LIFE IN THE 18TH CENTURY WITH THAT OF THE PRESENT TIME

and with a few trifling exceptions, notably in the years from 56 to 62, the expectation of life for all higher ages was greater then than it is now. Or we see in the eighteenth century the same *kind* of result as in the seventeenth, only differing in degree.

The changes in expectation of life from the middle of the seventeenth century to the present time furnish a record of a real evolutionary progression. In this respect at least man has definitely and distinctively changed, as a race, in a period of three and a half centuries. This is, of course, a matter of extraordinary interest, and at once stimulates the desire to go still farther back in history and see what the expectation of life then was. Fortunately, through the labors of Karl Pearson, and his associate, W. R. Macdonell, it is possible to do this, to at least a first approximation. Pearson has analyzed the records as to age at death which were found upon mummy cases studied by Professor W. Spiegelberg. These mummies belonged to a period between 1900 and 2000 years ago, when Egypt was under Roman dominion. The data were extremely meager, but from Pearson's analysis of them it has been possible to construct the diagram which is shown in Figure 4. Each circle marks a point where it was possible definitely to calculate an expectation of life. The curve running through the circles is a rough graphic smoothing of the scattered observed data. Unfortunately, there were no records of deaths in early infancy. Either there were no baby mummies, or if there were they have disappeared. For comparison, the expectation of life from Glover's 1910 United States life table is inserted.

It will be seen at once that the general sweep of the line is of the same sort that we have already observed in the case of the seventeenth century table. In the early years of life the expectation was far below that of the present time, but somewhere between ages 65 and 70 the

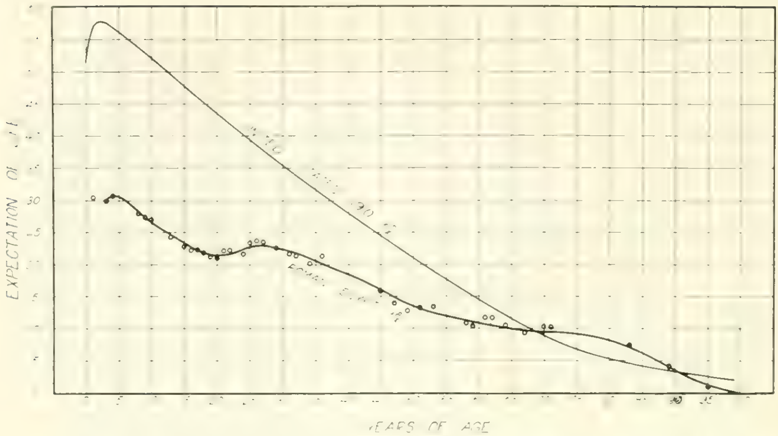

FIG. 4. COMPARING THE EXPECTATION OF LIFE OF ANCIENT EGYPTIANS WITH THAT OF PRESENT DAY AMERICANS. Plotted from Pearson's and Glover's data

Egyptian line crosses the modern American line, and from that period on the individuals living in Egypt at about the time of the birth of Christ could look forward to a longer remaining duration of life, on the average, than can the American of the present day. Pearson's comment on this fact is worth quoting. He says: "In the course of those centuries man must have grown remarkably fitter to his environment, or else he must have fitted his environment immeasurably better to himself. No civilized community of to-day could show such a curve as the civilized Romano-Egyptians of 2,000 years ago exhibit. We have here either a strong argument for the survival of the physically fitter man or for the survival of the civilly fitter society. Either man is constitutionally fitter to survive to-day, or he is mentally fitter, i. e., better able to organize his civic surroundings. Both conclusions point perfectly definitely to an evolutionary progress. . . . That the expectation of life for a Romano-Egyptian over 68 was greater than for a modern English man or woman is what we might expect, for with the mortality of youth and of middle age enormously emphasized only the very strongest would survive to this age. Out of 100 English alive at 10 years of age 39 survive to be 68; out of 100 Romano-Egyptians not 9 survived. Looking at these two curves we realize at a glance either the great physical progress of man, which enables him far more effectually to withstand a hostile environment, or the great social and sanitary progress he has made which enables him to modify the environment. In either case we can definitely assert that 2,000 years has made him a much 'fitter' being. In this comparison it must be remembered that we are not placing a civilized race against a barbaric tribe, but comparing a modern civilization with one of the highest types of ancient civilization."

Macdonell was able to continue this investigation, on much more extensive material extracted from the *Corpus Inscriptionum Latinarum* of the Berlin Academy, which gives records as to age of death for many thousand Roman citizens dying, for the most part, within the first three or four centuries of the Christian era. His material may, therefore, be taken to represent the conditions a few centuries later than those of Pearson's Romano-Egyptian population. Macdonell was able to calculate three tables of expectation of life—the first for Roman citizens living in the city of Rome itself; second, for those living in the provinces of Hispania and Lusitania; and third, for those living in Africa. The results are plotted against the United States 1910 data, as before, in Figures 5, 6 and 7.

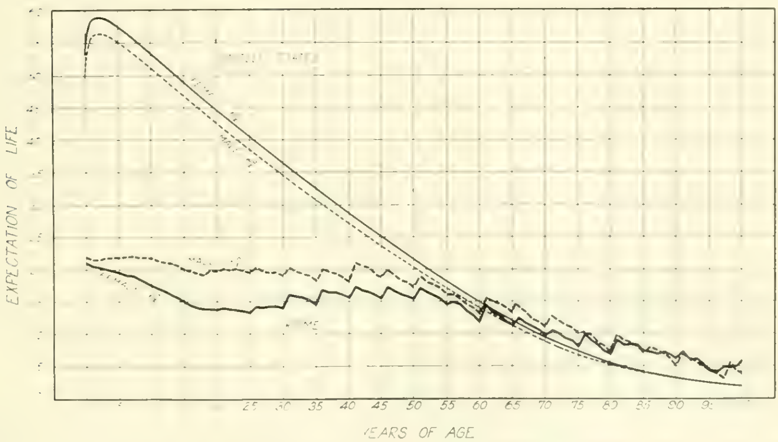

FIG. 5. COMPARING THE EXPECTATION OF LIFE OF ANCIENT ROMANS WITH THAT OF PRESENT DAY AMERICANS. Plotted from Macdonell's and Glover's data

Figure 5 relates to inhabitants of the city of Rome itself. The populations from which the expectations are calculated run into the thousands, and fortunately one is able to separate males and females. As in Pearson's case, which we have just examined, modern American data are entered for comparison. It will be noted at once that just as in the Romano-Egyptian population the expectation of life of inhabitants of ancient Rome was, in the early years of life, immensely inferior to that of the modern population. From about age 60 on, however, the expectation of life was better then than now. Curiously enough, the expectation of life of females was poorer at practically all ages of life than that of the males, which exactly reverses the modern state of affairs. Macdonell believes this difference to be real, and to indicate that there were special influences adversely affecting the health of females in the Roman Empire, which no longer operate in the modern world. Up to something like age 25 the expectation of life of dwellers in the city of Rome was extremely bad, worse than in the Romano-Egyptian population which Pearson studied, or in the populations of other parts of the Roman Empire as we shall see in the following diagram. Macdonell thinks that this difference is real and due to circumstances peculiar to Rome.

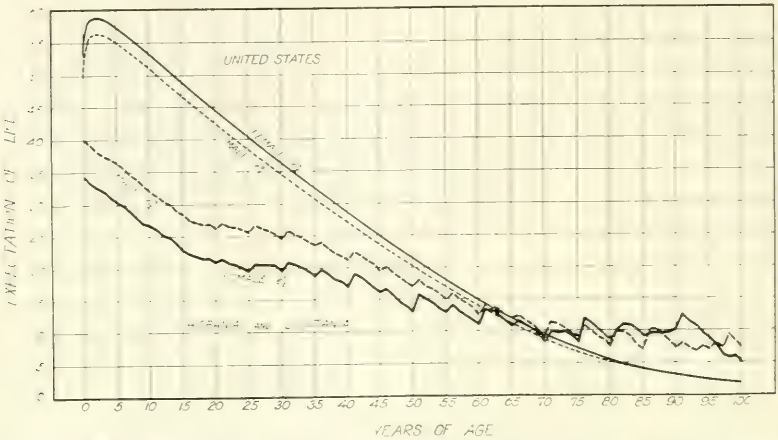

FIG. 6. COMPARING THE EXPECTATION OF LIFE OF THE POPULATION OF THE ROMAN PROVINCES HISPANIA AND LUSITANIA WITH THAT OF PRESENT DAY AMERICANS. Plotted from Macdonell's and Glover's data

The general features of the diagram for the population of Hispania and Lusitania (Figure 6) are similar to those that we have seen, with the difference that the expectation of life up to age 20 or 25 is not as bad as in the city of Rome itself. Again the females show a lower expectation practically throughout life than do the males. The lines cross the modern American lines at about age 60 and from that point on these colonial Romans had a better expectation of life than the modern American has.

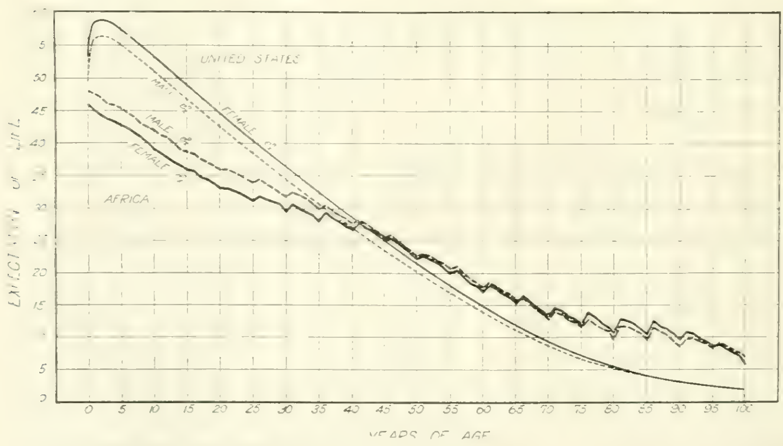

FIG. 7. COMPARING THE EXPECTATION OF LIFE OF THE POPULATION OF THE ROMAN PROVINCES IN AFRICA WITH THAT OF PRESENT DAY AMERICANS. Plotted from Macdonell's and Glover's data

The Romano-African population diagram appears to start at nearly the same point at birth as does the modern American and in general the differences up to age 35 are not substantially more marked from modern conditions than they are in the seventeenth century Breslau table. The striking thing, however, is that at about age 40 the lines cross, and from then on the expectation of life was definitely superior in the early years of the Christian era to what it is now.

It should be said that the curious zigzagging of the lines in all of these Roman tables of Macdonell is due to the tendency, which ancient Romans apparently had in common with present day American negroes, towards heavy grouping on the even multiples of 5 in the statement of their ages.

Summarizing the whole matter we see that during a period of approximately 2,000 years man's expectation of life at birth and subsequent early ages has been steadily improving, while at the same time his expectation of life at advanced ages has been steadily worsening. The former phenomenon may be attributed essentially to ever increasing knowledge of how best to cope with the lethal forces of nature. Progressively better sanitation, in the broadest sense, down through the centuries has saved for a time the lives of ever more and more babies and young people who formerly could not withstand the unfavorable conditions they met, and died in consequence rather promptly. But just because this process tends to preserve the weaklings, who were speedily eliminated under the rigorous action of unmitigated natural selection, there appear now in the higher age groups of the population many weaker individuals than formerly ever got there. Consequently the average expectation of life at ages beyond say 60 to 70 is not nearly so good now as it was under the more rigorous régime of ancient Rome. Then any individual who attained age 70 was the surviving resultant of a bitterly destructive process of selection. To run successfully the gauntlet of early and middle life he necessarily had to have an extraordinarily vigorous and resistant constitution. Having come through successfully to 70 years of age it is no matter of wonder that his prospects were for a longer old age than his descendants of the same age to-day can look forward to. Biologically these expectation of life curves give us the first introduction to a principle which we shall find as we go on to be of the very foremost importance in fixing the span of human longevity, namely that *inherited constitution fundamentally and primarily determines how long an individual will live.*

3. Analysis of the Life Table

I shall not develop this point further now, but instead will turn back to consider briefly certain features of the d_x line of a life table. Figure 1 shows that this line, which gives the number of deaths occurring at each age, has the form of a very much stretched letter S resting on its back. Some years ago Pearson undertook the analysis of this complex curve, and drew certain interesting conclusions as to the fundamental biological causes lying behind its curious sinuosity. His results are shown in Figure 8.

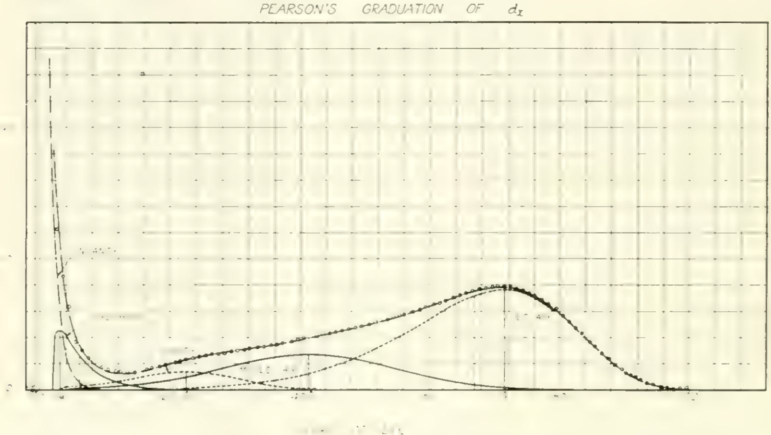

FIG. 8. SHOWING PEARSON'S RESULTS IN FITTING THE *Dx* LINE OF THE LIFE TABLE WITH 5 SKEW FREQUENCY CURVES. Plotted from the data of Pearson's original memoir on "Skew Variation" in the Phil. Trans. Roy. Soc.

He regarded the d_x line of the life table as a compound curve, and by suitable mathematical analysis broke it up into five component frequency curves. The data which he used were furnished by the d_x line of Ogle's life table, based on the experience of 1871 to 1880 in England. This line gives the deaths per annum of one thousand persons born in the same year. The first component which he separated was the old age mortality. This is shown by the dotted curve having its modal point between 70 and 75 years, at the point lettered O_1 on the base of the diagram. This component, according to Pearson's graduation, accounted for 484.1 deaths out of the total of 1,000, or nearly one-half of the whole. Its range extends from under 20 years of age to the upper limit of life, at approximately 106 years. The second component includes the deaths of middle life. This is the smooth curve having its modal point between 40 and 45 years at the point on the base marked O_2. Its range extends from about 5 years of age to about 65. It accounts for 175.2 deaths out of the total of 1,000. It is a long, much spread out curve, exhibiting great variability. The third component is made up by the deaths of youth. This accounts for 50.8 deaths out of the total of a thousand, and its range extends from about the time of birth to nearly 45 years. Its mid-point is between 20 and 25 years, and it exhibits less variability than either the middle life or the old age curves. The fourth component, the modal point of which is at the point on the base of the diagram marked O_4 covers the childhood mortality. It accounts for 46.4 deaths out of the total of 1,000. Its range and variability are obviously less than those of any of the other three components so far considered. The last, excessively skew component, is that which describes the mortality of infancy. It is given by a J shaped curve accounting for 245.7 deaths after birth, and an antenatal mortaliy of 605. In order to get any fit at all for this portion of the mortality curve it is necessary to assume that the deaths *in utero* and those of the first months after birth are a homogeneous connected group.

Summing all these components together it is seen that the resulting smooth curve very closely fits the series of small circles which are the original observations. From the standpoint merely of curve fitting no better result than this could be hoped for. But about its biological significance the case is not quite so clear, as we shall presently see.

Pearson himself thinks of these five components of the mortality curve as typifying five Deaths, shooting with different weapons, at different speeds and with differing precision at the procession of human beings crossing the Bridge of Life. The first Death is, according to Pearson, a marksman of deadly aim, concentrated fire, and unremitting destructiveness. He kills before birth as well as after and may be conceived as beating down young lives with the bones of their ancestors. The second marksman who aims at childhood has an extremely concentrated fire, which may be typified by the machine gun. Only because of the concentration of this fire are we able to pass through it without appalling loss. The third marksman Death, who shoots at youth has not a very deadly or accurate weapon, perhaps a bow and arrow. The fire of the fourth marksman is slow, scattered and not very destructive, such as might result from an old fashioned blunderbus. The last Death plies a rifle. None escapes his shots. He aims at old age but sometimes hits youth. His unremitting activity makes his toll large.

We may let Pearson sum the whole matter up in his own words: "Our investigations on the mortality statistics have thus led us to some very definite conclusions with regard to the chances of death. Instead of seven we have five ages of man, corresponding to the periods of infancy, of childhood, of youth, of maturity or middle age, and of senility or old age. In the case of each of these periods we see a perfectly regular chance distribution, centering at a given age, and tailing off on either side according to a perfectly clear mathematical law. . .

"Artistically, we no longer think of Death as striking chaotically; we regard his aim as perfectly regular in the mass, if unpredictable in the individual instance. It is no longer the Dance of Death which pictures for us Death carrying off indiscriminately the old and young, the rich and the poor, the toiler and the idler, the babe and its grandsire. We see something quite different, the cohort of a thousand tiny mites starting across the Bridge of Life, and growing in stature as they advance, till at the far end of the bridge we see only the gray-beard, and the 'lean and slippered pantaloon.' As they pass along the causeway the throng is more and more thinned: five Deaths are posted at different stages of the route longside the bridge, and with different skewness of aim and different weapons of precision they fire at the human target, till none remains to reach the end of the causeway—the limit of life."

This whole, somewhat fanciful, conception of Pearson's needs a little critical examination. What actually he has done is to get a good empirical fit of the d_x line by the use of equations involving all told some 17 constants. Because the combined curve fits well, *and fundamentally for no other reason,* he implicitly concludes that the fact that the fit is got by the use of five components means biologically that the d_x line is a compound curve, and indicates a five-fold biological heterogeneity in the material. But it is a very hazardous proceeding to draw biological conclusions of this type from the mere fact that a theoretical mathematical function or functions fits well a series of observational data. I have fully discussed this point several years ago (Pearl: Amer. Nat. Vol. XLIII) where I pointed out:

"The kind of evidence under discussion can at best have but inferential significance; it can never be of demonstrative worth. It is based on a process of reasoning which assumes a fundamental or necessary relationship to exist between two sets of phenomena because the same curve describes the quantitative relations of both sets. A little consideration indicates that this method of reasoning certainly can not be of general application, even though we assume it to be correct in particular cases. The difficulty arises from the fact that the mathematical functions commonly used with adequate results in physical, chemical, biological, and mathematical investigations are comparatively few in number. The literature of science shows nothing clearer than that the same type of curve frequently serves to describe with complete accuracy the quantitative relations of widely different natural phenomena. As a consequence any proposition to include that two sets of phenomena are casually or in any other way fundamentally related solely because they are described by the same type of curve is of a very doubtful validity."

Henderson has put Pearson's five components together in a single equation, and says regarding this method of analyzing the life tables: " . . . it is difficult to lay a firm foundation for it, because *no analysis of the deaths into natural divisions by causes or otherwise has yet been made* such that the totals in the various groups would conform to those frequency curves." The italics in this quotation are the present writer's for the purpose of emphasizing crucial points of the whole matter, which we shall immediately discuss in more detail.

Now it is altogether probable that one could get just as good a fit to the observed d_x line as is obtained by Pearson's five components by using a 17 constant equation of the type

$$y=a+bx+cx^2+dx^3+ex^4+fx^5+gx^6+\text{--------}+nx^{16}$$

and in that event one would be quite as fully justified (or really unjustified) in concluding that the d_x line was a homogeneous curve as Pearson is in concluding from his five-component fit that it is compound.

Indeed Wittstein's formula involving but four constants gives substantially good fit over the whole range of life.

But in neither case is the curve-fitting evidence, by and of itself, in any sense a demonstration of the biological homogeneity or heterogeneity of the material. Of far greater importance, and indeed conclusive significance, is the fact, to be brought out in a later paper in this series, that in material *experimentally known to be biologically homogeneous*, a population made up of full brothers and sisters out of a brother x sister mating and kept throughout life in a uniform environment identical for all individuals,*one gets a d_x line in all its essential features*, save for the absence of excessive infant mortality arising from perfectly clear biological causes, *identical with the human d_x line.* It has long been apparent to the thoughtful biologist that there was not the slightest biological reason to suppose that the peculiar sinuosity of the human d_x line owed its origin to any fundamental heterogeneity in the material, or differentiation in respect of the forces of mortality. Now we have experimental proof, to be discussed in a later paper in this series, that with complete homogeneity of the material, both genetic and environmental, one gets just the same kind of d_x line as in normal human material. We must then, I think, come to the conclusion that brilliant and picturesque as is Pearson's conception of the five Deaths, actually there is no slightest reason to suppose that it represents any *biological* reality, save in the one respect that his curve fitting demonstrates, as any other equally successful would, that deaths do not occur chaotically in respect of age, but instead in a regular manner capable of representation by a mathematical function of age.

PUBLISHED FIGURES AND PLATES OF THE EXTINCT PASSENGER PIGEON[1]

By Dr. R. W. SHUFELDT
WASHINGTON, D. C.

(Photographs by the Author)

WITH the view of portraying its natural appearance in life, few birds, either living or extinct, have exceeded the Passenger Pigeon (*Ectopistes migratorius*) as a subject for artists and engravers. For nearly two centuries, representations of this now extinct species have been published in all sorts of avenues, ranging all the way from the cuts found in dictionaries and school-books to reproductions of life-size colored figures illustrating the most sumptuous of the world's great works devoted to ornithology. It would seem to be quite a safe statement to make that upwards of five hundred figures or more of this bird, published in many quarters of the world, have appeared, illustrating the great variety of accounts, both popular and scientific, that avian biographers have given us upon its natural history.

No species of bird known to man, in all time, can in any way rival the extraordinary series of chapters that go to make up the history of the life-span of this now totally extinct pigeon. As a story filled with romance, prodigality, cruelty and short-sightedness, it outranks the most unbelievable fables of the ancients. For one among many who witnessed the marvelous flight of these birds in the early seventies, I never for a moment thought how soon the species would be in the same category with those other birds, of which the world shall never again see living specimens. We can now only regretfully look back on the picture and systematize the data at hand with respect to the literary part of this, and not a little has been accomplished by those competent to undertake it. But with all this we have nothing to do here, as it is a subject quite apart from a consideration of what we have by way of portraits of a form that man shall never see again in life.

As just stated, there is a very extensive array of these portraits in the many biographies that have appeared of the bird, and they represent a great variety of grades of excellence, of caricature, of faithfulness, and of grotesqueness. Many of these will here be ignored, as they contribute nothing of any value in aiding one to correctly visualize our subject; indeed, in most instances, such cuts convey a decidedly

[1]Read at the Thirty-eighth Stated Meeting of the American Ornithologists' Union, Washington, D. C., November, 1920.

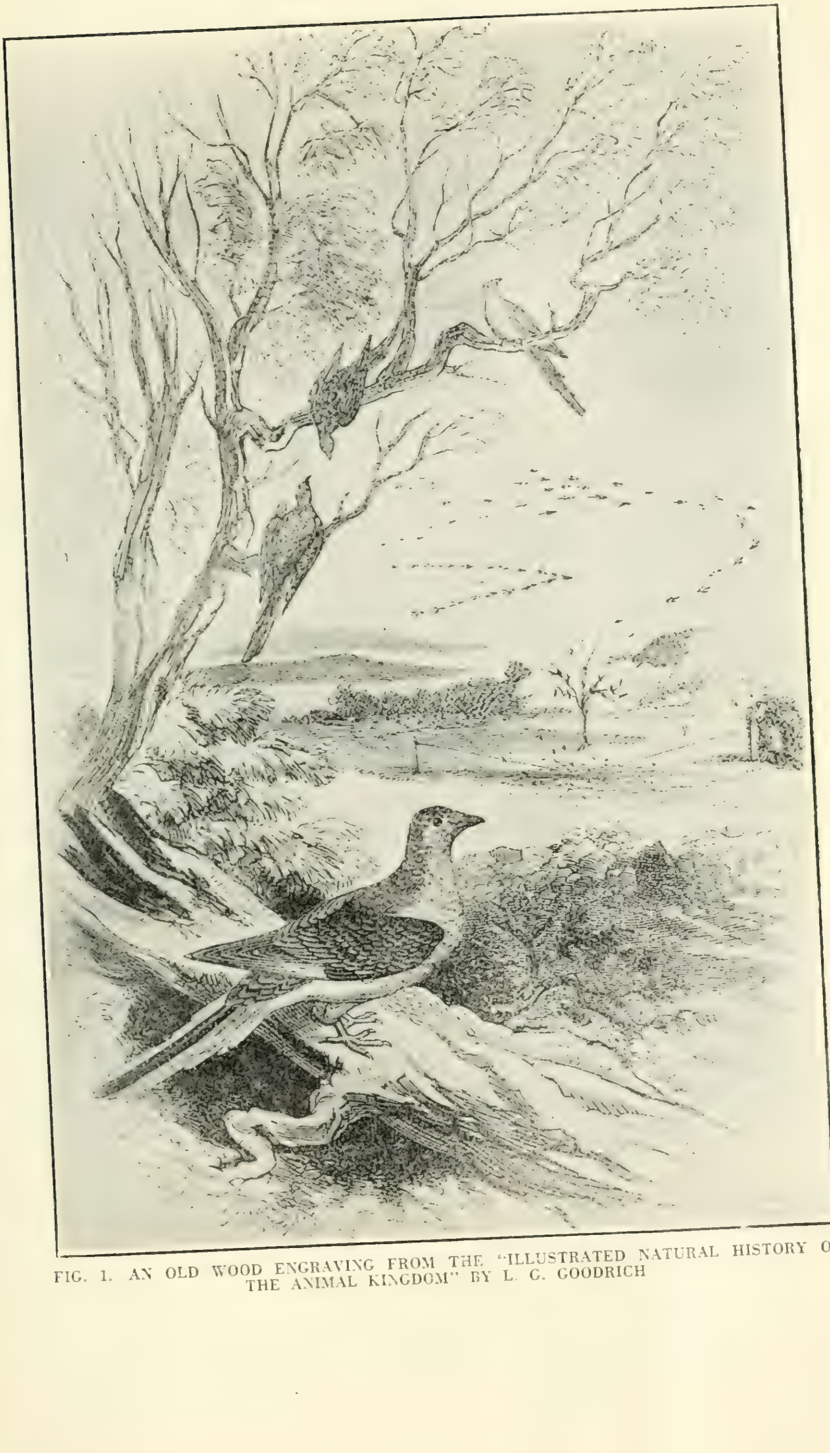

FIG. 1. AN OLD WOOD ENGRAVING FROM THE "ILLUSTRATED NATURAL HISTORY OF THE ANIMAL KINGDOM" BY L. G. GOODRICH

FIG. 2. AN IMMATURE WILD PIGEON. FROM A PHOTOGRAPH BY THE LATE DR. C. O. WHITMAN

erroneous idea as to how this bird appeared in life. This statement may be relied upon coming from me, as not only have I shot a number of specimens of them and handled them afterwards, but I have seen them, close to, in all their natural attitudes in the forest; so that, with such opportunities, added to what faculties I may possess for memorizing the normal postures of birds in life, following upon a study of any particular species of them for that purpose, I may be more or less competent to judge of the faithfulness of portrayal in any picture of the wild pigeon which, up to the present time, has been published.

Turning first, then, to a few of the minor cuts that have appeared of this bird, it is to be noted that they are of a great variety, and based on all sorts of data. Some are reduced woodcuts, or electros, or halftones, made from the large plates in the standard works of the world's recognized ornithologists. Some are fanciful pictures reproduced from drawings made by those who knew nothing of the wild pigeon, or who had examined the figures or plates of others possessing more or less reliable data upon which to base such productions. Not a few are represented by excellent examples of pictorial piracy, with widely varying success as to correctness of copy; in the case of still others, attempts have been made to conceal the piracy, and the value of the result rests upon the skill of the artist to succeed in such a trick. In a few instances, the pirated picture appears to be truer to nature than the one from which it was copied. And, again, such copies are duly acknowledged, either under the cut or in the text which accompanies it.

L. G. Goodrich published his "Illustrated Natural History of the Animal Kingdom" in 1861; it carried 1,500 engravings in the two volumes, and came off the presses of Derby and Jackson, of New York City. On page 231 of Volume II. there is an attractive woodcut of the wild pigeon engraved by Lossing and Barritt. (Fig. 1.) In the foreground a single adult bird faces to the right, standing on the trunk of a fallen tree; in the middle distance there are three more of these birds in a tree to the left, while in the background we have a man, partly concealed in a "blind," netting pigeons. Numerous birds are on the ground; others are in a near-by tree, while still others are coming down to the lure, and a few others are, apparently, for the moment passing in the form of an acute angle, with one bird directly behind another in the two lines forming it.

Whether this is the place where this picture was first published, I am unable to state; but I am inclined to believe that it is not. for the reason that we find, in Thomas Nuttall's "A Manual of the Ornithology of the United States," a picture of a wild pigeon which is evidently the counterpart of the one in Goodrich. Here it is larger, however, and the bird is turned to the left; the surroundings are changed some-

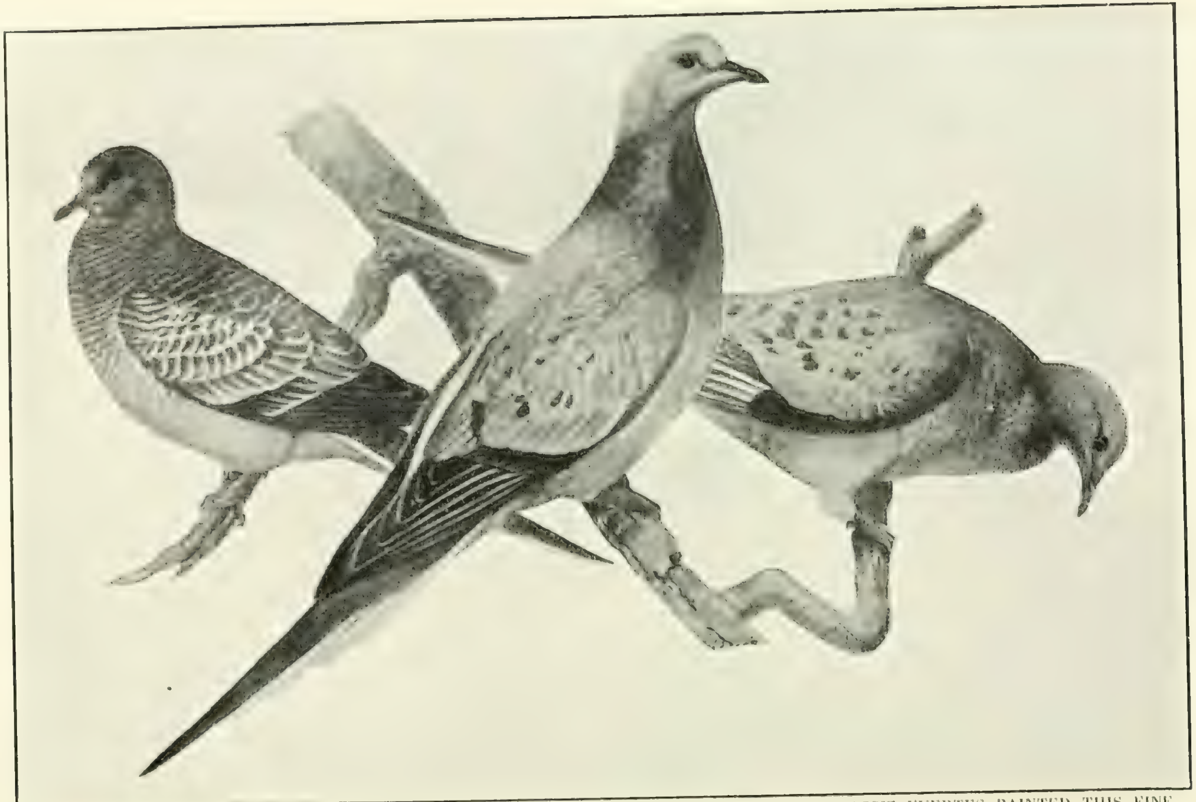

FIG. 3. A GROUP OF WILD PIGEONS FROM EATON'S "BIRDS OF NEW YORK." LOUIS AGASSIZ FUERTES PAINTED THIS FINE PICTURE, WHICH CONSISTS OF AN ADULT PAIR AND A BIRD-OF-THE-YEAR

what, and the tree in the middle distance is absent. But in the background we find the same scene as in Goodrich, apart from a few trivial changes. This cut is on page 28 of Volume I. of Nuttall—the Land Birds—the account of the Wild Pigeon being on pages 628 to 635 inclusive. As this volume is dated 1832, or twenty-nine years before the Goodrich volume was published, it is evident that a still earlier cut of the kind existed, which was drawn upon by both the authors, or, what is more likely, Goodrich's engravers or his artist made up a wild pigeon scene for the work, and copied Nuttall's figure in the foreground, simply turning it to the right and slightly reducing it. Such procedures were by no means uncommon in those times—a fact one soon appreciates after studying the various published pictures of the Wild Pigeon. Nuttall acknowledges who engraved for him in his Preface to Volume I., on page vi., where he says: "The wood engravings, not sufficiently numerous in consequence of their cost, have been executed by Mr. Bowen, of Boston, and Mr. Hall, in the employ of Messrs. Carter and Andrews, of Lancaster." Cambridge was the place of publication.

To illustrate the word "pigeon" or "passenger-pigeon," we sometimes find our extinct wild one selected for the purpose, and a good example of this is seen in the case of the "Century Dictionary," where Thompson-Seton gives us a figure that is far above the average of such cuts in points of excellence.

Perhaps Wilson's rather quaint but attractive figure of the bird has been more extensively used as the basis for smaller cuts than that of any other artist. For example, Tenney used it in his text-book on zoology, and Coues, borrowing it from him, reproduced it on page 711 of Volume II. of the fifth edition of his "Key to North American Birds." To some extent, this cut was altered; for, as we know, Wilson represented his wild pigeon as standing on the top of a sawn-off stump of a tree, while the cuts in Tenney's and in Coues have the bird standing on the ground. In doing this, no change was made in the posing of the feet.

As we know, T. M. Brewer published an edition of Wilson's "American Ornithology" in 1852; and of all the colored plates known to me, the ones illustrating this work are the most unsatisfactory and incorrectly colored. They were reduced from the plates in Wilson's folio edition to a three-half, six-half size; and in my personal copy of this work, the plate carrying the wild pigeon is so inserted as to cause the bird to be up-side down. It has been tinted a curious shade of purple, with pale purple outer tail feathers, and with a bright pink breast. In this respect Audubon fared much better; for, with the exception of a few indifferent cuts based on his magnificent plate of a pair of Wild Pigeons, the latter has been reproduced in color in several works, a

FIG. 4. REPRODUCTION OF AUDUBON'S PLATE OF THE WILD PIDGEON

strikingly beautiful example of which may be seen in that most valuable and interesting book on the bird by W. B Mershon, given us in 1907 by the Outing Publishing Company. This volume has two reproductions of photographs of mounted specimens of the Passenger Pigeon that are above the average in the point of excellence; and, finally, it has a beautiful plate of Dr. C. O. Whitman's photograph from life of an immature bird of this species. (Fig. 2).

An admirable plate in color of a pair of Passenger Pigeons by Fuertes occurs as the frontispiece to the work just mentioned, the same having been used by various other authors. This painting was done in 1904, since which time, for all I know to the contrary, this most industrious avian artist may have given us other colored plates of this species,—at least I find a very beautiful one, and I may say a very faithful one, in the first volume of Eaton's magnificent work "The Birds of New York," where it is shown on Plate 42, upper figure, the group consisting of a pair of adults and a young bird. (Fig. 3). In my opinion, this is one of the most accurate, and decidedly the most pleasing of all the colored figures of the Wild Pigeon that have appeared up to date. It leads Audubon's plate for the reason that it is such a restful one to study, while in the case of Audubon's, the error he committed in so many of his representations of birds is there repeated—that is to say, that in technical ornithological works the portraits of birds should never be shown in unusual poses or performing some action. (Fig 4). In this criticism I found myself in agreement with the late, very distinguished British Ornithologist, Alfred Newton, who, many years ago, wrote me to that effect.

Eaton's "Birds of New York" bears date of 1910—that is, three years after Mershon, and two years before the splendid volume of Forbush appeared on "A History of the Game Birds, Wild Fowl, and Shore Birds of Massachusetts and Adjacent States"—a work too well known to ornithologists to require description here. In it we find three plates devoted to the Passenger Pigeon, one being of a beautifully mounted specimen, while the remaining two are of exceptional value, in as much as they are reproductions of photographs of living specimens of the bird itself. In so far as my knowledge carries, these are the only pictures of the kind extant. I have already referred to one of them as being an illustration in Mershon's work "The Passenger Pigeon," that is, the one reproduced from C. O. Whitman's photograph; the other, here to be noticed, is the reproduction of the last of all the Passenger Pigeons that ever lived: It is the Enno Meyer photograph, taken of the bird when it lived in the Zoological Garden of Cincinnati. (Fig. 5). It is quite unnecessary to comment on the value of this picture or its uniqueness, as it represents one of those things that can never be repeated.

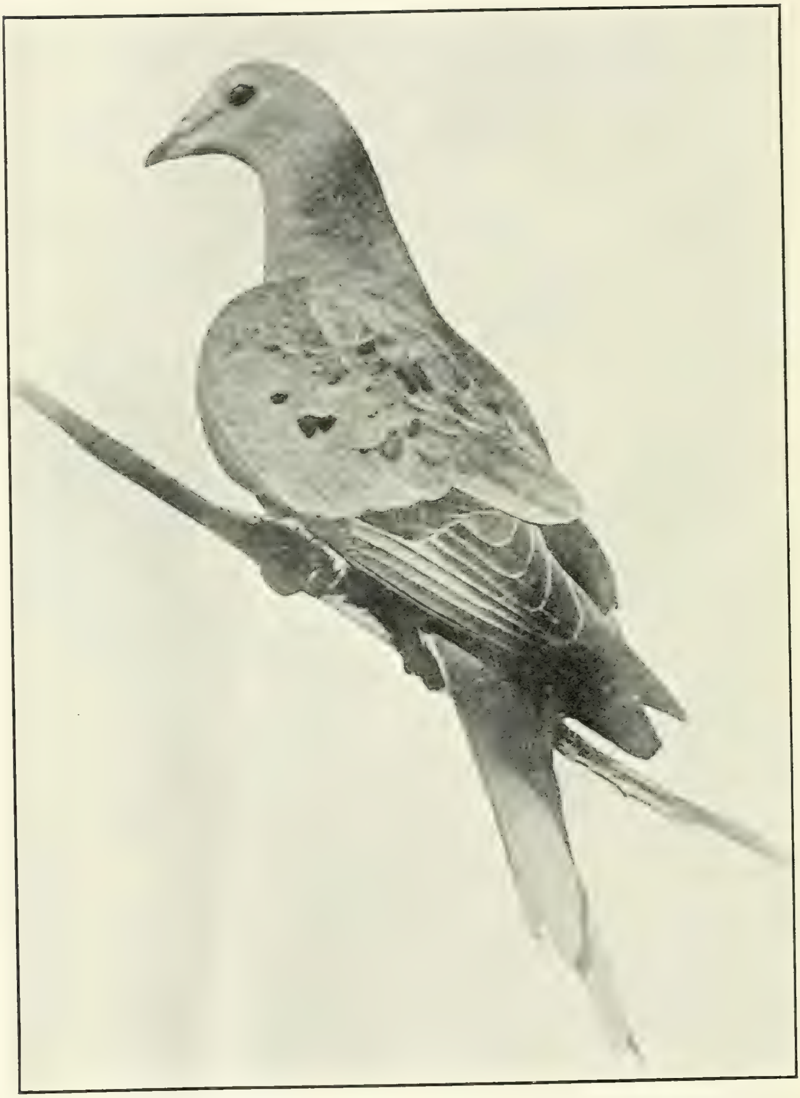

FIG. 5. THE PASSENGER PIGEON IN LIFE. PHOTOGRAPHED BY ENNO MEYER OF THE BIRD THAT LIVED IN THE ZOOLOGICAL GARDENS OF CINCINNATI, OHIO

FIG. 6. SAME SPECIMEN AS SHOWN IN FIGURE 5. MOUNTED AFTER ITS DEATH BY THE LATE MR. NELSON R. WOOD, AND NOW IN THE EXHIBITION SERIES OF THE UNITED STATES NATIONAL MUSEUM

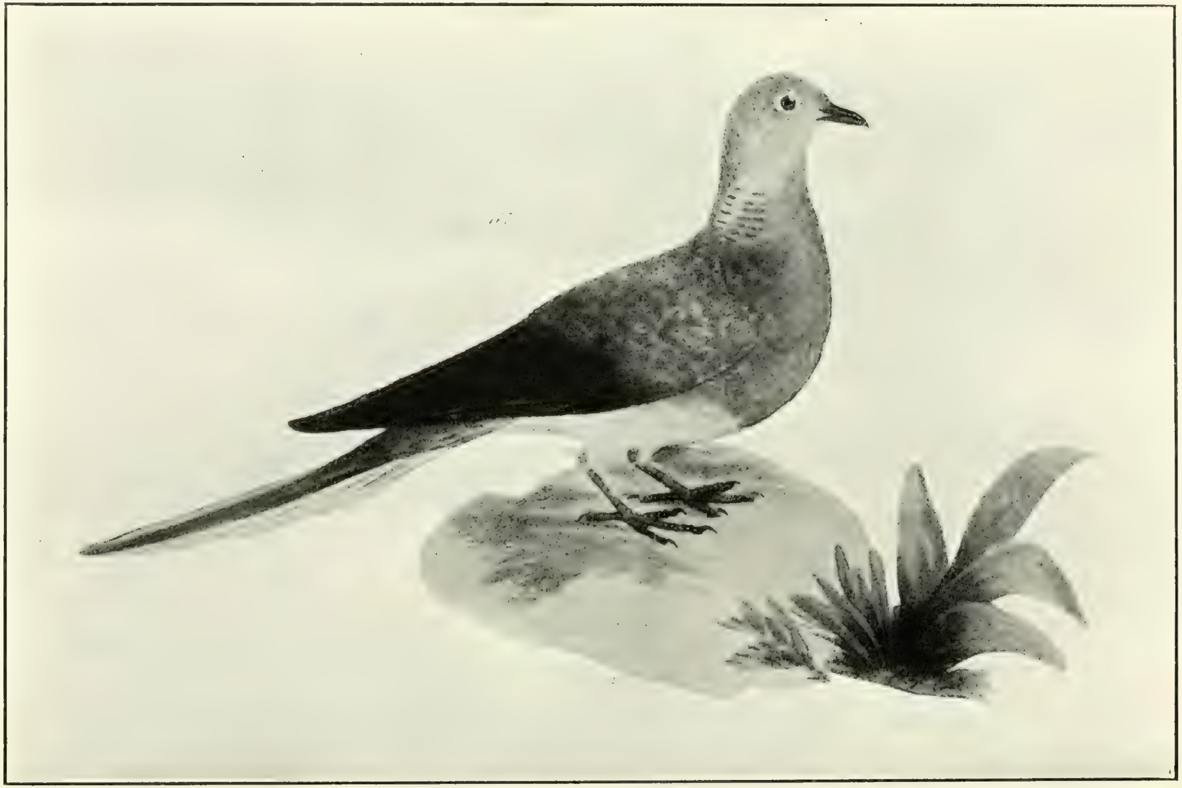

FIG. 7. THE COLORED FIGURE OF THE WILD PIGEON AS SHOWN IN THE WORK OF JAMES DE KAY ("NEW YORK FAUNA.")

This bird, after its death, was preserved by Mr. Wm. Palmer at my residence, and I have published an account of its gross anatomy. There are three other negatives of it posed by me at the photographic galleries of the United States National Museum, and they present the three different views of the specimen, namely the ventral, the dorsal and the lateral ones. After this specimen was mounted, I was permitted to make a photograph of it, and this latter has been published in *The Conservationist,* of Albany, N. Y., and in *American Forestry,* of Washington. (Fig. 6).

If there be a figure of the Wild Pigeon in "The Game Birds of the United States" by the late Dr. D. G. Elliott, I do not recall it, for a copy of that work has not been in my hands for many years. This is not the case, however, with respect to the "Zoology of New York," or the "New York Fauna," by James E. de Kay. Part II. of this well-known and much criticized work is devoted to the Birds, and on page 196 there is an half-page account of "*Ectopistes migratoria.*" The figure of the bird in color, five-eights natural size, is a male, engraved by J. W. Hill and lithographed by Endicott of New York. It is Plate 74, being a rather pleasing, not to say fairly correct representation of the species. (Fig. 7).

Coues, in his Biographical Appendix, gives the date of publication of this work as 1884, and says that the birds "are figured in colored lithographs, each plate containing two or three figures. The plates are all recognizable illustrations, but not of the highest order of artistic merit, the drawing being especially defective." (p. 633.)

There has been published at least one plate on which is given no fewer than fourteen Passenger Pigeons, representing both sexes and young in apparently typical plumages. This is Plate XXIX, opposite page 32 of "Studer's Popular Ornithology—The Birds of North America,"—a work illustrated throughout by Dr. Theodore Jasper, and edited and published under copyright in 1881 by Jacob H. Studer and Co., of New York and Columbus, Ohio. (Fig 8). Neither the text nor the plates of this folio volume seem to have met with favor in the eyes of ornithologists anywhere; but of all this interesting history nothing will be recorded here.

To appreciate Alexander Wilson's figure of the Wild Pigeon, one should see it in Volume V. of his folio set, which was published in Philadelphia in 1812. We find it to be Figure I. on Plate 44, opposite page 102, where it is designated as *Columbia migratoria.* and represented to be of natural size. On the same plate we find Figure II., the Blue Mountain Warbler, and Figure III., the Hemlock Warbler (Fig 9). There is a peculiar quaintness and charm about Wilson's figures of birds that attaches but to few others. I must believe that their pathetic history has something to do with all this, for we know that Wilson drew all his own figures of birds, while they were engraved

FIG. 8. DOCTOR JASPER'S GROUP OF THE FOURTEEN WILD PIGEONS, FROM STUDER'S "THE BIRDS OF NORTH AMERICA." (PL. XXIX.)

by I. G. Warnicke, of the firm of Messrs. Lawson, Murray, and Warnicke, his printers being Messrs. R. and W. Carr, a Philadelphia firm of note in those days.

There is but one criticism I would make of the Wild Pigeon as portrayed by Wilson; it is that the sawn-off stump upon which it stands is altogether too small. As the bird had a length between 16 and 17 inches, we can readily calculate what the diameter of that stump must have been. Surely the tree could not have been of a size sufficiently large to demand *sawing across* to fell it! This discrepancy has doubtless been observed by others—hence the placing of Wilson's Wild Pigeon on the ground in some of our modern text-books in zoology.

On page 10 of his preface, Wilson gives us a paragraph, the sentiment of which is quite as true to-day as in his time; he says: "Let but the generous hand of patriotism be stretched forth to assist and cherish the rising arts and literature of our country, and both will most assuredly, and that at no remote period, shoot forth, increase, and flourish with a vigor, a splendor, and usefulness inferior to no other on Earth."

In skimming through that most useful piece of work, the Biographical Appendix of Dr. Elliott Coues, we meet with various other works, of a minor sort or otherwise, in which cuts of the Wild Pigeon occur, or may occur, as those of E. A. Samuels, W. L. Bailey, W. P. Turnbull, and others. In the important ornithological works of Baird, Brewer, and Ridgway, only the heads of the birds described are figured; while in Mr. Ridgway's well-known "Manual" we find but an excellent character drawing, giving in outline simply the head, wing, tail, and foot of the Passenger Pigeon.

There is a quaint figure of the bird under consideration in the early work of P. Kalm, published in 1772, and entitled "Travels Into North America," with a very lengthy sub-title. The plate of the Wild Pigeon is opposite page 74; while in 1785, or thirteen years after Kalm published, there appeared the well-known classic of T. Pennant, entitled "Arctic Zoology." Here a very crude engraving of the Passenger Pigeon is given on the same plate (which is No. XIV.) with the Caroline Dove. (Fig. 10). This I examined in a copy of the work formerly in the personal library of the late Dr. Edgar A. Mearns, which is now in the library of the United States National Museum. Who engraved this plate is a fact still unknown to me, while the work was printed by Henry Hughs, of London. Volume II. is devoted to the Birds, which are grouped in Class II., and it is on page 322 that we find treated Order IV., the *Columbine*, under which a brief account of the Wild Pigeon is given.

Ornithologists are familiar with the remarkable history that attaches to the great folio work on Pigeons, of which C. J. Temminck is

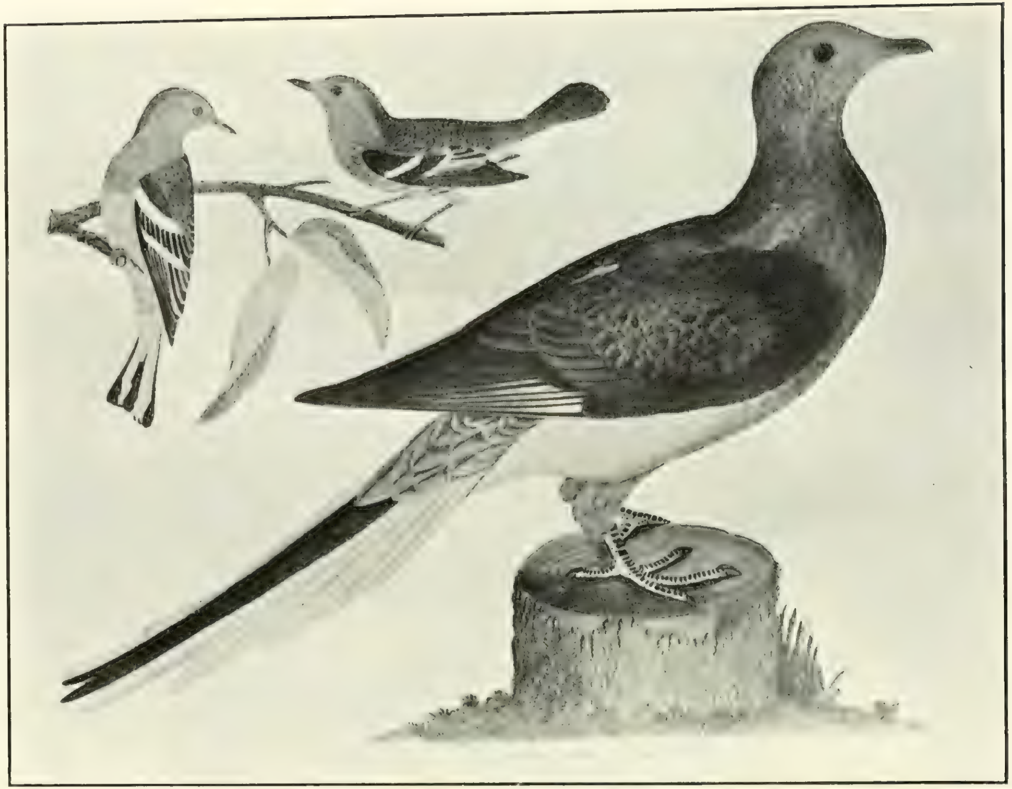

FIG. 9. THE PASSENGER PIGEON AS GIVEN US BY ALEXANDER WILSON. FIGURE 1 ON PLATE XLIV. OF HIS FOLIO SET

FIG. 10. PLATE FROM PENNANT'S "ARCTIC ZOOLOGY." CAROLINA DOVE IN THE FOREGROUND AND WILD PIGEON BEYOND. (PL. XIV.)

FIG. 11. MADAME KNIP'S PAINTING OF THE PASSENGER PIGEON, WHICH WAS PUBLISHED IN HER PIRATED EDITION AS WELL AS IN TEMMINCK'S, THE LATTER BEING THE AUTHOR OF THE TEXT OF THE WORK

the author, and which was published in 1808 to 1811; and how it was pirated, as a whole, by Madame Knip, née Pauline de Courcelles, at the time it was issued. Madame Knip was the artist who painted the life-size colored figures of the large number of pigeons figured in this work, while they were engraved by Cesar Macret, of Paris. Each species is given a plate to itself, and that of the Wild Pigeon is No. 48, which is said to be a male bird. As an artistic picture, it is excellent; but as a correct figure of the species it purports to represent, it is a failure. The model was evidently a skin, and this may account for the small head and bill, but not for the short tail that Madame Knip has endowed it with. (Fig. 11).

In 1857 to 1858, Charles Lucien Bonaparte published his magnificent folio, entitled "Iconographic des Pigeons;" but as the plates only gave such species as were not figured by Madame Knip, the Passenger Pigeon does not appear in it.

We next have to consider the work of Heinrich Gottlieb Ludwig Reichenbach, who was born at Leipzig on the 8th of January, 1793, and who died March 17, 1879, which made him eighty-six years of age at the time of his death. He was the author of a work on the Columbidæ, entitled "The Complete Account of the Natural History of the Pigeons and Pigeon-like Birds," a copy of which I have examined. It appeared in Dresden, in the German language, as a folio volume apart from the text, and illustrated with colored plates. With respect to the text of this work, I am indebted to Dr. Richmond for the opportunity to examine it. It was probably published about 1861, being unbound, and of a much smaller size than the plates. The account of the Wild Pigeon on pp. 81-85 is chiefly from Audubon and others. Plate 154 of the bound plates is devoted to *Ectopistes migratorius* (Fig 12), of which there are three figures in color resting on the limb of a tree; they are numbered 1374, 1378, and 1379, and all three are but indifferent representations of the species he aimed to delineate.

Reichenbach evidently got his middle figure of the Wild Pigeon from John Prideaux Selby's work, entitled "The Natural History of Pigeons," which appeared in Edinburgh in 1835, being one of the demi-octavos of *The Naturalists' Library*, edited by Sir William Jardine. It is the volume devoted to the Pigeons, and is illustrated by 32 colored plates of those birds together with numerous woodcuts. An account of the Passenger Pigeon, or, as Selby called it, the "Passenger Turtle," is given in Volume V. on pages 177 to 188 inclusive, the colored figure of the bird being Plate 19, opposite page 176. There is no question but that Reichenbach reproduced this figure in his plate: changed the limb and scenery, and then added another figure of the pigeon on either side of it, which he may possibly have obtained from still other sources. In doing this, the Selby figure was somewhat reduced

FIG. 12. A GROUP OF PASSENGER PIGEONS FROM THE ORNITHOLOGICAL WORK OF REICHENBACH'S

in size. E. Lear drew Selby's figures of the pigeons, and they were engraved by Lizars.

We may now enquire as to who published the first figure or plate representing the Wild Pigeon; and, in so far as I have been able to discover, it would seem to have been Mark Catesby, whose elephant folio work appeared in 1771; it is entitled "The Natural History of Carolina, Florida, and Bahama Islands, with a lengthy sub-title. The colored plate of the Wild Pigeon occurs in Volume I., and is Plate 23, its caption being "The Pigeon of Passage" (Palumbus Migratorius). (Fig. 13).

The bird is quite recognizable, although figured in the quaint style so characteristic of the ornithological artists of those times. The accessories consist of the leaves and acorns of the Red Oak, the bird standing on the upper surface of one of the separated leaves, the indications being that the leaf is on the ground and not floating in mid-air.

There is an elaborate Preface to this work (pp. V.-XII.), on page XI of which Catesby tells us that "As I was not bred a Painter, I hope some faults in Perspective, and other Niceties may be more readily excused, for I humbly conceive Plants, and other Things done in a Flat, tho' exact manner may serve the Purpose of Natural History, better in some Measure than in a bold and Painter like way. In designing the Plants, I always did them while fresh and just gathered: And the Animals, particularly the Birds, I painted them while alive (except a few) and gave them their Gestures peculiar to every kind of Bird, and where it would admit of, I have adapted the Bird to those Plants on which they fed, or have any Relation to."

Catesby had considerable trouble, on account of the expense, in securing an engraver; but as he adds in his Preface, "At length by the Kind Advice and Instructions of that inimitable Painter Mr. Joseph Goupy, I undertook and was initiated in the way of Etching them myself, which, though I may not have done in a Graver-like manner, choosing rather to omit their method of cross-Hatching, and to follow the humour of the Feathers, which is more laborious, and I hope has proved more to the purpose."

Next follows a long discussion of the colors used in this work, and other matters of interest.

This ancient classic is still consulted from time to time, and we turn to it for many reasons in a reverential way; and by no means the least one of the reasons is, that nearly a century and a half ago, its author published for us a plate of the Passenger Pigeon, little dreaming as he did so that this splendid species, then existing in unnumbered millions in this country, would so soon be utterly exterminated by those living in the regions where it occurred.

It would appear that Count de Buffon never published a figure or

FIG. 13. PROBABLY THE FIRST PLATE OF THE WILD PIGEON PUBLISHED. A PHOTOGRAPHIC COPY OF THE PIGEON IN MARK CATESBY'S ORNITHOLOGY (1771)

FIG. 14. HAYASHI'S FIGURE OF THE MALE WILD PIGEON IN THE WORK OF DR. C. O. WHITMAN

FIG. 15. BY THE SAME ARTIST WHO PAINTED THE PIGEON HERE SHOWN IN FIGURE 14. THIS IS THE FEMALE, AND IS PLATE 29 OF WHITMAN'S WORK ON THE PIGEONS

plate of the Wild Pigeon; but we find one in Daubenton that appeared in about the year 1780. This latter is a small quarto with colored plates, but no text. It was intended to illustrate, or rather be a complimentary work to Buffon, illustrating what the latter had published on birds. Daubenton gives a colored plate, No. 176, of an immature Passenger Pigeon, which he designates as the "Tourterelle du Canada" which is recognizable, but hardly anything more; it is about two-thirds the size of life.

Thomas E. Eyton published, in 1836, a small octavo in London, which he entitled "A History of the Rarer British Birds." On page 30 there is a small woodcut of the Passenger Pigeon which is fairly good, and he says of the species that "Our authority for introducing it into this work, as a member of the British Fauna, rests upon a specimen mentioned by Dr. Fleming in his 'History of British Animals,' shot at Westhall, in the parish of Monymeal, Fifeshire, on the 31st of December, 1825. The feathers were quite fresh and entire, like those of a wild bird. The specimen in question was presented to Dr. Fleming by the Rev. A. Esplin, schoolmaster at Monymeal." This specimen was evidently a "straggler" and very different from introduced birds, such as the lot that Audubon is responsible for turning loose in England in 1830—an exploit described in Smart's "Birds of the British List."

I have stated that it was perhaps Catesby who published the first plate of our Wild Pigeon; and it may now be asked: who holds the honor of having published the last plate of the bird? This is an event of only about a year ago, when the posthumous works of Charles Otis Whitman appeared. This great treatise, entitled "Inheritance, Fertility, and the Dominance of Sex and Color in Hybrids of Wild Species of Pigeons," is edited by Mr. Oscar Riddle, and published by the Carnegie Institution of Washington in four handsome quarto volumes. Its carefully executed colored plates were engraved by the Hoen Company, of Baltimore, and two plates of the Passenger Pigeon occur in the second volume. They are reproductions of the work of the well-known Japanese artist, Hayashi. Plate 28 (Fig. 14) represents an adult male bird (x. 06), and has not a little to recommend it. It may be suggested, however, that the limb upon which the specimen is represented as standing, is too vertical for the pose the artist has given the bird.

The female, to which Plate 29 is devoted, (Fig. 15) is better, and to me, a far more pleasing figure. It is of an adult individual and beautifully tinted (x o .05). Mr. Hayashi also painted the picture of which this plate is a copy—indeed, I believe he is responsible for all the colored plates that illustrate this superb work—a veritable monument to the department of scientific ornithology of which it treats.

THE PROGRESS OF SCIENCE

PROFESSOR EINSTEIN'S VISIT TO THE UNITED STATES

Plans have been under consideration for lectures by Professor Einstein in the United States, but his arrival at the beginning of April on a mission to promote the Zionist movement was a surprise. He is accompanied by Professor Chaim Weizmann, director of the chemical research laboratories of the British Admiralty during the war, now head of the World Zionist Organization, and two other leaders in the movement. Professor Einstein is reported to be especially interested in the establishment of a University of Jerusalem and to be ready to take part in its work, but it is not likely that he will leave Berlin permanently. Professor Bergson has denied the report that he would leave Paris to become professor at Jerusalem.

Arrangements were promptly made for scientific lectures by Professor Einstein at several universities, the first being appropriately given at Columbia University, which awarded to him last year the Barnard Medal on the recommendation of the National Academy of Sciences. Four lectures have been given at the College of the City of New York and a series of five lectures is announced to be given at Princeton University from May 9 to 13. Scientific men are invited to attend the Princeton lectures; those wishing to do so should write to Professor H. A. Thompson.

It is satisfactory that there should be such widespread popular interest in Professor Einstein and his work. In the article on the History of Mathematics by Professor Ernest Brown in the present issue of the MONTHLY and in the article on the History of Physics by the late Professor Andrews Henry Bumstead in the last issue will be found statements of Professor Einstein's contributions in their historic continuity. An article on the Theory of Relativity by Professor E. B. Wilson was printed in the issue of the MONTHLY for March, 1920. In the issue of *Nature* for February 17 last will be found a series of articles on all aspects of the theory of relativity. Professor Einstein himself contributes an article on the development of his theory in which he writes:

> The development of the special theory of relativity consists of two main steps, namely the adaptation of the space-time "metrics" to Maxwell's electro-dynamics, and an adaptation of the rest of physics to that altered space-time "metrics." The first of these processes yields the relativity of simultaneity, the influence of motion on measuring-rods and clocks, a modification of kinematics, and in particular a new theorem of addition of velocities. The second process supplies us with a modification of Newton's law of motion for large velocities, together with information of fundamental importance on the nature of inertial mass.
>
> It was found that inertia is not a fundamental property of matter, nor, indeed, an irreducible magnitude, but a property of energy. If an amount of energy E be given to a body, the inertial mass of the body increases by an amount E/c^2, where c is the velocity of light *in vacuo*. On the other hand, a body of mass m is to be regarded as a store of energy of magnitude mc^2.
>
> Furthermore, it was soon found impossible to link up the science of gravitation with the special theory of relativity in a natural manner. In this connection I was struck by the fact that the force of gravitation possesses a fundamental property, which distinguishes it from electro-magnetic forces. All bodies fall in a gravitational field with the same acceleration, or—what is only another formulation of the same fact—the gravitational and inertial masses of a body are numerically equal to each other. This numerical equality suggests identity in character. Can gravitation and inertia be identical? This question leads directly to the General Theory of Relativity. Is it not pos-

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PROFESSOR ALBERT EINSTEIN

Photograph by Underwood and Underwood, N. Y.

LEADERS OF THE WORLD ZIONIST ORGANIZATION ON THEIR ARRIVAL AT NEW YORK

PRINCIPAL MOSSINSON — PROFESSOR EINSTEIN — DR. WEIZMANN — DR. USSISHKIN sible for me to regard the earth as free from rotation, if I conceive of the centrifugal force, which acts on all bodies at rest relatively to the earth, as being a "real" field of gravitation, or part of such a field? If this idea can be carried out, then we shall have proved in very truth the identity of gravitation and inertia. For the same property which is regarded as *inertia* from the point of view of a system not taking part in the rotation can be interpreted as *gravitation* when considered with respect to a system that shares the rotation. According to Newton, this interpretation is impossible, because by Newton's law the centrifugal field can not be regarded as being produced by matter, and because in Newton's theory there is no place for a "real" field of the "Koriolis-field" type. But perhaps Newton's law of field could be replaced by another that fits in with the field which holds with respect to a "rotating" system of coordinates? My conviction of the identity of inertial and gravitational mass aroused within me the feeling of absolute confidence in the correctness of this interpretation. In this connection I gained encouragement from the following idea. We are familiar with the "apparent" fields which are valid relatively to systems of coordinates possessing arbitrary motion with respect to an inertial system. With the aid of these special fields we should be able to study the law which is satisfied in general by gravitational fields.

A NEWS SERVICE FOR SCIENCE

Science Service is the name of an agency newly established in Washington for the diffusion of knowledge. It is generously supported by Mr. E. W. Scripps and will be a corporation conducted without profit, all receipts being used for the work and its extension.

The Service will pay adequately for notes and articles that are scientifically correct and of popular interest and will dispose of them through the existing news syndicates and in other ways that will provide the largest possible circulation. It plans also to take up motion pictures and all other methods useful for the popularization of science.

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DR. ERNEST FOX NICHOLS
PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

composed of five members, one selected from each group of trustees from the different organizations represented on the board. The present members of the committee are the president and vice-president of the board, Dr. J. McKeen Cattell and Dr. J. C. Merriam. A member from the journalistic group is yet to be selected.

As editor the board of trustees has selected Edwin E. Slosson, Ph.D., who for twelve years was professor of chemistry in the University of Wyoming and for seventeen years literary editor of *The Independent*, New York. He has been associate in the Columbia School of Journalism since its foundation and is the author of "Creative Chemistry," "Easy Lessons in Einstein," and other scientific and literary publications.

As manager of the new enterprise the board has selected Howard Wheeler, formerly editor of the San Francisco *Daily News*, Pacific coast manager of the Newspaper Enterprise Association, managing editor of *Harpers Weekly*, and for five years editor of *Everybody's Magazine*.

The headquarters of Science Service have been provisionally established in the building of the National Research Council, at 1701 Massachusetts Avenue, Washington, D. C.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND PRESIDENT NICHOLS

The election of Dr. Ernest Fox Nichols, as president of the Massachusetts Institute of Technology, was announced by the corporation on March 30. Dr. Nichols succeeds the late Dr. Richard C. Maclaurin, also a distinguished physicist, under whose administration the institute moved to its new buildings and made notable progress in its educational work.

For the last twelve months Dr. Nichols has been director of physical research at the Nela Park Laboratory of the National Electric Lamp Association, Cleveland. He was born in 1869 at Leavenworth, Kansas, graduated from the Kansas Agricultural College and received from Cornell University the degree of doctor of science in 1897. In 1892 Dr. Nichols was appointed to the chair of physics and astronomy at Colgate University, where he remained for six years. More than two years of this time, however, was spent on leave of absence during which he studied at the University of Berlin. There he discovered the metallic reflection of quartz and its anomalous dispersion in the infra-red spectrum, which led to a new method of spectrum analysis by which the spectrum was extended to six times the previous limits. Rubens, Wood and von Bayer were thus enabled to make a further extension, detecting heat waves 1/64 inch in length.

In 1898 Dr. Nichols was called to the professorship of physics in Dartmouth College, where he made the first measurements of the heat received from several of the brighter stars and planets, by using a radiometer of his own invention, and with Dr. Hull, in 1901, discovered the pressure of a beam of light which had been predicted by Maxwell. Simultaneously the Russian physicist, Lebedev, was able to detect this pressure, but unable to measure it.

After five years at Dartmouth, Dr. Nichols was called to the chair of experimental physics in Columbia University. The year 1904-05 Dr. Nichols spent at Cambridge, England, and lectured at the Royal Institution in London and the Cavendish Laboratory of Cambridge University. He remained at Columbia until 1909, when he was called to the presidency of Dartmouth, resigning in 1916 to become professor of physics at Yale University. This latter position he held until 1920, but during the war he was associated with the Bureau of Ordnance of the Navy Department.

SCIENTIFIC ITEMS

We record with regret the death of John Burroughs, the distinguished naturalist; of Henry P. Cushing, professor of geology in Western Reserve University, and of Louis Compton Miall, the English biologist.

The annual meeting of the American Philosophical Society at Philadelphia and of the National Academy of Sciences at Washington were held toward the end of April. The evening lecture before the American Philosophical Society was given by Professor James H. Breasted, of the University of Chicago, whose series of lectures on "The Origins of Civilization" were recently printed in this journal. Prince Albert of Monaco gave the evening address before the National Academy of Sciences, and its Alexander Agassiz gold medal was conferred on him in recognition of his promotion of oceanographic research.

The Albert medal of the Royal Society of Arts has been presented to Professor Albert Michelson, for his discovery of a natural constant which has provided a basis for a standard of length. The award was made last year, but the actual presentation was deferred until Professor Michelson could go to England to receive it.

Dr. William Crocker, associate professor of botany in the University of Chicago, has been appointed director of the newly founded Thompson Institute for Plant Research at Yonkers, New York. He will enter on his work next autumn. The board of trustees of the new foundation will consist of three business men and three scientific men. Professor John M. Coulter, head of the department of botany at the University of Chicago, and Raymond F. Bacon, of the Mellon Institute of Pittsburgh, will be two of the scientific men, and these two will select the third.

From Punch.

NEWTON AND THE RELIC HUNTER: AN APPLE NOT A STONE

THE SCIENTIFIC MONTHLY

JUNE, 1921

THE BIOLOGY OF DEATH—IV. THE CAUSES OF DEATH[1]

By Professor RAYMOND PEARL

THE JOHNS HOPKINS UNIVERSITY

I. Classification of The Causes of Death

WE have seen in earlier papers that natural death of the metazoan body comes about fundamentally because of the differentiation of structure and function in that body. It is a complex aggregate of cells and tissues, all mutually dependent upon each other and in a delicate state of adjustment and balance. If one organ for any accidental reason, whether internal or external, fails to function normally it upsets this delicate balance, and if normal functioning of the part is not restored, death of the whole organism eventually results. Furthermore, we have been impressed by the fact that death does not strike in a haphazard or random manner, but instead in a most orderly way. There are certain periods of life—notably youth—where only an insignificant fraction of those exposed to risk ever die. At other ages, as, for example, extreme old age and early infancy, death strikes with appalling precision and frequency. Further we recall with Seneca that *nascimus uno modo multis morimur.* Truly there are many ways of dying. The fact is obvious enough. But what is the biological meaning of this multiplicity of pathways to the River Styx? There is but one pathway into the world. Why so many to go out? To the consideration of some phases of this problem I invite attention in this paper.

By international agreement among statisticians the causes of human mortality are, for statistical purposes, rather rigidly defined and separated into something over 180 distinct units. It should be clearly understood that this convention is distinctly and essentially statistical in its nature. In recording the statistics of death the registrar is confronted with the absolute necessity of putting every death record into

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 31.

some category or other in respect of its causation. However complex biologically may have been the train of events leading up to a particular demise, the statistician must record the terminal "cause of death" as some particular thing. The International Classification of the Causes of Death is a code which is the result of many years' experience and thought. Great as are its defects in certain particulars, it nevertheless has certain marked advantages, the most conspicuous of which is that by its use the vital statistics of different countries of the world are put upon a uniform basis.

The several separate causes of death are grouped in the International Classification into fourteen general classes. These are:

I. General diseases.
II. Diseases of the nervous system and of the organs of special sense.
III. Diseases of the circulatory system.
IV. Diseases of the respiratory system.
V. Diseases of the digestive system.
VI. Non-venereal diseases of the genito-urinary system and annexa.
VII. The puerperal state.
VIII. Diseases of the skin and of the cellular tissue.
IX. Diseases of the bones and organs of locomotion.
X. Malformation.
XI. Early infancy.
XII. Old age.
XIII. External causes.
XIV. Ill-defined diseases.

Perhaps the most outstanding feature which strikes one about the International List is that it is not primarily a biological classification. Its first group, for example, called "General Diseases," which caused in 1916 in the Registration Area of the United States approximately one-fourth of all the deaths, is a most curious biological and clinical mélange. It includes such diverse entities as measles and malaria, tetanus and tuberculosis, cancer and gonococcus infection, alcoholism and goiter, and many other unlike causes of death. For the purposes of the statistical registrar it perhaps has useful points to make this "General diseases" grouping, but it clearly corresponds to nothing natural in the biological world. Again in such parts of the scheme as do have some biological foundation the basis is different in different rubrics. Some have an organological basis, while others have a causational.

For purposes of biological analysis I developed some time ago an entirely different classification of the causes of death, on what I think is a reasonably consistent basis. The underlying idea of this new classification was to group all causes of death under the heads of the several organ systems of the body, the functional breakdown of which is the immediate or predominant cause of the cessation of life. All except a few of the statistically recognized causes of death in the International Classification can be assigned places in such a biologically grouped list. It has a sound logical foundation in the fact that, biologically considered, death results because some organ system, or group of organ systems, fails to continue its functions.

The headings finally decided upon in the new classification were as follows:

I. Circulatory system, blood and blood-forming organs.
II. Respiratory system.
III. Primary and secondary sex organs.
IV. Kidneys and related excretory organs.
V. Skeletal and muscular systems.
VI. Alimentary tract and associate organs concerned in metabolism.
VII. Nervous system and sense organs.
VIII. Skin.
IX. Endocrinal system.
X. All other causes of death.

The underlying idea of this rearrangement of the causes of death is to put all those lethal entities together which bring about death because of the functional organic breakdown of the same general organ system. The cause of this functional breakdown may be anything whatever in the range of pathology. It may be due to bacterial infection; it may be due to trophic disturbances; it may be due to mechanical disturbances which prevent the continuation of normal function; or to any other cause whatsoever. In other words; the basis of the classification is *not* that of pathological causation, but it is rather that of organological breakdown. We are now looking at the question of death from the standpoint of the pure biologist, who concerns himself not with what causes a cessation of function, but rather with what part of the organism ceases to function, and therefore causes death.

In a series of papers already published I have given a detailed account of this classification, and the reasoning on which particular causes of death are placed in it where they are. Space is lacking here to go into the details, and I must consequently ask the reader either to take it on faith for the time being that the classification is at least a fairly reasonable one, or to take the trouble to go over it in detail in the original publication.[2]

2. General Results of Biologically Classified Death Rates

Here I should like to present first some general statistical results of this new classification. The data which we shall first discuss were in the form of death rates per hundred thousand living at all ages from various causes of death, arranged by organ systems primarily concerned in death from specified diseases. The statistics came from three

[2]Cf. particularly Pearl, R. "On the embryological basis of human mortality." (Proc. Natl. Acad. Sci. Vol. 5, pp 593-598, 1919) and "Certain evolutionary aspects of human mortality rates." (Amer. Natl. Vol. LIV. pp. 5-44, 1920). The following section as well as section 4 of this paper are largely based upon the second of the two papers.

widely separated localities and times, viz., (a) from the Registration Area of the United States; (b) from England and Wales; and (c) from the City of Sao Paulo, Brazil.

The summarized results are shown in graphic form in Fig. 1.

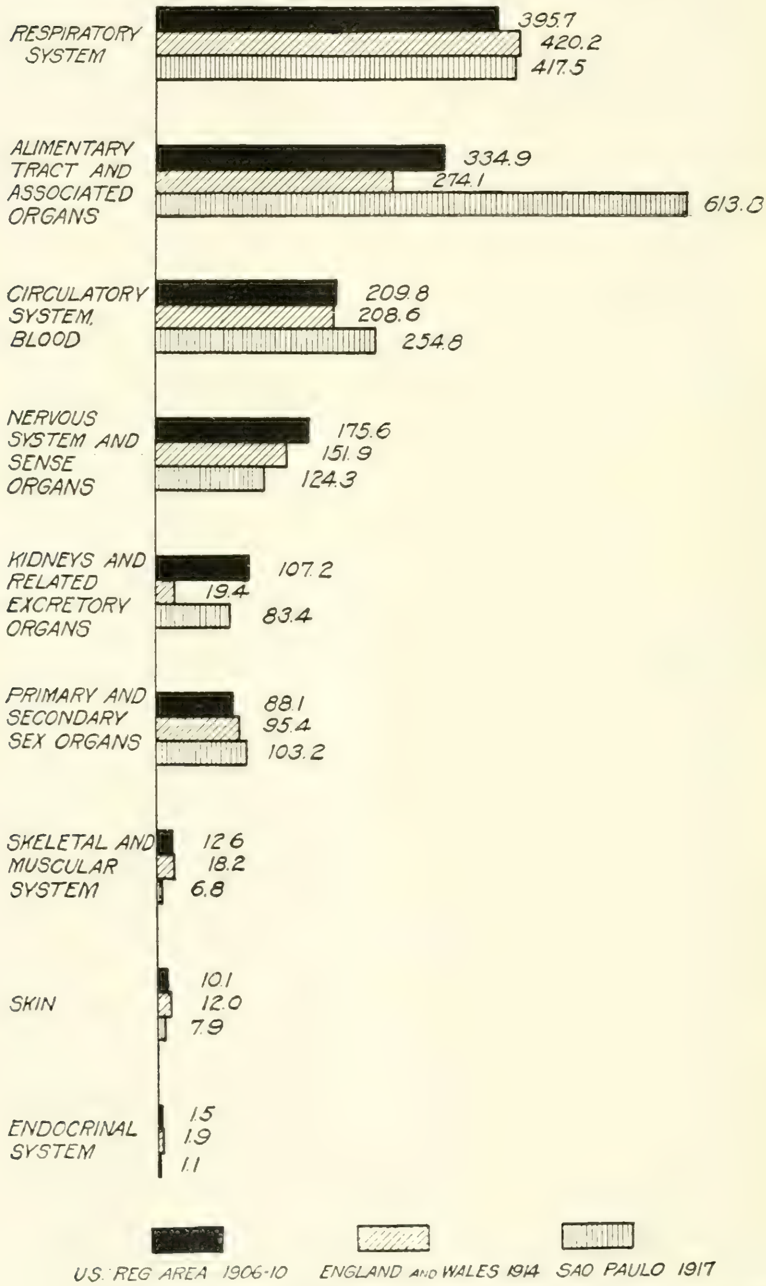


FIG. 1. SHOWING THE RELATIVE IMPORTANCE OF THE DIFFERENT ORGAN SYSTEMS IN HUMAN MORTALITY

In the United States, during the decade covered, more deaths resulted from the breakdown of the respiratory system than from the failure of any other organ system of the body. The same thing is true of England and Wales. In Sao Paulo the alimentary tract takes first position, with the respiratory system a rather close second. The tremendous death rate in Sao Paulo chargeable to the alimentary tract is chiefly due to the relatively enormous number of deaths of infants under two from diarrhea and enteritis. Nothing approaching such a rate for this catagory as Sao Paulo shows is known in this country or England.

In all three localities studied the respiratory and the alimentary tract together account for rather more than half of all the deaths biologically classifiable. These are the two organ systems which, while physically internal, come in contact directly at their surfaces with environmental entities (water, food, air) with all their bacterial contamination. The only other organ system directly exposed to the environment is the skin. The alimentary canal and the lungs are, of course, in effect invaginated *surfaces* of the body. The mucous membranes which line them are far less resistant to environmental stresses, both physical and chemical, than is the skin with its protecting layers of stratified and cornified epithelium.

The organs concerned with the blood and its circulation—the heart, arteries and veins, etc.—stand third in importance in the mortality list. Biologically the blood, through its immunological mechanism, constitutes the second line of defense which the body has against noxious invaders. The first line is the resistance of the outer cells of the skin and the lining epithelium of alimentary tract, lungs, and sexual and excretory organs. When invading organisms pass or break down these first two lines of defense the battle is then with the home guard, the cells of the organ system itself, which, like the industrial workers of a commonwealth keep the body going as a whole functioning mechanism. Naturally it would be expected that the casualties would be far heavier in the first two defense lines (respiratory and alimentary systems and the blood and circulation) than in the home guard. Death rates when biologically classified bear out this expectation.

It is at first thought somewhat surprising that the breakdown of the nervous system is responsible for more deaths than that of the excretory system. When one bears in mind however the relative complexity of the two pieces of machinery it is perceived that the relative position of the two in responsibility for mortality is what might reasonably be expected.

In the United States the kidneys and related excretory organs are responsible for more deaths than the sex organs. This relation is reversed in England and Wales and in Sao Paulo. This difference is mainly due in the case of England to two factors premature birth and cancer. In Sao Paulo it is due to premature birth and syphilis. The higher premature birth rate for these two localities as compared with the United States might conceivably be explained in either of two ways. It might mean better obstetrics here than in the other localities, or it might mean that the women of this country as a class are somewhat superior physiologically in the matter of reproduction, when they do reproduce. The first suggestion seems definitely more improbable than the second. The higher apparent syphilis rate of Sao Paulo probably means nothing more than better reporting, a less prudish disinclination to report syphilis as a cause of death in Sao Paulo than in the other two countries. It is by no means beyond the bounds of possibility that if all deaths really due to syphilis and gonorrhea were actually reported as such, the rate for the sex organs would be decidedly higher than for the excretory organs in all countries.

The last three organ systems, skeletal and muscular system, skin and endocrinal organs, are responsible for so few deaths relatively as not to be of serious moment.

There is one general consequence of these results upon which I should like to dwell a moment longer. In a broad sense the efforts of public health and hygiene have been directed against the affections comprised in the first two items in the chart, those of the respiratory system and the alimentary tract. The figures for the two five-year periods in the United States, 1901-05 and 1906-10, indicate roughly the rate of progress such measures are making, looking at the matter from a broad biological standpoint. In reference to the respiratory system there was a decline of fourteen per cent in the death rate between the two periods. This is substantial. It is practically all accounted for in phthisis, lobar pneumonia and bronchitis. For the alimentary tract the case was not so good—indeed far worse.

Between the two periods the death rate from this cause group fell only 1.8 per cent. All the gain made in typhoid fever was a great deal more than offset by diarrhea and enteritis (under two), congenital debility and cancer. Child welfare, both prenatal and postnatal, seems by long odds the most hopeful direction in which public health activities can expect at the present time substantially to reduce the general death rate. This is a matter fundamentally of education. Ignorant and stupid people must be taught, gently if possible, forcibly if necessary, how to take care of a baby, both before and after it is born. It seems at present unlikely, that mundane law will regard feeding cucumber to a two months' old baby, or dispensing milk reeking with deadly poison makers, as activities accessory to first-degree murder.

But we are moving in that direction under the enthusiastic and capable leadership of the Federal Children's Bureau. And there is this further comfort, that if that final Judgment Seat, before which so many believe we must all eventually appear, dispenses the even-handed justice which in decncy it must, many of our most prominent citizens who in the financial interests of themselves or their class block every move towards better sewage disposal, water and milk supply, and the like, or force pregnant women to slave over a washtub and sewing bench that they may live, will find themselves irrevocably indicted for the wanton and willful slaughter of innocent babies.

3. Specific Death Rates Biologically Classified

Up to this point in our discussions we have been dealing with crude death rates uncorrected for the age and sex distributions of the populations concerned. It is, of course, a well known fact that differences in age and sex constitution of populations may make considerable differences in crude death rates in cases where no real differences in the true force of mortality exist. What is essential for the further prosecution of the analysis of the causes of death is to get *specific* death rates for the several causes. By an age and sex specific death rate is meant the rate got by dividing the number of persons of a *particular specified age and sex* dying from a particular cause by the total number of persons living in the same population *of the same age and sex*. In other words we need to get as the divisor of our rate fraction the number of persons who can be regarded as truly exposed to risk. This exposed-to-risk portion of the population is never correctly stated in a crude death rate. For example, a person now 75 years old can not be regarded as exposed to risk of death at age 45. He was once exposed to that risk but passed it safely. Yet in a crude death rate he is counted with those of age 45.

With the aid of Dr. William H. Davis, director of vital statistics in the Census Bureau, who very kindly provided me with the necessary unpublished data, it has been possible to calculate the specific death rates for each of the 189 causes of death of the International List, for each sex separately, and for each age in 5 year groups, for the United States Registration Area exclusive of North Carolina, in 1910. These results have been put together in the biological scheme of classification and may be presented briefly in the form of diagrams.

Let us first consider deaths from all causes taken together, in order to refresh our memories as to the general form of a death rate curve. It will be noted at once that the rates are plotted along the vertical axis on what strikes one at first as a peculiar scale. The scale is logarithmic. The horizontal lines are spaced in proportion to the logarithms of the numbers at their left, instead of in proportion to the numbers themselves. The advantages of this method of plotting in the present case are two-fold. First, it is possible to get a much wider range of values on the diagram; and second the logarithmic scale permits direct and accurate estimation of the rate of change of a variable. A straight line forming an angle with the horizontal on a logarithmic scale means that the variable is increasing or decreasing, as the case may be, *at a constant rate of change.*

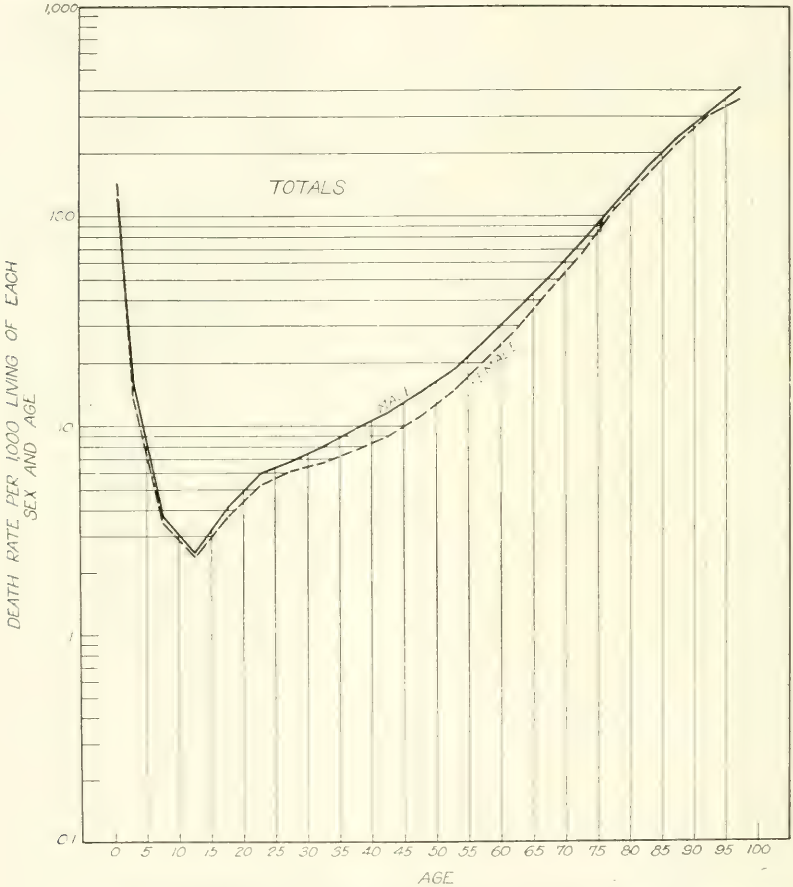


FIG. 2. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FOR DEATHS FROM ALL CAUSES TAKEN TOGETHER

Fig. 2 gives the specific death rates for the combined total of all causes. The curve in general has the form of a V with one limb much extended and pulled over to the right. Examining it more in detail, we note that in the first year of life the specific death rate, or, as we may roughly call it, the force of mortality, bears heavier on female infants than on the males. Out of a thousand exposed to risk, 124 male babies die in that year, and 143 female. This is the only year of life in which the total force of mortality is heavier among females than males. From that time on to the end of the span of life the female curve lies, by greater or less amounts, below the male curve. After the heavy mortality of early infancy, the curve drops in almost a straight line to the age period 10-15, where it reaches its lowest point, and only approximately 2½ persons out of a thousand exposed to risk die. The specific mortality curve then begins to rise and continues to do so at an approximately constant and rapid rate for ten years—that is to the age period 20-25. From then on to the age period 50-55 it rises at a slower but constant rate. This is the period of middle life, and here the female curve drops farther below the male curve than at any other place in the span of life. After the age period 50-55 with the on-coming of old age, both male and female curves begin again to rise more rapidly. They continue this rise at a practically constant rate of increase to the end of life, which is here taken as falling in the age period 95-100. In

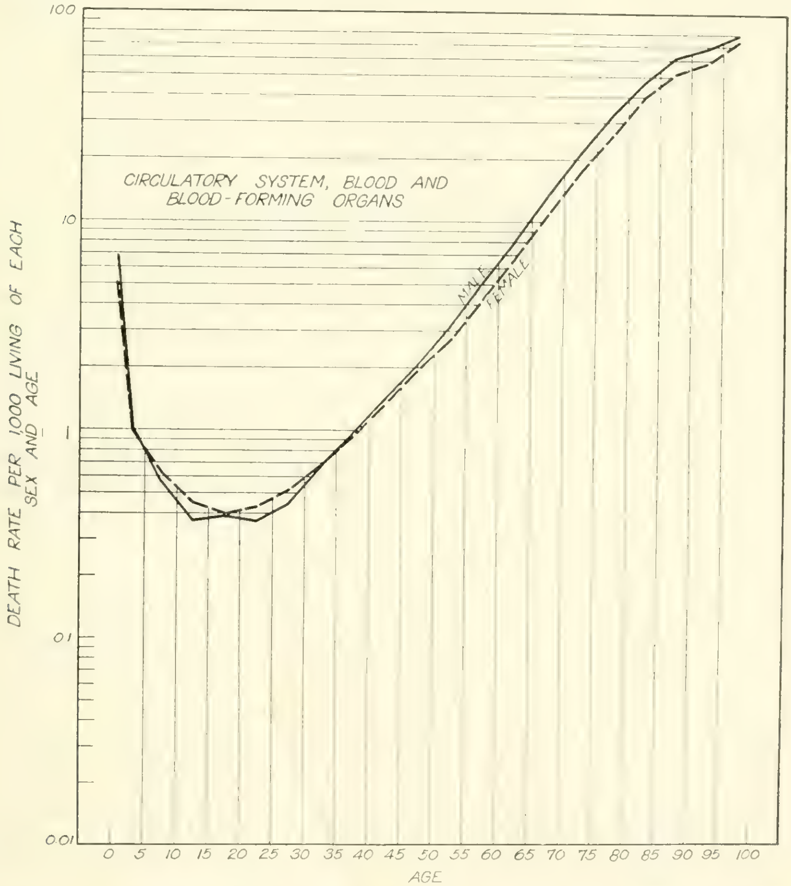


FIG. 3. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FROM BREAKDOWN OF THE CIRCULATORY SYSTEM, BLOOD AND BLOOD FORMING ORGANS

this last class the rate has become very high. Out of 1,000 persons living at the ages of 95 and 100, and therefore exposed to risk of death within that period, 494 males and 473 females die, taking an average for the whole five-year period. Of course, before the completion of the period, practically all of the thousand will have passed away.

The important things to note about this curve are these: First, the highest specific forces of mortality occur at the extreme ends of life, and are higher at the final end than at the beginning. In the second place, there is a sharp and steady drop in almost a straight line from the high specific force of mortality in infancy to the low point at about the time of puberty. From then on to the end of the span of life the force of mortality becomes greater every year at a nearly constant rate of increase with only such slight deviations from this constancy of rate as have already been pointed out.

Turning next to the mortality of our first biological group—namely, deaths caused by breakdown of the circulatory system, blood and blood forming organs—we note a marked difference in the form of the curve from what we have seen for the case of all causes of death. In the first place, the specific force of mortality of this group of causes is relatively low in infancy and childhood. Out of a thousand infants of each sex exposed to risk, only 7 males and 5 females die from breakdown of this group of organs during the first year of life. The trough of the curve associated with the mortality of childhood and youth is very much less pointed than in the case of "all causes." It is a smoothly rounded, rather than a sharply pointed depression. It is also noteworthy that between approximately the ages of 5 and 35 the specific force of mortality from diseases of the circulatory system and related organs is higher for females than it is for males. This condition of affairs is probably connected with the graver physiological changes and readjustments called forth by puberty in the female than accompany the same vital crisis in the male. From early adult life, say age 25-30 on, the specific death rate from diseases of the circulatory system and related organs increases at an almost absolutely constant rate until age 85 is reached. After that the rate of increase slows down somewhat. Of those reaching the age 95-100, between 70 and 80 out of each thousand living die from breakdown of this group of organs.

The specific mortality curve for deaths from breakdown of the respiratory system, as shown in Fig. 4, presents a number of points of peculiar interest. In the first place we note that this organ system is much more liable to breakdown than is the circulatory system during all the earlier years of life up to about age 60-65. The decline in the curve from the high point of infancy to the low point of the period about puberty is more sharp and sudden than that of the circulatory system curve. Again, however, just as in the former case, we note that the specific force of mortality from breakdown of this organ system impinges more heavily upon females than upon males in the years from 5-20. This difference is probably connected, as before, with the greater physiological disturbance of puberty in the female than in the male. The lowest point of the respiratory curve falls in the age group 10-15. Between the ages 25-70 there is a very striking difference in the two sexes in respect of specific mortality from breakdown of the respiratory system. The male curve rises in nearly a straight line, while the female curve lies far below it, and actually shows a point of inflection at about age 45 becoming for a short period convex to the base. The explanation for the great separation of the two curves in this period is probably fundamentally occupational. From the nature of their activity males during this period of life are probably subject to a greater risk of breakdown of the respiratory system than are the more protected female lives. From age 70 on, both curves ascend with

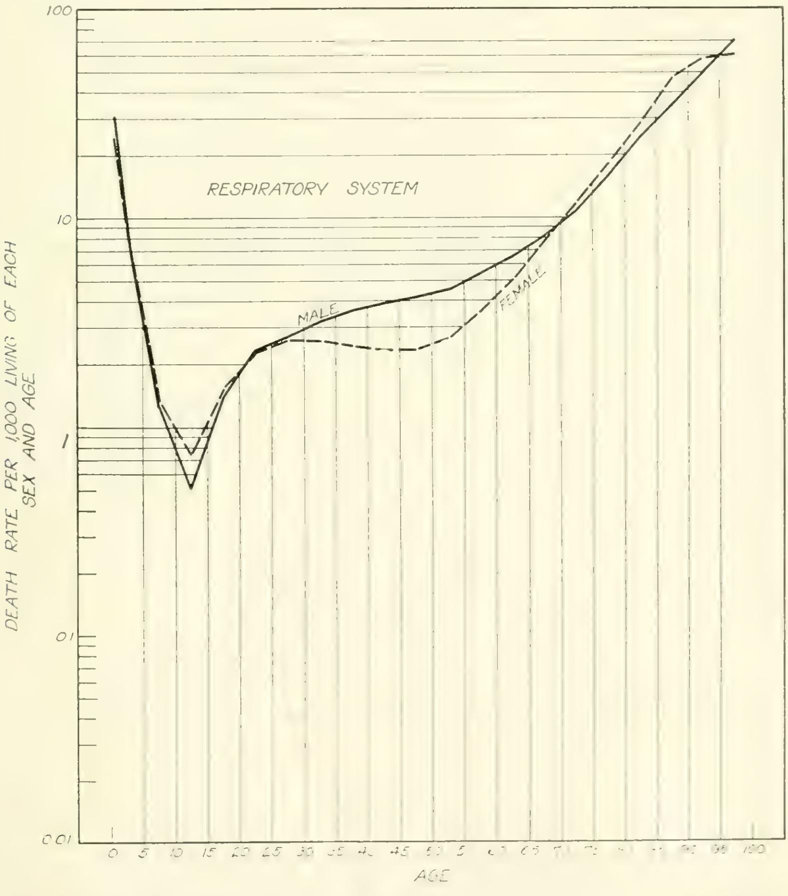


FIG. 4. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FROM BREAKDOWN OF THE RESPIRATORY SYSTEM

increased rapidity, the female curve rising above the male, presumably in compensation for the marked dip which it exhibits in middle life. It is, of course, well known that respiratory mortality bears heavily upon the aged.

The next group which we shall consider has to do with deaths from breakdown of the primary and secondary sex organs. This cause group furnishes an extremely interesting pair of curves shown in Fig. 5. Before discussing in detail their form a word of explanation as to their makeup should be given. In this rubric are included "Premature birth" and "Injuries at birth." The question at once arises, why should these two items, "Premature birth" and "Injuries at birth" be included with the primary and secondary sex organs, since it is obvious enough that the infants whose deaths are recorded under these heads in the vast majority of cases, if not all, have nothing whatever the matter with either their primary or secondary organs. The answer is, in general terms, that on any proper biological basis, deaths coming under of these two categories are not properly chargeable organically against the infant at all, but should be charged, on such a basis, against the mother. To go further into detail, it is apparent that when a premature birth occurs it is because the reproductive system of the mother, for some reason or other, did not rise to the demands of the situation of carrying the foetus to term. Premature birth, in short, results from a failure or breakdown in some particular of the *maternal reproductive system.* This failure may be caused in various ways, which do not here concern us. The essential feature from our present viewpoint is that the reproductive system of the mother does breakdown, and by so doing causes the death of the infant, and that death is recorded statistically under this title "Premature birth." The death organically is chargeable to the mother.

A considerable number of cases of premature birth are unquestionably due to placental defects and the placenta is a structure of foetal origin, so such deaths could not be properly charged to the mother. On the other hand, however, they would still stay in the same table because the placenta may fairly be regarded as an organ intimately concerned in reproduction.

The same reasoning which applies to premature births, *mutatis mutandis,* applies to the item "Injuries at birth." An infant death recorded under this head means that some part of the reproductive mechanism of the mother, either structural or functional, failed of normal performance in the time of stress. Usually "injury at birth" means a contracted or malformed pelvis of the mother. But in any case the death is purely external and accidental from the standpoint of the infant. It is organically chargeable to a defect of the sex organs of the mother. The female pelvis, in respect of its conformation, is a secondary sex character.

Turning now to the consideration of Fig. 5, which gives the curves of specific mortality from breakdown of the reproductive organs we note at once the high specific death rate of infants under one recorded by the female line. This rate is over 40 per thousand exposed to risk. It includes of course both male and female infants dying from congenital debility, premature birth and injuries at birth, because according to the reasoning just explained these deaths are organically chargeable to breakdown or failure to function properly of the reproductive organs of the mother. These deaths, therefore, go into the female group. By the fifth year of life the specific rates of mortality chargeable to reproductive organs have dropped in both sexes practically to zero, amounting to less than 0.01 per thousand exposed to risk. At about the time of puberty the female curve begins to rise and goes up very steeply. By age 30 it has reached a value of 1 per thousand ex-

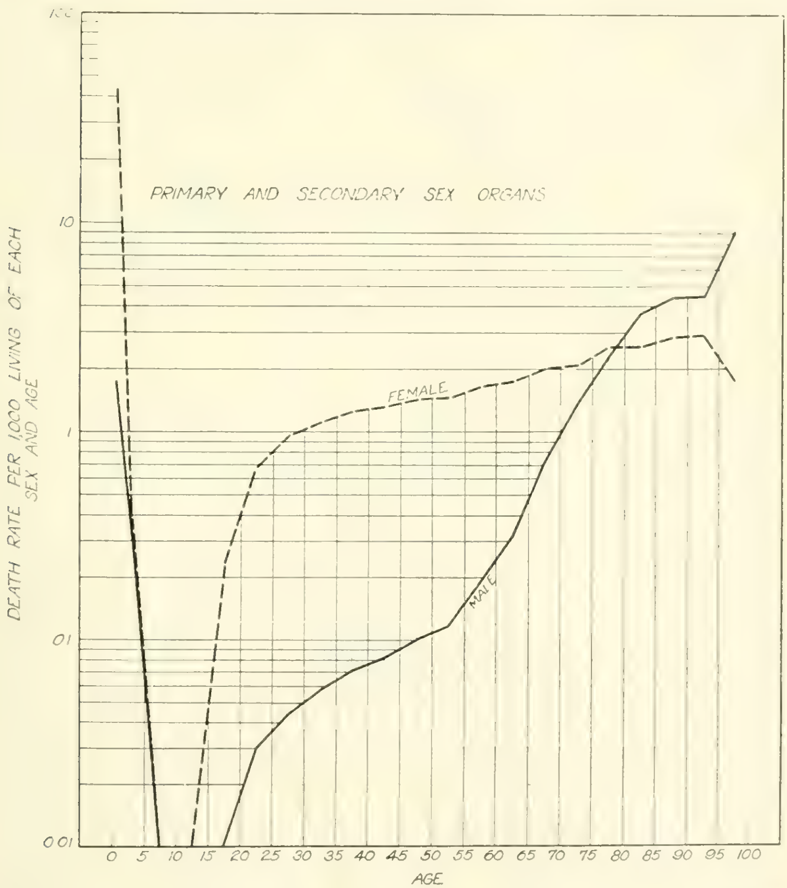


FIG. 5. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE PRIMARY AND SECONDARY SEX ORGANS

posed to risk. From that point the force of this specific mortality rises slowly, but at a practically constant rate, to extreme old age. The

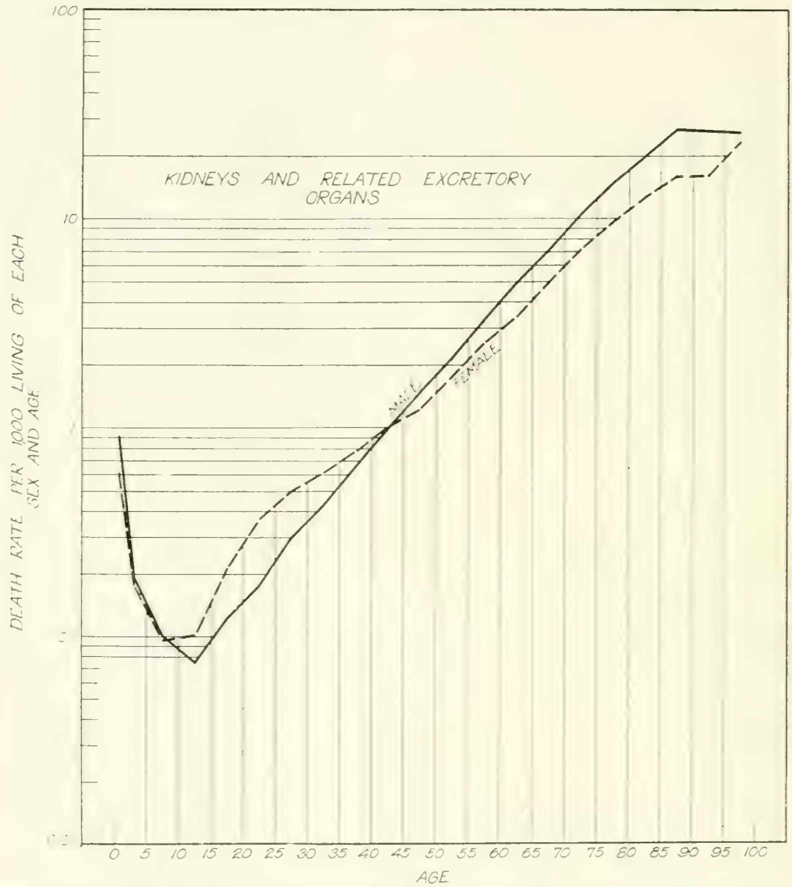


FIG. 6. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE KIDNEYS AND RELATED EXCRETORY ORGANS

male curve is in striking contrast to the female. From about age 20 it rises steadily, at an almost constant rate of increase, but a much slower one than the female, until the end of the life span. It crosses the female curve—indicating a higher specific rate of mortality from breakdown of the reproductive organs in men than in women—for the first time at about age 78. This is of course, the time of life when disturbed functioning of the prostate gland in the male begins to take a relatively heavy toll.

Fig. 6 shows specific rates of mortality from breakdown of the kidneys and related excretory organs. Death from these causes is relatively infrequent in infancy and early childhood. The low point

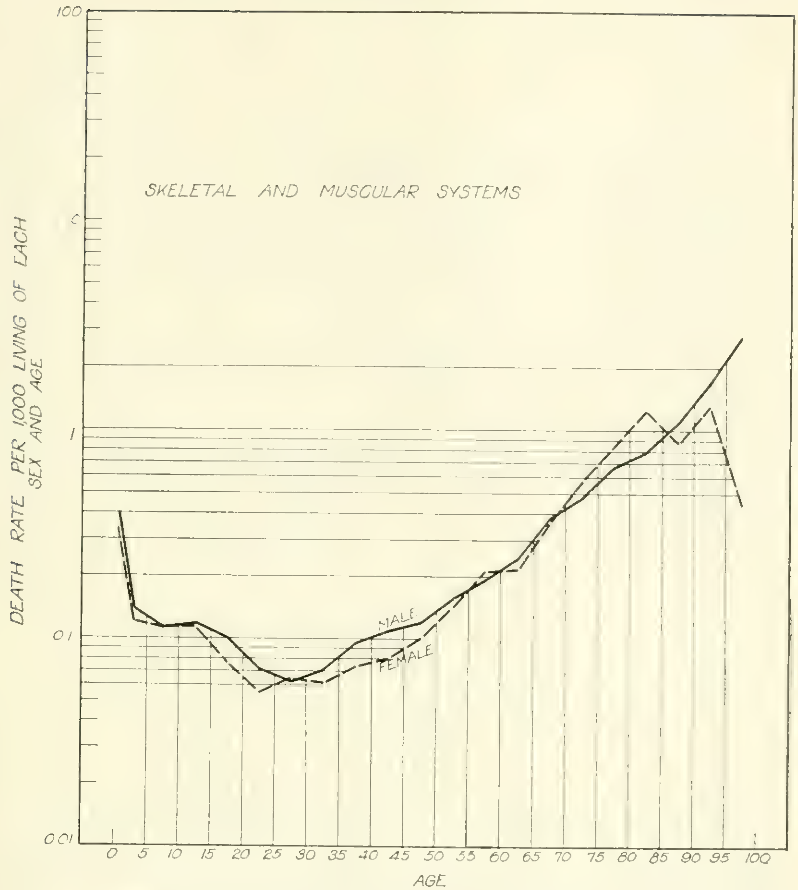


FIG. 7. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE SKELETAL AND MUSCULAR SYSTEMS

is reached, as in so many of the other cases, at about the time of puberty. From then on practically to the end of the span of life the specific force of mortality from excretory failure increases at an almost constant rate. During the reproductive period from about 15 to 45 years of age specific rates of mortality from these causes are higher in the female than in the male. After that point the male curve is higher. The relatively heavy specific mortality of the female in early life is undoubtedly due to the heavy strain put upon her excretory organs by child-bearing.

The specific force of mortality from breakdown of the skeletal and muscular systems shown in Fig. 7 presents an interesting pair of curves. Throughout the span of life there is practically no difference between the female and male in the incidence of this mortality, the curves winding in and out about each other. The striking characteristics of the

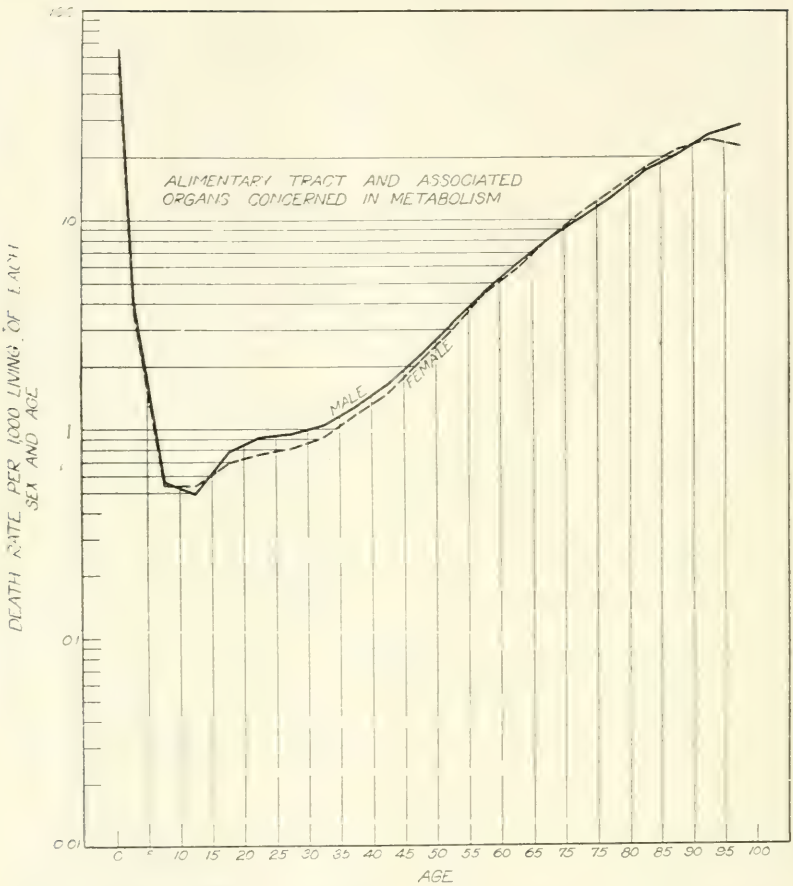


FIG. 8. DIAGRAM SHOWING THE SPECIFIC RATES OF DEATH AT EACH AGE FROM BREAKDOWN OF THE ALIMENTARY TRACT AND ASSOCIATED ORGANS OF METABOLISM

curve are: first, that the specific forces of mortality are absolutely low for these organ systems; and second, that the minimum point is reached not as in most of the other cases around the time of puberty, but at a much later period—namely in the late twenties. The whole curve shows a very gradual change in the rates.

The next diagram, Fig. 8, shows one of the most significant organ groups in the force of its specific mortality. Breakdown and failure to function properly of the primary organs of metabolism—the organs which transform the fuel of the human machine into vital energy—occur with relatively heavy frequency at all periods of life. These curves are among the few which show an absolutely higher specific force of mortality in infancy than in extreme old age. There is practically no significant difference between the male and female curve at any portion of life. During early adult life the female curve lies be-

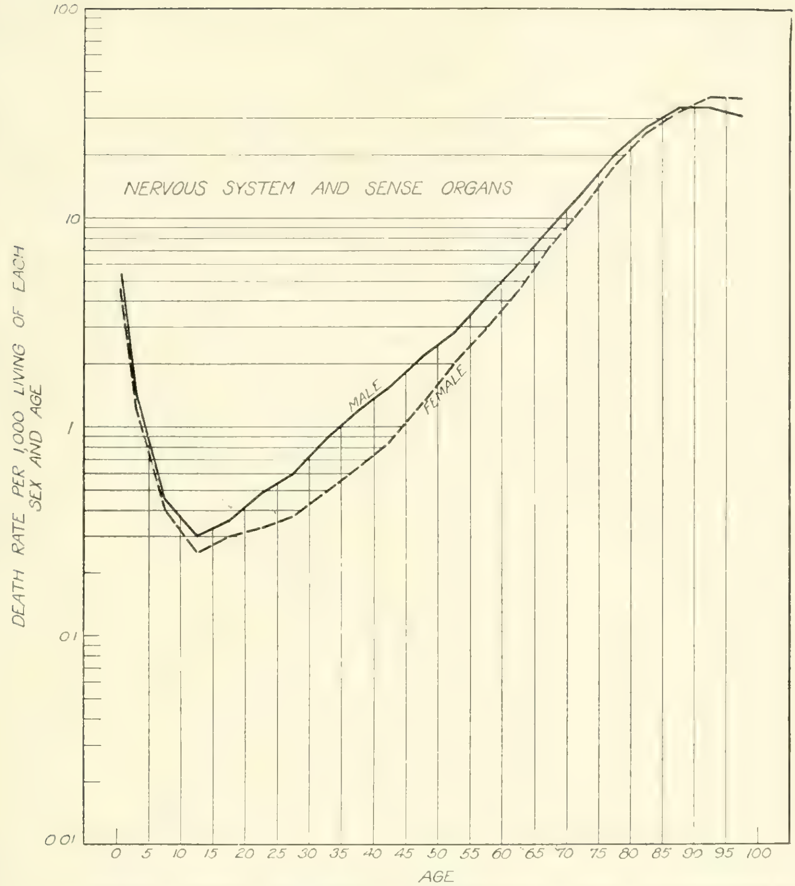


FIG. 9. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE NERVOUS SYSTEM AND SENSE ORGANS

low the male, but by only a small amount. Out of every thousand infants under one, about sixty die in the first year of life from breakdown of the alimentary tract and its associated organs. After the low point, which falls in the relatively early period of 7 to 12 years of age, there is a rapid rise for about ten years in the specific rates of mortality, followed by a slowing off in the rate of increase for the next ten or fifteen years, after which point the curve ascends at a practically uniform rate until the end of the span of life.

Fig. 9 shows the trend of the specific mortality from breakdown of the nervous system and sense organs. This organ group on the whole functions very well, giving a relatively low rate of mortality until towards the end of middle life. Then the specific rates get fairly large. The low point in this curve is, as in most of the others, at about the time of puberty. From then on to the end of the life span

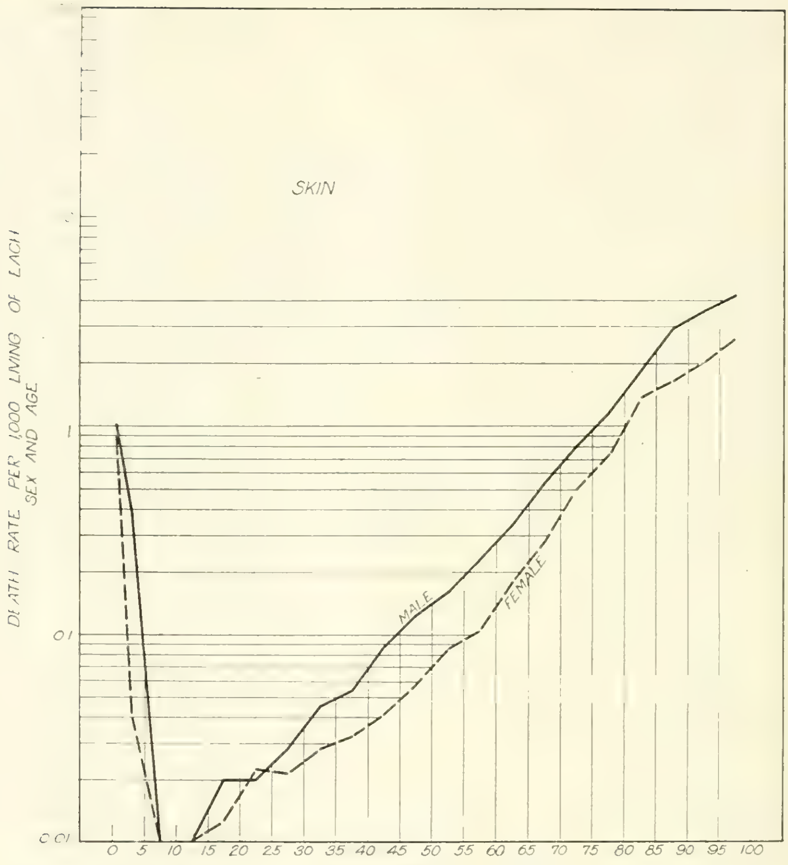


FIG. 10. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE CHARGEABLE AGAINST THE SKIN

the specific rates increase at a practically uniform rate. The female curve everywhere lies below the male curve except at the extreme upper end of the life span. Before that time, and particularly between the ages of 20 and 50, the business of living evidently either imposes no such heavy demand on the nervous system of the female as it does on that of the male, or else the nervous system of the female is organically sounder than that of the male. The former suggestion seems the more probable.

That breakdown and failure to function properly of the skin as an organ system is a relatively insignificant factor in human mortality is demonstrated by Fig. 10. From a specific death rate of about 1 per 1,000 in the first year of life it drops abruptly practically to zero in early childhood. At about the time of puberty it begins to rise again and ascends at a steady rate during all the remainder of life. The final high point reached is absolutely low, however, amounting to a specific death rate among those exposed to risk of only a little more than 4 per 1,000 at the extreme end of life. The female curve lies well below the male curve practically throughout its course.

Deaths from failure to function properly of the organs of the endocrinal system, including the thyroid gland, suprarenal glands, etc., do not become significant until middle life in the case of the male, as shown in Fig. 11, although in the female the curve begins to rise from puberty on. The specific rates at all ages, of course, are extremely small, practically never rising to more than 1/10 of one person per 1,000 exposed to risk. The well-known fact that these glandular organs, whose secretions are so important for the normal conditions of life, are much more unstable and liable to breakdown in the female than in the male is strikingly shown by this diagram.

Finally, we have the diagram for our *omnium gatherum* group, the "All other causes of death," in Fig. 12. Here we see that because of

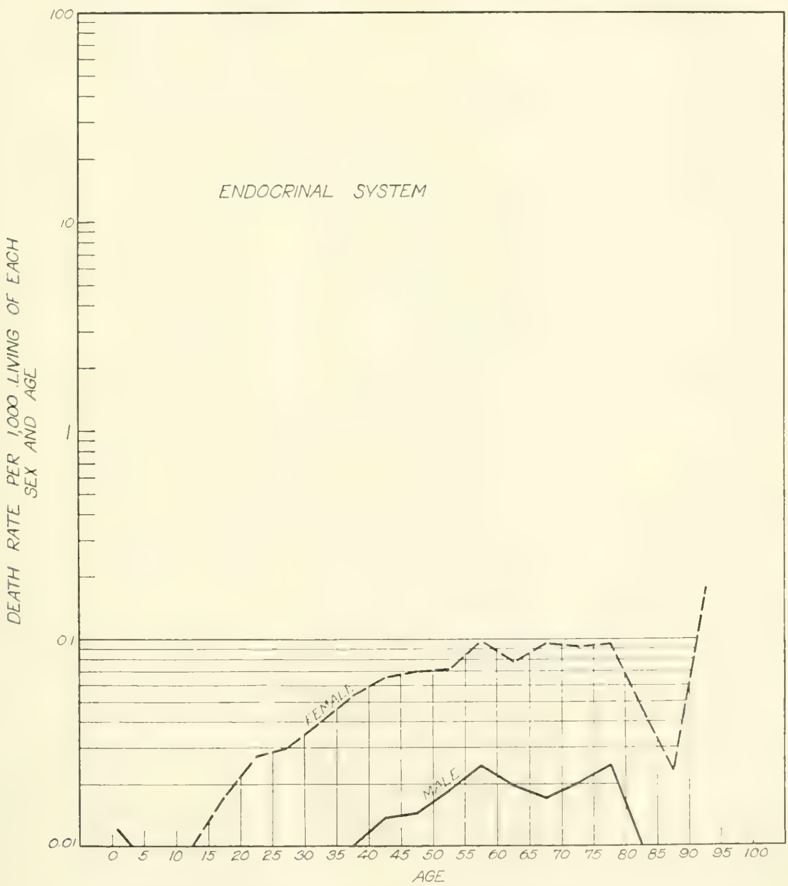


FIG. 11. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE ENDOCRINAL SYSTEM

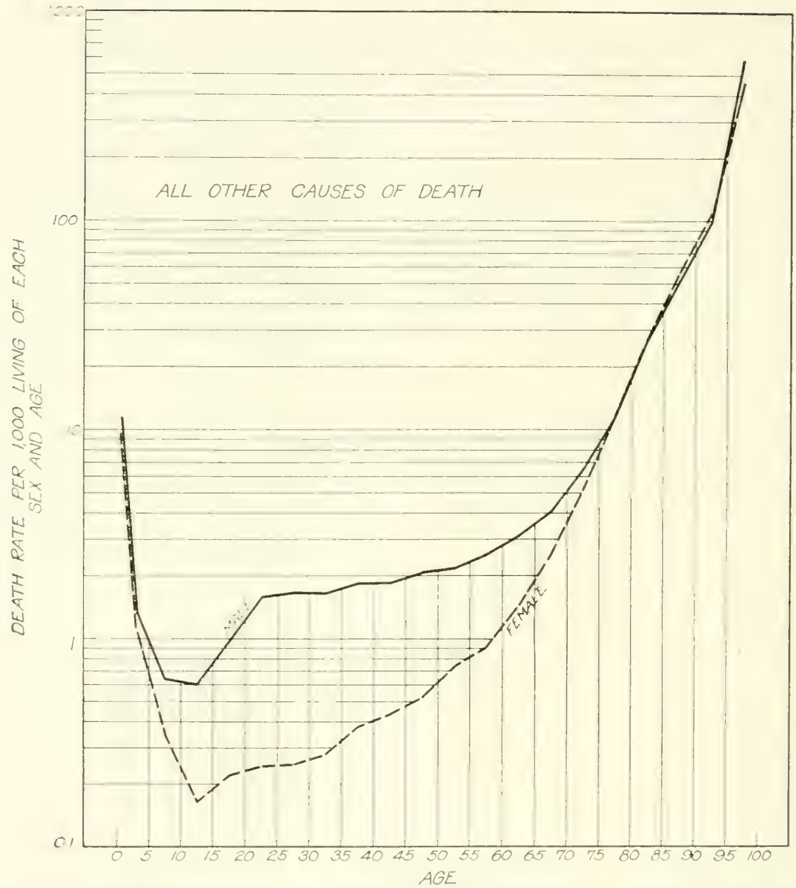


FIG. 12. DIAGRAM SHOWING THE SPECIFIC DEATHS FROM ALL OTHER CAUSES OF DEATH NOT COVERED IN THE PRECEDING CATEGORIES

accidental and violent deaths the male specific mortality curve lies far above the female, from youth until old age has set in about age 75. From that point on to the end of the span of life both curves ascend rapidly together, as a result of the deaths recorded as resulting from senility. Eventually it is to be expected that no deaths will be registered as resulting from senility. We shall have them all put more nearly where they belong.

These diagrams of specific forces of mortality give altogether a remarkably clear and definite picture of how death occurs among men. We see that failure of certain organ systems, such as the lungs, the heart, the kidneys, to maintain their structural and functional integrity, has an overwhelmingly great effect in determining the total rate of mortality as compared with some of the other organ systems. One can not but be impressed too with the essential orderliness of the phenomena we have examined. The probability of any particular organ system breaking down and causing death is mathematically definite at each age, and changes in a strikingly orderly manner as age changes, as is shown in Table 1. Thus we find that in the first year of life it is the alimentary tract and its associated organs which most frequently break down and cause death. From age 1 to age 60 the specific force of mortality from breakdown of the respiratory system is higher (with a few insignificant exceptions in the females) usually by a considerable amount, than that associated with any other organ system of the body. From 60 to 90 years of age the circulatory system takes the front rank, with a higher specific mortality rate than any other organ system.

TABLE I.

The Most Fatal Organ Systems at Different Ages

MALES			FEMALES	
Per cent of all biologically classifiable deaths due to breakdown of specified organ system.	Most fatal organ system	Age Group	Most fatal organ system	Per cent of all biologically classifiable deaths due to breakdown of specified organ system.
68.8	Alimentary tract	0 — 1	Alimentary tract	40.6
50.1	Respiratory	1 — 4	Respiratory	51.3
41.2	"	5 — 9	"	42.5
27.1	"	10—14	"	33.3
43.6	"	15—19	"	43.8
52.6	"	20—24	"	46.0
49.7	"	25—29	"	44.2
45.6	"	30—34	"	39.5
39.9	"	35—39	"	33.2
33.3	"	40—44	"	27.5
28.0	"	45—49	"	22.1
23.6	"	50—54	Alimentary tract	21.6
25.0	Circulatory	55—59	"	22.6
28.4	"	60—64	Circulatory	24.4
30.9	"	65—69	"	25.6
32.5	"	70—74	"	28.0
32.9	"	75—79	"	28.4
33.3	"	80—84	"	30.4
		85—89	"	30.8

If our lungs were as organically good relatively as our hearts, having regard in each case for the work the organ is called upon to do and the conditions under which it must do it, we should live a considerable number of years longer on the average than we do now. One can not but feel that the working out of a rational and scientifically grounded system of personal hygiene of the respiratory organs, on the broadest basis, to include all such matters as ventilation of buildings, etc., and the putting of such a personal hygiene into general use through education, would pay about as large dividends as could be hoped for from any investment in public health securities. I am aware that much has already been done in this direction, but in order to reap any such dividends as I am thinking of, a vast amount must be added to our present knowledge of the physiology, pathology, epidemiology, and every other aspect of the functions and structures of respiration.

4. The Embryological Basis of Mortality

Up to this point in our discussion we have confined our attention to the organological incidence of death. It is possible to push the matter of human mortality still farther back. In the embryological development of the vertebrate body, there are laid down at an early stage, in fact immediately following the process of gastrulation, three morphologically definite primitive tissue elements, called respectively the ectoderm, the mesoderm, and the endoderm. These are termed the

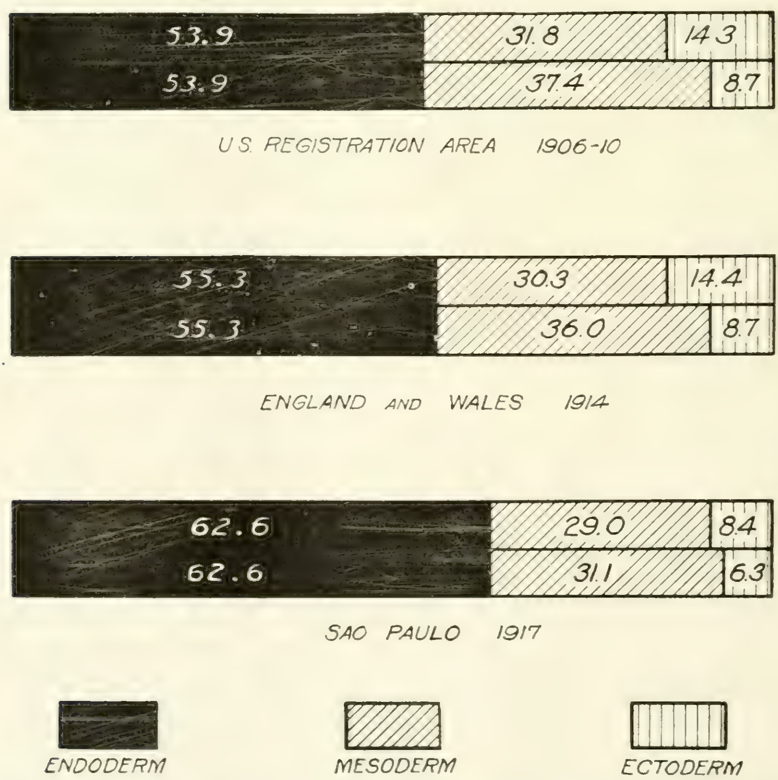


FIG. 13. DIAGRAM SHOWING THE PERCENTAGES OF BIOLOGICALLY CLASSIFIABLE HUMAN MORTALITY RESULTING FROM BREAKDOWN OF ORGANS DEVELOPING FROM THE DIFFERENT GERM LAYERS. Upper bar of pair gives upper limit of mortality chargeable to ectoderm: lower bar gives lower limit of mortality chargeable to ectoderm

germ-layers, and embryological science has, for a great many forms, succeeded in a broad way in tracing back to the primitive germ layer from which it originally started its development, substantially every one of the adult organs and organ systems of the body. It makes no difference to the validity or significance of the discussion which we are about to enter upon, in what degree of esteem or contempt in biological philosophy the germ layer theory or doctrine, which occupied so large a place in morphological speculation 50 years ago, may be held. We are here concerned only with the well established broad fact, that in general all adult organ systems may be traced back over the path of their embryological development to the germ layer, or combination of germ layers, from which they originally started.

Having arranged so far as possible all causes of death on an organological basis, it occurred to one to go one step further back and combine them under the headings of the primary germ layers from which the several organs developed embryologically. To do this was a task of considerable difficulty. It raised intricate, and in some cases still unsettled, questions of embryology. Furthermore, the original statistical rubrics under which the data are compiled by registrars of vital statistics were never planned with such an object as this in mind. Still the thing seemed worth trying because of the biological interest which would attach to the result, even though it were somewhat crude and in respect of minor and insignificant details open to criticism. It is not possible here to go into details as to how the causes of death were combined in making up the final tables. For these details one must refer to the original papers.

Fig. 13 gives the result for the crude mortality of the U. S. Registration Area, England and Wales, and Sao Paulo, Brazil. The figures show that in man, the highest product of organic evolution, about 57 per cent of all the biologically classifiable deaths result from a breakdown and failure further to function of organs arising from the endoderm in their embryological development, while but from 8 per cent to 13 per cent can be regarded as a result of breakdown of organ systems arising from the ectoderm. The remaining 30 to 35 per cent of the mortality results from failure of mesodermic organs. The two values stated for ectoderm and mesoderm, shown by the two bars in the diagram, differ by virtue of the fact that two important causes of death, cerebral hemorrhage and apoplexy, and softening of the brain, are put in the one case with the ectoderm and in the other case with the mesoderm. The pathological arguments for the one disposition as against the other of these two diseases are interesting, but lack of space prevents their exposition here. I have chosen rather to present the facts in both ways.

Taking a general view of comparative anatomy and embryology it is evident that in the evolutionary history through which man and the higher vertebrates have passed it is the ectoderm which has been most widely differentiated from its primitive condition, to the validity of which statement the central nervous system furnishes the most potent evidence. The endoderm has been least differentiated in the process of evolution, while the mesoderm occupies an intermediate position in this respect.

Degree of differentiation of organs in evolution implies degree of adaptation to environment. From the present point of view we see that that germ layer, the endoderm, which has evolved or become differentiated least in the process of evolution is least able to meet successfully the vicissitudes of the environment. The ectoderm has changed most in the course of evolution. Of this the central nervous system of man is the best proof. There have also been formed in the process of differentiation, protective mechanisms, the skull and vertebral column, which very well keep the delicate and highly organized central nervous system away from direct contact with the environment. The skin also exhibits many differentiations of a highly adaptive nature to resist environmental difficulties. It is then not surprising that the organ systems developed from the ectoderm break down and lead to death less frequently than any other. The figures make it clear that man's greatest enemy is his own endoderm. Evolutionally speaking, it is a very old-fashioned and out-of-date ancestral relic, which causes him an infinity of trouble. Practically all public health activities are directed towards overcoming the difficulties which arise because man carries about this antediluvian sort of endoderm. We endeavor to modify the environment, and soften its asperities down to the point where our own inefficient endodermal mechanism can cope with them, by such methods as preventing bacterial contamination of water, food and the like, warming the air we breathe, etc. But our ectoderm requires no such extensive amelioration of the environment. There are at most only a very few if any germs which can gain entrance to the body through the normal, healthy, unbroken skin. We do, to be sure, wear clothes. But it is at least a debatable question whether upon many parts of the earth's surface we should not be better off without them from the point of view of health.

These data indicate further in another manner how important are the fundamental embryological factors in determining the mortality of man. Of the three localities compared, England and the United States may be fairly regarded as much more advanced in matters of public health and sanitation than Sao Paulo. This fact is reflected with perfect precision and justice in the relative proportion of the death rates from endoderm and ectoderm. In the United States and England about 55 per cent. of the classifiable deaths are chargeable

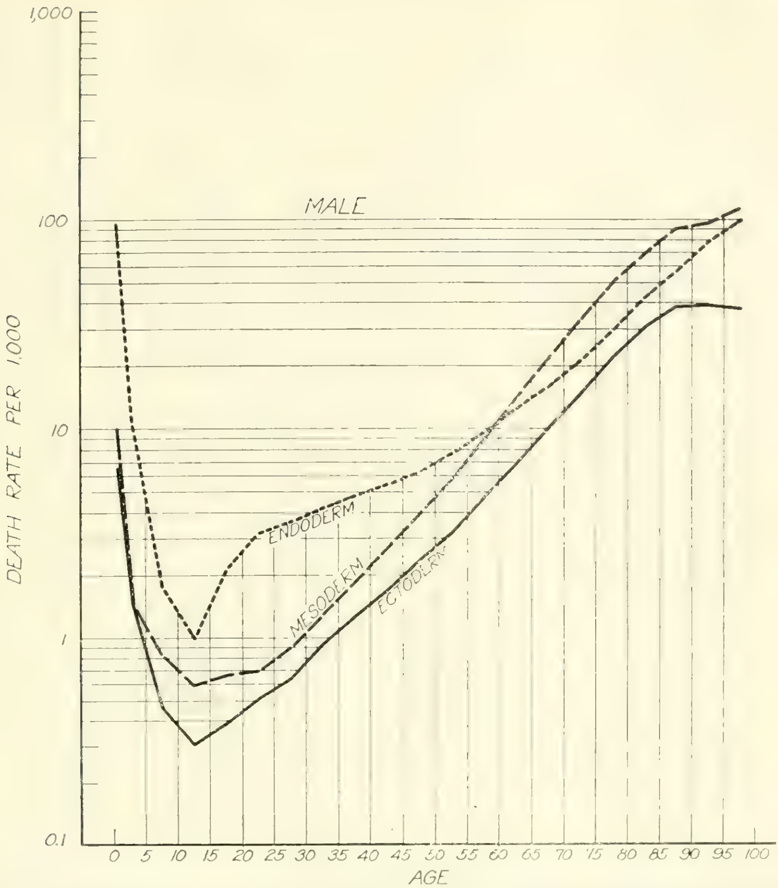


FIG. 14. SHOWING SPECIFIC DEATH RATES IN MALES ACCORDING TO THE GERM LAYER FROM WHICH THE ORGANS DEVELOPED WHERE BREAKDOWN LEADS TO DEATH

to endoderm and about 9 to 14.5 per cent to ectoderm. In Sao Paulo 62.6 per cent. fall with the endoderm, and but 6.3 to 8.4 per cent. with the ectoderm. Since, as we have already shown, public health measures can and do affect practically only the death rate chargeable to endoderm this result which is actually obtained is precisely that which would be expected.

A question which naturally occurs is as to what the age distribution of breakdown of ectodermic, mesodermic, or endodermic organs may be. Are the endodermic organs for example relatively more liable to breakdown in early life, and less so later, as general observation would lead one to conclude?

To answer this and similar questions which come to mind we need to distribute our specific rates upon an embryological basis.

In Fig. 14 the result of doing this is shown for males. We note that prior to age 60 the curve for the breakdown of organs of endo-

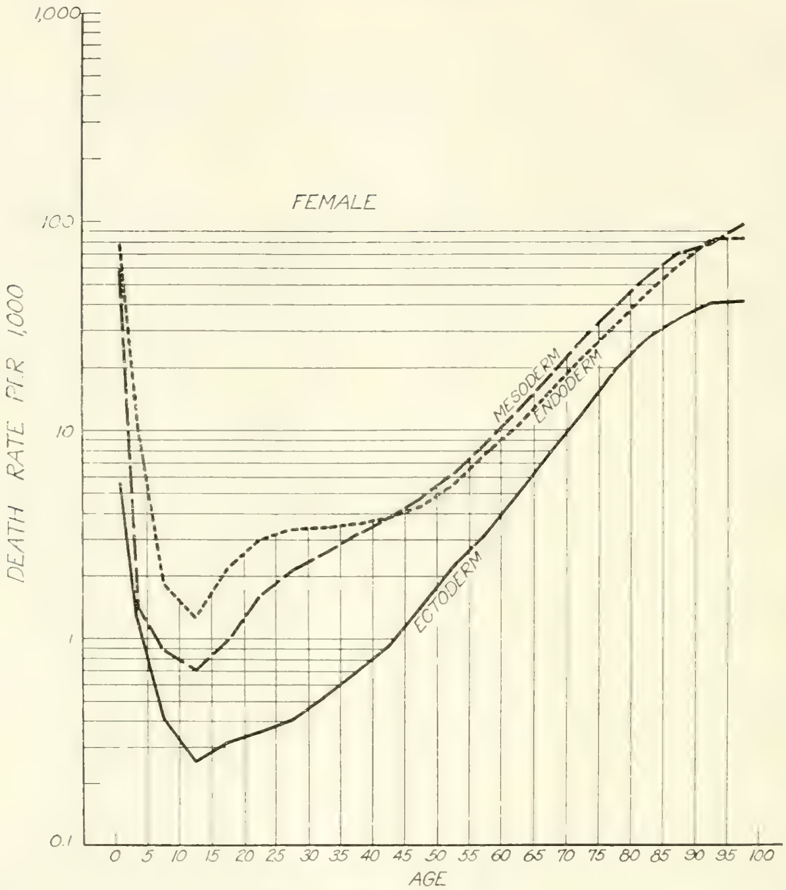


FIG. 15. SHOWING SPECIFIC DEATH RATES FOR FEMALES, CLASSIFIED IN THE SAME MANNER AS IN FIG. 14

dermic origin lies at the top of the diagram; next below it comes the curve for the breakdown of organs of mesodermic origin; and finally at the bottom the curve for the breakdown of organs of ectodermic origin. All three of the curves have in general the form of a specific death rate curve. The rates for all three germ layers are relatively high in infancy and drop at a practically constant rate to a low point in early youth. In infancy the heaviest mortality in males is due to the breakdown of organs of endodermic origin. This part of the death rate accounts for something like 10 times as many deaths as either mesoderm or ectoderm at this period of life. From about age 12 on in the case of organs of ectodermic origin, and from about age 22 on in cases of mesodermic origin, the death rate curves rise at a practically constant rate to extreme old age. The ectodermic and mesodermic curves during this portion of the life span are nearly parallel, diverging only slightly from each other with advancing age.

The curve for the death rate resulting from breakdown of organs of endodermic origin has an entirely different course. It rises sharply for ten years after the low point in early youth, and then makes a rather sharp bend at about age 22, and passes off to the end of the life span, at a reduced rate of change. In consequence of this it crosses the mesodermic line at age 60. From that point on to the end of life deaths from breakdown of organs of mesodermic origin stand first in importance.

Fig. 15 shows the same set of facts for the female, and at once a number of striking differences between the conditions in the two sexes appear. In the first place, the breakdown of mesodermic organs is practically of equal importance in determining the mortality of infants with the breakdown of endodermic organs, in the case of the female. This fact, of course, arises because of the heavy mortality of infancy due to failure of the female reproductive organs, a matter which has already been discussed. The curve for breakdown of the ectodermic organs follows substantially the same kind of course in the female as it does in the male. The mesoderm and endoderm lines cross nearly 20 years earlier in the case of females than in the males. This circumstance arises from the fact that throughout life the mesodermic organs play a relatively more important rôle in the determination of mortality in the female than they do in the male.

What reward in the way of useful generalizations may be claimed from the details reviewed? I hope that these facts will have served in some measure to complete and round out in clearer outlines one part of the picture of the general biology of death. It has been shown in what has preceded that natural death is not a necessary or inherent attribute or consequence of life. Many cells are potentially immortal and the potentiality is actually realized if appropriate conditions are provided. Protozoa are immortal. Germ cells are immortal. Various somatic cells, and even tissues have been proved to be potentially immortal by demonstrating in a variety of ways that under appropriate conditions they continue to live indefinitely. This is the lesson taught us on the one hand by successive transplantations of tumor cells, which are only modified somatic cells, and on the other hand by successful culture of many sorts of somatic cells *in vitro*.

Analytical consideration of the matter shows very clearly that why the somata of multicellular organisms die is because of the differentiations and specializations of structure and function which they exhibit in their make-up. Certain cells are differentiated to carry on certain specialized functions. In this specialization they forego their power of independent and indefinitely continued existence. The cells lining the lungs, for example, must depend in the body upon the unfailing normal activity of the cells of the alimentary tract and the blood in order that they, the epithelial cells of the lungs, may get proper nutrition. If in such an interlocking and mutually dependent system any one part through accident or in any way whatever gets deviated from its normal functioning, the balance of the whole system is upset. If the departure of any part from its normal functional course is great enough to be beyond correction promptly through the normal regulatory powers of the organism, death of the whole will surely ensue.

What I have tried to show in the present paper is a quantitative picture of how the different organ systems get out of balance, and wreck the whole machine. The broad orderliness and lawfulness of the whole business of human mortality is impressive. We have seen that different organ systems have well-defined times of breakdown. Or, put in another way, we see that in the human organism, just as in the automobile, the serviceability of the different parts varies greatly. The heart outwears the lungs, the brain outwears both. But we have further, I believe, got an inkling of the fundamental reason why these things are so. It is broadly speaking, because evolution is a purely mechanistic process instead of being an intelligent one. All the parts are not perfected by evolution to even an approximately equal degree. It is conceivable that an omnipotent person could have made a much better machine, as a whole, than the human body which evolution has produced. He would presumably have made an endoderm with as good resisting and wearing qualities as the mesoderm or ectoderm. Evolution by the haphazard process of trial and error which we call natural selection, makes each part only just good enough to get by. In the very nature of the process itself it can not possibly do anything any more constructive than this. The workmanship of evolution, from a mechanical point of view, is extraordinarily like that of the average automobile repair man. If evolution happens to be furnished by variation with fine materials, as in the case of the nervous system, it has no objection to using them, but it is equally ready to use the shoddiest of endoderm provided it will hold together just long enough to get the machine by the reproductive period.

It furthermore seems to me that the results presented in this paper add one more link to the already strong chain of evidence which indicates the highly important part played by innate constitutional biological factors as contrasted with environmental factors in the determination of the observed rates of human mortality. Here we have grouped human mortality into broad classes which rest upon a strictly biological basis. When this is done it is found that the proportionate subdivision of the mortality is strikingly similar in such widely dissimilar environments as the United States, England and Southern Brazil. It is inconceivable that such congruent results would appear if the environment were the predominant factor in human mortality.

THE DEBT OF MATHEMATICS TO THE CHINESE PEOPLE[1]

By Professor GINO LORIA
UNIVERSITY OF GENOA, ITALY
and Professor R. B. McCLENON
GRINNELL COLLEGE

To write a satisfactory account of the contributions of the Chinese to the development of mathematics has always been a task beset with peculiar difficulties. These difficulties consist in the extreme uncertainty which the historian always feels as to the date and authenticity of any Chinese manuscript, coupled with the known tendencies of the Chinese people to glorify their ancestors and to exaggerate greatly the discoveries which they had made, in many cases attributing to them ideas and concepts which it is quite impossible that they can in reality have known.

As an illustration of these difficulties, let us mention two interesting examples where results obtained by Chinese mathematicians, and claimed as original discoveries by them, can with little short of absolute certainty be traced back to Greek influence and indeed to the particular influence of the greatest of the Greek mathematicians, Archimedes. First, we find attributed by later Chinese writers to a Buddhist monk Hang a proof that the number which we write 3^{361} is not infinite, but can be expressed either in words or in writing. To do this, Hang introduces a system of "octads," that is, groups of 10^8 successive integers, in such a way that the "first octad" consists of the integers from 1 to 10^8, the second octad of the numbers from 10^8 to 10^{16}, and so on. This scheme obviously permits a simple expression to be found for integers even much larger than 3^{361}, the number with which Hang was concerned. This procedure, as a moment's thought will convince us, is but one of an unlimited number of possible means of accomplishing the same object; and it is precisely the method adopted by Archimedes in his "Sand-reckoner," which makes it seem certain that the Chinese work was inspired by the result previously obtained by the great Syracusan.

[1]This article is based on a communication made to the society "Mathesis" by Professor Gino Loria, and published in the *Bollettino della Mathesis* in April, 1920. Through the kindness of Professor David Eugene Smith the communication came to my hands, and I am glad to take this means of presenting it to the notice of Americans who are interested in the history of science. Professor Loria's communication has been much condensed, and accordingly he is not responsible for the form of this article, but only for its content.—R. B. McClenon.

As our second illustration, we find a remarkably accurate approximation to the value of π worked out by Tsu Ch'ung-Chih in the 5th century. By working with a circle of radius 10^8 (it is significant that this is the same number that had been chosen by Hang as the basis of his system of "octads") Tsu found that π lies between 3.1415926 and 3.1415927. He accordingly suggested a better approximation for π than the familiar 3 1/7, namely 355/113 (which is equal to 3.1415929+). We have here an extension of the results given by Archimedes in his "Measurement of the Circle," and if we accept P. Tannery's[2] emendation of a passage in Heron's *Metrica,* Archimedes had further obtained the result,

$$\frac{195882}{62351} > \pi > \frac{211872}{67441}$$

Writing these values in the form of continued fractions,

$$3+\cfrac{1}{7+\cfrac{1}{16+\cfrac{1}{8+\cfrac{1}{1+\cfrac{1}{60}}}}} > \pi > 3+\cfrac{1}{7+\cfrac{1}{16-\cfrac{1}{31+\cfrac{1}{2+\cfrac{1}{9}}}}}$$

we are led to the approximation $\pi = 3 + \frac{1}{7+1/16} = \frac{355}{113}$, which could thus have easily reached China along with the other work of Archimedes. And even if we grant that Tsu may have originated this particular approximation for π, it still remains certain that the *method* which he used was not original with him, and it is almost a certainty that he obtained this method from Archimedes's famous work.

These illustrations, with many others of the same kind that might be cited, give rise to legitimate doubts whether in other cases, even where no direct connection can be established with other countries, the Chinese writers did not also receive their inspiration from abroad. These doubts are not quieted when we observe that practically all of the Chinese mathematical works are merely collections of problems, solved by rules which are not demonstrated; so that it is very difficult to determine whether these rules were really understood by the writer

[2] Memoires scientifiques, t. 3, Paris, 1915, p. 149.

or not. What shall we say when we find in the midst of a set of trivial or even nonsensical problems one like the following? "There is a group of objects whose number is unknown; dividing by 3, the remainder is 2; by 5, the remainder is 3; and by 7, the remainder is 2; what was the number?" The author of the collection in which this occurs, Sun Tsu, obtains a solution, 23, by using a method called Ta Yen, which does not differ from that taught by Gauss[3] for solving similar problems in general: and what more significant praise could be given? But as Sun Tsu gives not the slightest indication that he regards this problem as more interesting or valuable than its trivial companions, we may well question his claim to the discovery of Ta Yen.

One of the classical Chinese mathematical productions was the "Arithmetic in Nine Sections," but unfortunately nothing is known definitely as to the date at which the collection took its present form. Parts of it very likely go back to the period before the "burning of the books" (by the emperor Shih Hoang-ti) in 213 B. C. but much of it is certainly of later date. The following interesting and original problem is found in this collection:

"A square city of unknown side is crossed by a street which joins the centers of the north and south sides; at a distance of 20 paces north of the north gate is a tree which is visible from a point reached by going 14 paces south from the south gate and then 1775 paces west. What is the length of each side?"

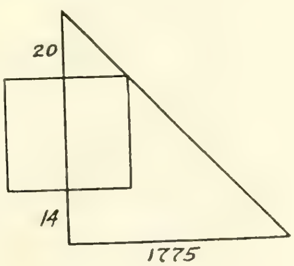


FIG. 1

The Chinese writer gives correctly the equation to which this problem leads, viz., $x^2+34x-2\cdot 20\cdot 1775=0$, but his statement as to how to solve the equation has probably been corrupted by copyists, as it merely states that the root of a certain expression must be found. As a matter of fact, the only positive root of this equation is $x=250$; which makes it clear that the originator of the problem must have chosen the numbers involved deliberately, so as to produce a simple result.

[3] *Disquisitiones Arithmeticae*, Sec. 32-36.

Whether the originator was a Chinese at all seems questionable, after examination of another problem of a similar kind which is met with in a work composed much later, namely, the "Nine Sections of Mathematics," written in 1247 by Ch'in-Chiu-Shoa. The problem reads:

"A circular castle has four gates facing the cardinal points; at a distance $a(=3)$ to the north of the north gate is a tree, which is visible from a point situated at the distance $b(=9)$ to the east of the south gate. What is the diameter of the castle?" Ch'in says this leads to the equation

$$1x^{10}+7ax^8+8a^2x^6-4(b^2-a^2)x^4-2b^2\cdot 8a^2x^2-2b^2\cdot 8a^2b=0$$

and states that the root is $x=9$, the length of the diameter.

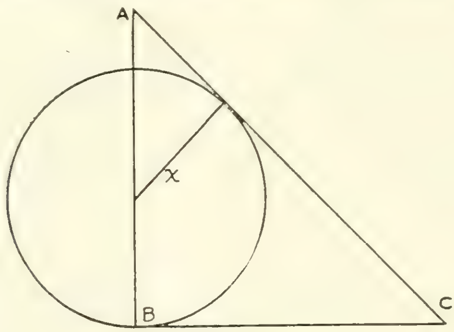


FIG. 2

Before commenting on this, let us solve the problem for ourselves. Thus, taking x as the radius, and expressing the hypotenuse of the right triangle ABC in two ways, we have

$$\overline{AC}^2=b^2+(2x+a)^2=(b+\sqrt{a^2+2ax})^2$$

from which we obtain $2x^3+ax^2=ab^2$,
an equation enormously simpler than that given by Ch'in. And not only that, but the result stated by Ch'in, $x=9$, does not satisfy his equation at all! Hence even if there is some copyist's error present, we seem forced to the conclusion that Ch'in did not very fully understand the problem, else he could not have supposed that it required so formidable an equation to solve it. Hence the doubt just expressed as to the Chinese origin of the problem. Moreover, no information whatever is given as to how an equation of this kind is to be solved. Presumably the method was similar to the one used in another case, which is more fully reported by Ch'in; but which also leaves much to be desired in the way of clearness and completeness. This other problem is as follows:

$$-x^4+763{,}200x^2-40{,}642{,}560{,}000=0.$$

"The first figure of the root is seen to be 8" we are told; but how this important fact "is seen" we are not informed. This significant omission arouses suspicion that the answer may have been known beforehand, as in the case of other problems referred to above. Knowing that a root of the equation lies between 800 and 900, the process known as Horner's method enables us to find a new equation whose roots shall be 800 less; and without going into the details of the computation it is sufficient to say that the transformed equation is

$$y^4+3200y^3+3,076,800y^2+826,880,000y-38,205,440,000=0,$$

and this way may be taken to be the meaning of the following table, which Ch'in gives in connection with his explanation of the problem:

8	root	
38,205,440,000	absolute term	
— 82,688	"	of 1st degree
— 30,768	"	" 2nd "
— 32	"	" 3rd "
— 1	"	" 4th "

Barring the omission of zeros, which we must attribute to a copyist's error, this result coincides with the correct one given just above. But we still have too meager information as to the details of the work for us to be able to affirm confidently that Horner's method was known to the Chinese in the 13th century; we can only say that this method, or one practically identical with it, was known at that time, and we must await further evidence before affirming or denying the priority of the Chinese in its discovery.

Biernatzki[4] quotes from Ch'in Chiu-shao another illustration of the method, which however, has been so badly mangled by copyists, that we can not judge as to whether Ch'in was really able to solve the equation in question or not.

It is thus clear that much further investigation will be necessary before this interesting and important question in the history of mathematics, the question as to how much the progress of the science in reality owes to the Chinese people, can be answered with any degree of certainty. It is to be hoped that scholars qualified by knowledge of the language will in the near future enter upon these researches and carry them through to a successful conclusion.

[4]Crelle's Journal, 52.

MANUELITO OF THE RED ZERAPE

By C. M. GOETHE

SHOULDERS wrapped in red zerape, Manuelito, an undersized chunky Mexican, leaned against a weather-stained column of the Guanajuato jail entrance. He has just tilted forward his high-peaked hat to better shade his eyes, when suddenly, taking his cigarette from his lips, he hissed: "The Gringoes." Into those two words was compressed all the race hatred he could contain.

His country's President, Diaz, had welcomed foreign capital. Eager Americans invested heavily in its mines. This caused race friction. In Guanajuato, one American superintendent became convinced his peon miners were "high grading." With two countrymen he went one evening to the tunnel's mouth to meet his outcoming day shift. He knew that the peon, because of years of Spanish misrule, had evolved as a bred-in-the-bone smuggler. Each approaching peon that evening had in his hand a suspiciously heavy kerchief. The superintendent demanded to see the contents of the first miner's bundle. The latter had evidently anticipated such a move. Rather than be caught with stolen ore, the Mexicans treated the "Americano's insult" as a signal to open their characteristic guerilla warfare. Soon they were firing from behind rock piles. A quarter hour later one American was limping home. Beside him walked the superintendent, a flesh wound in his arm. The corpse of one "high-grader" was being carried through the opening of the cactus fence surrounding his adobe home, amid the wailing of his women folk.

The news spread with prairie-fire rapidity. Nearing Guanajuato's outskirts, the Americans were met by the police, arrested, thrown into jail. In those days, government policy caused Mexican jails to offer no inducement to prolonged lodgers. Even food was not provided unless sent in by mother, sweetheart or friend. The American trio was cared for by its fellow exiles of the town. Therefore, hardly had the former spent an hour in jail when three baskets, sent by the American colony, arrived at the jail door.

It was these baskets that had caused Manuelito of the red zerape to hiss: "The Gringoes." The jailer spat at the baskets. Then, overcome by curiosity, he lifted, one by one, their covers. A diabolical grin expanded over his coffee-brown face. One basket contained a day's food for the three men. The second had a similar supply of bottled water, the jail water being notorious for its content of typhoid germs. The third basket had cigars and magazines. Manuelito already had intentionally isolated his prisoners in, respectively, his North, his South and his East towers. Thus intercommunication was made practically impossible. "Innocentia!" he cried clapping his hands as an additional signal. In high-pointed sombrero, and a single white cotton garment, the barefooted Innocentia appeared. The jailer pointed to the baskets. "One to each Americano" was the laconic order.

For two days one American gorged on three men's *enchilidas* and *frijoles*. The second smoked more cigarettes than ever before. The third, the superintendent himself, a heavy smoker, was without food or tobacco. His wound pained him. He feared a nervous breakdown would come before starvation brought death. But his basket contained only bottled water. It was he who bribed Innocentia to carry a splinter to his downtown friends. Laboriously upon it he had scratched, with a bit of oxidized ore, two words: "Mix baskets." Next morning when the thrifty Innocentia walked through the arched gate, past Manuelito of the red zerape, the stick was concealed in his high hat. That noon the superintendent's basket carried within its wicker walls a welcome mixture of food, water and tobacco. The wounded man heaved a sigh of relief. As he finished his meal, he repeated the Hindu proverb: "Even the Sahibs have not all the wisdom."

In the game of international politics, too, the Saxon, the Sahib of the Hindu, "has not all the wisdom." Nor has our attitude toward our nearest neighbor in Latin America been clearly understood. Turgidity of thought has been increased by certain forces. One of these, powerfully organized and at work on both sides of the border, has labored to generate suspicion, to fan the embers of international hatred.

Because of the suspicion with which much of Latin America persistently has regarded the Saxon Northland, as illustrated in the Guanajuato incident, the work of the group at the Archeological Museum at Santa Fe deserves the attention of every American who is devoted to his country, and who has faith in the noble part his land is destined to take in world affairs. Of all the commonwealths whose stars shine on our banner, probably none has so serious a problem in socializing, in Americanizing, a great extra-racial group as has that state of which Santa Fe is the capital and whose very name, New Mexico, indicates its centuries of attachment to the land of the Aztec.

Santa Fe is approximately 20 per cent. Saxon. The other 80 per cent. is Mexican Amerind. The Mexican element ranges from the illiterate peon of practically all native Mexican stock to the man of nearly pure Castillian blood. Of the latter, some are of that dominant Nordic strain which furnished those remarkable Conquistadores, the old Gothic aristocrats of the Iberian Peninsula, whose blue veins, showing through their fair northern skin, gave rise to the term "*sangre*

FIG. 1. NEW MUSEUM BUILDING SHOWING SANTA FE'S USE OF THE PUEBLO STYLE OF ARCHITECTURE. OUT OF THIS NEW MEXICO'S CAPITAL IS BECOMING THE ONE STATE CAPITAL OF OUR COUNTRY ARCHITECTURALLY TRUE TO ITS INDIVIDUALITY

azul", which we have anglicanized into "blue-blooded." These Latin folk of New Mexico, blue-blooded or swarthy, Castillian or Aztec, are bound to the Motherland across the Rio Grande by ties, social, political, and what is always most deep-seated of all—religious. To break down the barriers of race hatred, race suspicion, and race mistrust between the 20 per cent. of Saxons and the 80 per cent. Latin-Mexican-Amerinds, to lead both to learn to appreciate and respect the good in the other and to know that this good is far more important than racial differences of opinion, was, and is a task requiring no little tact, no little nice discrimination.

The founders of the New Mexico Museum at Santa Fe did not hesitate to commence work when the vision of these possibilities came to them. While their basic interest in creating their museum was of course the archaeological one, they still kept before them this dream of making it more than a mere museum, more than even a community recreation center. They glimpsed it as a laboratory within whose crucibles they, twentieth century alchemists, might discover, in experimenting with Saxon, Latin, Amerind, that which was to be more desired than fine gold—interracial sympathy and good will.

The old Santa Fe Palace, facing the plaza, built on the walls of an ancient pueblo, and since occupied by Spanish, Mexican and American governors, was their first laboratory. Here commenced the foundational experimenting,—that with the Saxon group. Three subdivisions

FIG. 2. THE OLD PALACE OF THE GOVERNORS, HOUSING ANOTHER PORTION OF THE COLLECTIONS

of this Saxon group were perhaps most easily handled. These were the Women's Club, the Chamber of Commerce, the State Government.

The average Western Women's Club is known for its progressiveness. In their struggle for the suffrage, Western women have evolved with a capacity for moulding civic ideals. In Santa Fe their interest in the museum community center, once aroused, has continued constant. They make it *their* center. One of its halls, for example, became the center for Red Cross work during America's struggle for world democracy. Historically doing this was consistent, because in the plaza opposite is the spot where General Kearney, in raising the American flag, gave Santa Fe's Latin citizens their first message of American democracy. The charmingly appropriate furniture of the museum room wherein these women met is evidence that the museum group discovered that there is a New Mexican Colonial, as well as a New England Colonial style. Rawhide was strung while yet green. Native woods were skillfully used in chest, chair, panel and picture frame. Reveries of history made when the Americans cut short the rule of the Mexican governors who taxed each passing prairie schooner $500, mingled thus with Red Cross workers' thoughts of history then-in-the-making.

The Chamber of Commerce was also brought into the experiment. Most Chambers can be accurately judged by their slogans. Santa Fe's is "America's most interesting 50-miles-square." The Chamber's slogan, based upon the museum's activities, has crystallized into it the

FIG. 3. DWELLING HOUSE IN SANTA FE IN PUEBLO STYLE

daring and resourcefulness that is characteristic of life on trail and in desert. An aesthetic slogan? Yes. Yet it has conclusively demonstrated that the aesthetic, the clean in civics does more than gratify a human hunger—it pays dividends commercially. The Santa Fe-Taos artist colony is an example of such commercial profit. This community is largely an outgrowth of the museum's activities. Some of the artists are housed on the museum grounds. All cooperate with the museum staff, whose research in turn makes for historical accuracy in the artists' work. The Museum's art gallery is expanded by loan collections, also by artists' exhibition. The 30,000 tourist visitors, many of them art-loving, not a few able and glad to buy, make a welcome market for their canvasses. In 1917, a war year, the artists' output is said to have been $175,000. Assuming $800 yearly as a then average annual wage, this equals the earnings of a factory of 218 hands. The value of the artist group as a community asset, however, is not to be measured by the factory standard. Like Los Angeles, Copenhagen, also Geneva, Santa Fe thus shrewdly has been "corralling" as residents, to use the expression of her red-kerchiefed cowboys, those citizens eugenically fit. Single individuals of this artist type are, with their keen imagination and foresight, in their resulting contribution to community life, particularly in matters of education, worth more than several smoke belching chimneys.

Thus two Saxon groups, the Chamber of Commerce, as well as the Women's Club, were thus skillfully aligned to back the State government in doing what the progressive official is always ready to do with

FIG. 4. ONE OF THE "PYRAMID CITIES OF TAOS," SHOWING THAT PUEBLO ARCHITECTURE HAS BEEN MADE THE BASIS OF THE ARCHITECTURE OF THE MUSEUM AND OTHER BUILDINGS IN SANTA FE

such organized approval, i. e. the making of reasonable appropriations. Thus New Mexico has already *done* that of which the city planning groups of most other American States are as yet but *dreaming*. New Mexico, recognizing the wisdom of the European method, therefore made the solution of Santa Fe's City planning problems a matter of state concern. Its legislature studied the plan of the museum as a forceful example of what already was coming to be called the "Santa Fe" style of architecture. The statesmen said, "We want to own a part of this." Thus state appropriation was added to money from municipal and from other sources. All these funds went toward crystallizing into this community-center-structure the Santa Fe spirit. Space does not permit telling how community ideals have been shaped, other than to suggest that Santa Fe bids fair to become the first American capital to be architecturally true to its own individuality.

Thus into the museum crucible were brought the three elements, feminist, commercial, political, composing the leadership of Santa Fe's 20 per cent. of Saxon citizenry. Eighty per cent. remained. This 80 per cent. was Mexican. This group was high-strung, sensitive. They were proudly conscious of their own culture. They knew only too well that the Saxon had conquered their leaders in battle—that he had not always refrained from showing that he did not always think in the way in which they did. The task was to bring these folk into the melting pot, to soften and eliminate mutual race hatred, to make each Mexican

FIG. 5. PUEBLO INDIAN, WITH OVEN IN THE BACKGROUND

Amerind understand the museum was also his, that, to make it a real community center, their glad use of it was also essential.

Perhaps the best way to tell how this was accomplished with these folk, is to briefly refer to the museum chapel, and to the Mexican pastoral plays, which have been presented therein. To grasp the breadth of this success our thought must run back to medieval Europe. The miracle plays of that period have persisted longest in that conservative environment which, characteristic of Spain, is even more so of her colonies. It was not an accident that the last faggots of the Inquisition were ignited in Mexico City. Buttressed by this conservatism in Mexico, also in the Santa Fe countryside that formerly floated Mexico's banner of eagle, rattlesnake and cactus, there have survived, always still in unwritten form, those miracle plays which Europe, which even Spain, had almost forgotten. There is, therefore, no better evidence that the intensely conservative Latin New Mexican has accepted the spirit of the Museum center than his rendition, in the Museum community-center chapel, of such plays as "Los Pastores," (The Shepherds). This chapel hall takes the outward form of one of his missions. Its ceiling

FIG. 6. ANOTHER EXAMPLE OF PUEBLO ARCHITECTURE

is of aspen trunklets carried by burros from the canyons that dent his mesas. They duplicate those of these self-same missions. Its floor is of stone flags from the mountains he had, from their sunset hues, reverently called "Sangre de Christi" (Blood of Christ). Its beams are hand carved and lovingly colored in the old way by his neighbors, the Indian artisans. What setting could be more fitting?

The problem of the residual element in the crucible, the Pueblo Amerind, was vastly more complicated. The American Indians around Santa Fe are largely Tewa, belonging to what we commonly call the "Pueblos." The vicinity contains evidences of their wonderful culture of the long ago. Long before Charlemange was pushing the frontier of his empire to where the then rude Saxons afterward built their capital, Dresden, the ancestors of these Tewas, with knives chipped from lustrous black obsidian, had carved their cave dwellings out of the friable, faded pink volcanic tufa that formed the walls of the basalt-capped mesas. Here this people had evolved their wonderful culture. To-day their descendants live in such pueblos as the Sky City of Acoma, or the twin pyramid towns of Taos, astride the little stream that cas-

FIG. 7. PUEBLO FAMILY GROUP

cades down from 13,000 foot snow-capped giants forming their background. The Tewa culture of these folk deserves more respect than the Saxon is wont to show. In many things the Amerind anticipated his pale-faced brother. We are proud of our democracy born of our long struggles. There is evidence that the Tewa had a comparatively pure democracy centuries before one of the French Bourbons had cast into the bronze of his cannon, the dogma, "Cannon—the last argument of Kings." Apartment houses? When cattle lifting was a gentleman's occupation along the Scottish border, the Tewa had not only built, but almost no longer remembered that he ever had occupied community structures which the Santa Fean volubly will tell you "had twice as many rooms as the Waldorf-Astoria." Vocational training? In these forgotten rooms, chiselled farther back in history than when Crusader Kings were struggling through the blistering sands toward Jerusalem, raven-haired mammas, between their grinding of blue corn meal on stone metates, trained little folk for the pottery making wherein they were to record their epics—by toy models—perfect in design, some of which may to-day be seen in the museum. Recreation centers?

In the Kivas of the Tewa were done much of the work now done by the Y. M. C. A. This was more centuries before than have elapsed since Luther nailed the Theses to a certain German door and commenced the protestant reformation.

These Tewas, who rightfully have pride in their culture, still live to-day in the valley of the Rio Grande. The accumulated experience of the ages has been handed down, as was the ancient Greek epic, from father to son. These Pueblo Amerinds are deeply religious. No venture is undertaken without prayer to Those Above, generally with the scattering of the sacred Corn Meal. Poets to their fingertips—deeply conservative—highly sensitive—what has been the contact of the Saxon with them?

Two examples suffice as to the extremes: An Illinois woman visits a pueblo. She goes to the first house, saying "I want a guide." She holds out a gold piece. The bargaining instinct arises in the man. He shows a few things to the woman. "Now, I want to see the inside of one of the houses up those ladders." "Not until you pay me five dollars more." She pays it. The Amerind has ten dollars for a half hour's work. The woman with a shrug of the shoulders remarks "I never give anything at home to 'charity'. I have much. They have little. It does not hurt me." But an injury has been done to the Amerind. He has acquired a new standard as to what work should be exchanged for American gold.

A second example as to the other extreme. An Arizona trader wants a blanket upon which an Indian woman in one of the district settlements has worked for months. He knows her need for money. They bargain. The blanket will bring him $85. He spreads out in silver quarters, coins totaling $4, then $5, $6, $7. She yields to the arguments of the exploiter. He clears, for a couple of hours work, a profit many times the amount which she received for weeks of labor.

The museum, with the spirit of true community service, has become the real friend of these Tewas. It has recognized alike the danger of the crafty trader exploitation, of thoughtless tourist pauperization. It has, therefore, among other things, opened a pottery exchange at the museum community-center. It encourages some of the Indian artisans to work even within its patios. This brings an addition of local color to the street scenes which has a chamber-of-commerce value, reflected in hotel income. Indian as well as customer is insured a just price. But, above all, it holds the Pueblo Amerind true to the ancient art. It has stopped careless moulding, careless decoration, careless firing. More than all, by pressure, tactfully applied, it has eliminated such intruded designs as locomotives and automobiles from a creation that was once, at the same time, both a poem and a prayer.

Out of this loyalty to the best in the red man's ancient culture has grown mutual confidence, at times even real affection, between Saxon and Amerind. In the chapel, also, sometimes in the soft moonlight of the museum patio, the Tewa now presents his wonderful dance-dramas, such as the Green Corn Dance of his delight-makers. This he does with a gladness, with a commendable freedom from commercialization. Knowing the sympathetic interest of the onlooker, these dance dramas are acted with the same deep religious fervor that anciently accompanied them in the plaza of his native pueblo.

The chapel door is ajar on museum night. Peeping through, there is seen a "Fireplace Party." The listeners are from all three groups. There is a club woman whose ancestors were nobles under the Great Charles of Spain. There are other club women. One is a Daughter of the American Revolution, proud of her F. F. V. ancestry. That Pueblo Indian boy in front is the one who painted the pictures that the blue-eyed speaker has been using. The latter is Saxon. He is telling fairy tales to the wide-eyed listeners. They are not stories of the lands of his Teutonic forebears, of gloomy forests in the days of Woden, and of Thor, of chimney-resting storks, of fairy princes with whom the wide-eyed children in the flickering firelight have no real contact. The blue-eyed man proceeds with tales of the long ago in Cliff-dweller Land, of the things Santa Fe's children knew, of the yucca of the browned desert, whose leaves went to a "chewing bee" when willing boys thus separated the sugarly pulp from the much-needed fibre. Tales, too, the Saxon tells of the pottery, shards of which, with designs of clouds, of rain, of eagles, are familiar to every New Mexican lad who roams the mesas. There are stories of hunting wild turkeys in the stone age. Hardly a child is present who has not searched for and found at least one jewelled arrowpoint of these softly-treading huntsmen. Santa Fe's children, Saxon, Latin, Amerind, through such fairy stories, are being taught, at the levelling museum-center, not only nature-wisdom and desert folklore, but they are simultaneously absorbing interracial respect. They are coming to appreciate, like the American of the Guanajuato jail, that "the Sahibs have not all the wisdom,"—that the other fellow, even Manuelito of the red zerape, can strike back, that his good will is more to be desired than his hatred.

THE MENTAL STATUS OF THE AMERICAN NEGRO

By GEORGE OSCAR FERGUSON, JR.
UNIVERSITY OF VIRGINIA

A FEW years ago the speaker of the lower house of a state legislature, in delivering the annual address before a college alumni association, chose as his theme the education of the Negro. He argued that the Negro as a race is mentally incapable of any real participation in modern civilization, and that the attempt to educate Negroes should therefore be abandoned.

But at a recent meeting held to consider race relationships in the South, a prominent publicist, pointing out the great progress made by the Negro in this country in the space of two generations, gave it as his opinion that no race could have come so far in so short a time without inherent capacity for civilization equal to that of any other people of history.

Between these extremes lie the views of the great majority of thoughtful students of the problems presented by and confronting the Negro race in America. The intellectual ability of many Negroes is indubitable. The apparently unchangeable stupidity of many others is also indubitable. Generalizing from contact primarily with gifted or with dull representatives of the race, observers have been led to conclusions favoring one extreme view or the other. But in the main they seem to have taken a middle ground to the effect that, while Negroes are often very capable, the general level of intelligence among the masses of the race is considerably below that of whites. That this alleged racial difference can not be removed by education is probably taken for granted, since it is held to be hereditary.

In view of the crucial importance of native intellectual ability for civilized attainment of any sort, it seems to be worth while to summarize the information at present available concerning the intelligence of the Negro as compared with that of the white man. Only through careful, painstaking study and experiment and the gradual development of a scientific psychological technique can the haze of debate and belief be replaced by established knowledge. As yet comparatively little of a scientific nature has been accomplished in investigating the mind of the Negro. But such facts as there are should be incorporated into the thought which is the basis of our action.

By a man's intelligence is meant his ability to think quickly and accurately, to obtain an insight into new problems, to comprehend situations, to learn easily, to arrive at and apply conclusions, to be mentally alert. Dullness or stupidity is the absence of these abilities. An intelligent man "catches on", apprehends the meanings and significances of things, has "sense" and can meet the demands of life. A dull or stupid person lives in a world in which things and people are relatively simple and arbitrary; he does not know or inquire into the hows and whys of affairs; he can perform routine tasks, but relationships and possibilities are so lacking in his apprehension that he can not meet new situations successfully or devise new ways of acting. To intelligence the complex meaningfulness of life and its institutions is apparent; stupidity cares nothing for such things because it knows nothing of them.

Obviously a man may have excellent intelligence but poor sense organs and power of bodily movement. Keenness of sight, hearing, taste or smell is not necessary to intellectual power, nor is muscular ability. That part of a man's body which determines his intelligence is the cortex or outer rind of his brain, where are found the intricately branching nerve cells and fibers that constitute his "grey matter". The sense organs of Negroes are as efficient as those of whites; the Negro's muscular system is as efficient as the white man's. If there is a difference in intelligence between the two races, its physical counterpart must be looked for in brain differences.

The brain of the average Negro weighs three or four ounces less than the brain of the average white man. But the brain of the average white woman also weighs three or four ounces less than that of the average white man. And while the brains of eminent men, on the average, weigh more than the brains of men in general, yet many men of inferior ability have brains much heavier than those of men of marked attainment, and many men of eminence have brains of much less weight than that of the average tramp. It is therefore evident that brain size does not determine intelligence. And while there are certain differences in the anatomical proportions of the brains of whites and Negroes, such differences are not great and their significance is not well established. Differences that may exist in the constitution of the brain cortex, with which intelligence is most intimately connected, can not be distinguished by the methods of investigation available at the present time.

While there is thus no difference of well established significance between the brains of the two races, it is not unreasonable to suppose that the great differences in physique and feature between typical Negroes and whites are accompanied by correspondingly important neural differences. Unless there be such corresponding neural differences the situation is probably unique among biological phenomena.

The obvious method of attack upon the question of the Negro's intelligence is by means of mental tests. In recent years the general nature of such tests has become familiar to most people. In general, they aim to measure native or natural intelligence, as distinct from the results of education or training. There are many kinds of tests and they differ greatly in the success with which they accomplish their purpose. But on the whole, when skilfully used, they undoubtedly afford an index of mental capacity vastly superior to unscientific judgments arrived at even after long acquaintance with the persons tested. There have been about a dozen trustworthy investigations of Negro mentality, nearly all of them made within the last decade. And the use of intelligence tests in the army has furnished an unexampled opportunity for psychological study of the Negro soldier.

Before the results of the tests are given, reference should be made to what is probably the best simple method of expressing the relationship between the abilities of groups. The distribution of ability among the individuals of any large and homogeneous group conforms to a well established law. Most of the members of a group are clustered closely around the average, and as the extremes of ability are approached the number of individuals becomes constantly smaller. But the extremes are not exceptions; they are normal variants from the group average, and their number and the amount of their divergence are the same both above and below the average. Thus 50 per cent. of the members of a group equal or exceed the average of that group. Two groups have the same ability if 50 per cent. of the individuals in one of them equal or exceed the average of the other. But if only 10 or 25 or 40 per cent. of group A equal or exceed the average of group B, then group A is inferior to group B. This method of comparing whites and Negroes affords a constant reminder of their "overlapping" in ability and enables us to state the results of different tests in the same terms.

The results of the investigations of whites and Negroes by means of tests have all pointed in the same direction. When Negro children of a given school grade or a given chronological age are compared with white children of the same grade or age, they fall below the intellectual standard of the whites. In the elementary school grades only 20 or 25 per cent. of Negro children equal or exceed the average score of white children. But in high school 30 or 35 per cent. of the Negroes equal or exceed the average white score. That the Negroes do better in the upper grades than in the lower when compared with whites is doubtless due to the fact that a much smaller proportion of Negroes than of whites is found in the upper grades; the Negroes in the upper grades are the selected few of their race to a greater extent than are the whites in the upper grades. It is rarer for a Negro than for a white child to go to school at all; it is much rarer for him to reach high school. This is amply demonstrated by the statistics showing the school attendance of the two races. And of course it is well recognized that elimination from the successive grades of the school system bears, in general, most heavily upon those pupils who have least capacity, and leaves in the upper grades those in whom ability is greatest. Negroes in the graduate or professional schools of universities probably have as great ability as the average white student there. But the Negroes are far fewer in number.

When the great unselected masses of Negroes in the army were compared with equally unselected masses of whites, the difference between the races, as revealed by the army intelligence tests, was found to be greater than it is in the schools. It was so great, indeed, as to lead to the supposition that the tests were unfair to the Negroes. There were separate tests for literates and for illiterates. The standard of literacy employed was the ability to read a newspaper and to write any sort of letter. Only one-third of the Negro drafted men qualified as literate under this standard, while three-fourths of the white drafted men qualified as literate. On the test for literates, only between 5 and 10 per cent. of the total group of literate Negroes equaled or exceeded the average score of the whites. When the comparison included only men who reported the same number of years of schooling, between 10 and 15 per cent. of the Negroes equaled or exceeded the average score of the whites. On the test for illiterates, the average white score was reached or surpassed by between 10 and 15 per cent. of the Negroes.

This disparity between the scores of the two races is almost certainly due in some measure to the difference in the amount of their education. The tests, and particularly the test for illiterates, were designed as measures of native capacity as opposed to the influence of schooling. But even the handling of a pencil, which the tests required, was probably a greater handicap to the Negroes than to the whites. This supposition is borne out by the results of the widely known Stanford-Binet test, which was employed to examine thousands of drafted men. This is doubtless the most reliable of all intelligence tests; it is adapted to measuring all degrees of ability, from feeblemindedness to such intellectual capacity as will enable a man to do high grade work in a university; and its results are demonstrably free from any considerable educational influence. On this test, between 20 and 25 per cent. of the Negro recruits equaled or exceeded the performance of the average white recruit. And this is everywhere regarded as one of the best indexes which we have of the relative intelligence of the two races.

But even the Binet test, like nearly all of the others which have been used to measure the intelligence of Negroes, requires, in large measure, the mental manipulation of the verbal symbols of ideas. Very few tests have required thinking in terms of concrete objects. Of course the highest type of intelligence is verbal and symbolic. But Negroes, as a race, live primarily in a world of material things and have less experience than whites in dealing with the world of words. This in itself may be due to an original racial difference; but it may also be due to social conditions. And it may be unfair to expect Negroes to compete on even terms with whites in dealing with words rather than with things. A few tests involving the handling of concrete materials have indicated that Negroes do somewhat better in them than in the more linguistic tests. It seems to the writer that this should be taken into account in estimating the mental difference of the races, and that probably the safest and most reasonable expression of the relative intelligence of whites and Negroes is that approximately 25 per cent. of the latter equal or exceed the average of the former.

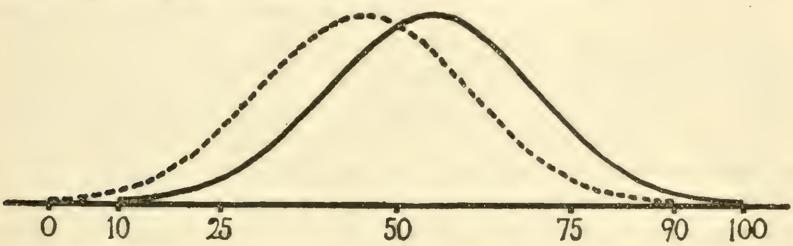


FIG. 1

The diagram exhibits this relationship. The solid curve represents the distribution of ability among whites and the broken curve represents the distribution of ability among Negroes. The curves are drawn in accordance with the law of distribution of individuals in a group, and the relationship between them indicates the relative intelligence of the two races. The figures on the base line are arbitrarily chosen and are intended only to facilitate comparison of the curves. Zero represents the ability of the lowest idiot; 100 represents the ability of the highest genius. The range of ability among the whites is thus indicated as from 10 to 100; among the Negroes it is indicated as from 0 to 90. The height of the respective curves above the base line shows the proportionate number of individuals in the groups at any point on the scale of ability. The average of the whites is approximately 55, while the average of the Negroes is approximately 45. We may express the difference between the averages of the races by saying that it is about one-fifth of the difference between the average white man and the lowest idiot, or one-fifth of the difference between the average white man and the highest genius. As an indication of the remarkable validity and usefulness of the law of group distribution, it may be remarked that Sir Francis Galton, long before the advent of intelligence tests, arrived at approximately this same conclusion as to the average capacities of whites and Negroes by studying only the geniuses of each race, and inferring from their relative abilities the relationship of the races as wholes.

From the diagram it may be computed that approximately 25 per cent. of the Negroes equal or exceed the average ability of the whites, and that approximately 25 per cent. of the whites have ability as low as or below the average ability of the Negroes. In other words, the level of ability reached by half of the whites is reached by only one-fourth of the Negroes, and only one-fourth of the whites are below that level of ability which is the upper limit of half of the Negroes. In passing up the scale from the average to the highest ability, it is evident that the proportion of Negroes to whites constantly decreases until the point is reached, above 90, where there are no Negroes at all. And in passing down the scale from the average to the lowest ability, it is evident that the proportion of Negroes to whites constantly increases until the point is reached, below 10, where there are no whites at all. There are very few Negroes above 75; there are very few whites below 25. The comparatively slight difference between the average abilities of the two groups makes a great difference in the relative proportions of individuals of very high and very low ability in the groups. Thus in the army, on the basis of the intelligence tests, one white recruit in 20 was rated A, or "very superior", while only one Negro recruit in 400 received this rating. And the proportion of feebleminded individuals among the Negroes was much greater than among the whites.

But it should be noted that while the proportion of Negroes in the higher grades of intelligence is small in comparison with the proportion of whites, there are yet Negroes in the higher grades. Few whites have greater intelligence than the highest of the Negroes, and few Negroes have less intelligence than the dullest of the whites. This fact should not be lost sight of in considerations of the status of the Negro. Nor should it be allowed to obscure the differences that exist between the two races.

Since there is such great overlapping in intelligence between whites and Negroes, it is obviously impossible to make a satisfactory statement of the difference between them in terms of the difference between any two classes of the white population. The ability that is typical of practically any large group of whites is also found among Negroes. And there is great variation in ability among any large group of whites, such as an occupational class. It is probable that there are no two large occupational classes which differ so greatly in ability that there is no overlapping between them. But while this is true, it is yet possible to state, although only suggestively, the difference between the *average* Negro and the *average* white in terms of the difference between the *average* abilities of certain occupational groups of whites. Thus it is probable that the difference in intelligence between the professional and the clerical classes of whites, or the clerical and the semi-skilled labor classes, is not far from equivalent to the difference between whites and Negroes as groups. It is probable that the intellectual difference between the average policeman or fireman and the average doctor or lawyer, or the difference between the average street car employee or salesgirl and the average elementary teacher or small business man, or the difference between the average tramp and the average groceryman, is not far from equivalent to the difference between the average white and the average Negro. As skilled differs from unskilled labor in intelligence, it is probable that the average white man differs from the average Negro. Or the difference between the races may be expressed as roughly equivalent to the difference between the average white man and unskilled labor, or the difference between the average white man and the clerical classes.

In considering the mental capacity of the Negro, up to this point no account has been taken of the feeling and dynamic sides of mental life as distinguished from the intellectual. It is a common opinion, based upon observation and experience, that the Negro differs more from the white in such traits than in intellect proper. His emotions are generally believed to be strong and volatile in their manifestations; instability of character is ascribed to him; it is contended that he lacks foresight and persistence, that he is improvident and content with immediate satisfactions, that he has small power of serious initiative and that he lacks ambition. Along with high emotionality and instability of character, defective morality is ascribed to him, and the statistical records of crime and sexual immorality are cited in this connection.

At the present time it is impossible to make adequate measurements of these important human traits. If the Negro differs from the white in his manifestations of temperament and character, such differences may be due to the total circumstances of his life rather than to the intrinsic nature of his disposition. It may be that his social condition would produce his alleged characteristics, even if he were possessed of the psychic nature of the white man. On the other hand, it may be that the emotional and dynamic qualities ascribed to the Negro are due to his demonstrable intellectual deficiency, rather than to the inherent strength of his active tendencies. Pronounced and changing expressions of emotion, improvidence of character and a tendency to immoral conduct are not unallied. They are all due to uncontrolled impulse. And a deficient development of the more purely intellectual functions may produce all three. Where the implications of ideas are not apprehended, where thought is not lively and fertile, where meanings and consequences are not grasped, the need for the control of impulse will not be felt. This is strikingly evident in cases of feeble-mindedness. And the supposition that the impulsive life of the Negro is explainable on this basis is reinforced by the common observation that the lower levels of intelligence among white men are accompanied by traits of character not unlike those ascribed to the Negro. It is among the intelligent classes of whites that uprightness of conduct, self control and foresight in the management of affairs are most generally found. And this is doubtless also true of the more intelligent classes of Negroes.

The term Negro is generally used to refer to all descendants of black stock in America, without regard to the presence of individuals of African lineage other than the true Negro. It is also generally used to refer to the whole colored population, without regard to the presence in it of individuals of mixed white and Negro blood. This paper has followed the general usage. But while little is known concerning the influence of ethnic stocks other than the true Negro, the presence of the so-called mulatto in the colored population complicates all statements of Negro capacity. The term mulatto is employed here to refer to Negroes with any perceptible trace of white blood, regardless of its amount. This is the usage of the United States Census, which states that in 1910 mulattoes constituted approximately one-fifth of the colored population of the country. Since there is an increase in the proportion of mulattoes from decade to decade, due of course in large measure to intermarriage between mulattoes and "pure" Negroes and among the mulattoes themselves, it is probable that they now constitute about one-fourth of the Negroes in America.

The proportion of mulattoes among the colored population is considerably higher in the cities than in the rural districts and it is considerably higher in the North than in the South. It is also considerably higher in the school population than in the colored population at large and it is considerably higher in the upper grades of the school system than in the lower. If this educational distribution of mulattoes were true only for the country as a whole or for entire states it would not be significant, since educational advantages are greater in the North and in the cities, where the greatest proportions of mulattoes are found. But it is true where the educational advantages are the same for all classes of Negroes, as in a given city. And of colored children of a given degree of educational attainment, as those in the same school grade, the mulattoes are generally younger than the pure Negroes. These facts as to the distribution of mulattoes would therefore seem to indicate that they have greater ability and energy than pure Negroes. They are apparently more ready to perceive and to take advantage of the reputed opportunities of Northern and urban life. And they are apparently more ready to perceive the advantages of education and to make progress in school work.

The supposition that mulattoes have greater ability than pure Negroes is borne out by the results of mental tests. It is doubtless true that skin color is not an accurate index of the amount of white blood in an individual. But when considerable numbers of Negroes in the schools are classified on the basis of skin color and compared age by age or grade by grade, it is found that those of lighter color obtain higher average scores on intelligence tests than those who are darker. Where there have been as many as four groups in the classification, corresponding roughly to pure Negroes, Negroes three-fourths pure, mulattoes proper and quadroons, it has been found that the average scores of the lighter classes were successively higher than those of the darker. And when several thousand Negroes in the army were similarly classified, the results of the army intelligence tests showed that the Negroes with the greater amount of white blood, as indicated by skin color, obtained uniformly higher average scores on a given test than those with less white blood. A summary of the test results indicates that roughly 20 per cent. of the pure Negroes, 25 per cent. of the Negroes three-fourths pure, 30 per cent. of the true mulattoes and 35 per cent. of the quadroons equal or exceed the average score of comparable whites.

It is worthy of note in this connection that when the Negro recruits in the army were classified on the basis of literacy, it was found that the percentage of mulattoes among the literates was approximately twice as great as among the illiterates, and that this was true when both literates and illiterates were from the same draft area. Indeed, the difference in skin color between the literates and the illiterates was such that after the illiterates had been eliminated from a company the complexion of the group remaining was noticeably lighter to casual observation. It is also worthy of note that the Northern Negroes obtained higher average scores on a given test than the Southern, and that the urban Negroes obtained higher average scores than the rural.

While mulattoes as a group have greater intellectual capacity than pure Negroes, the overlapping in ability between the two classes is very great. It is greater than the overlapping between mulattoes and whites, since the greater number of mulattoes have a preponderence of Negro blood and since probably a majority of them are descendants of inferior elements of the general population. But even a slight difference in capacity between Negroes of pure and of mixed blood would produce a considerable difference in the number of individuals of great ability in the two classes. According to the relative size of the total groups of mulattoes and pure Negroes, there should be three or four times as many persons of marked attainment in the latter as in the former. But the difference in capacity between the two groups leads to the supposition, which is supported by a not unfounded general belief, that there are at least as many mulattoes as pure Negroes among the leaders of the race in this country. The matter can not be conclusively decided, however, because of the lack of satisfactory lists of colored men of attainment and because there is no sure indication of the amount of white blood possessed by individuals included in such lists as we have.

It is not unlikely that the presence of the mulatto may affect the interracial relationship in America. His presence will tend to raise the standard of colored achievement. But it may also tend to increase race friction. The mulatto thinks and feels more nearly as does the white man, and he is therefore probably less content than is the pure Negro with a position of racial subordination. And the proportion of mulattoes among the colored population will undoubtedly continue to increase. There is no evidence for the opinion sometimes expressed that the death rate of mulattoes is higher than that of pure Negroes. On the contrary, there is evidence that the colored professional classes, which contain a very high proportion of mulattoes, have a lower death rate than the race as a whole.

The mental difference between whites and Negroes in general indicates that there should be a difference in the organization of the schools of the two races. The public elementary school course, both North and South, is adapted to the ability of those white children who are most nearly average in capacity. But since only the most capable of the Negroes, roughly one-fourth of the total number, equal or exceed the average of white ability, it is unreasonable to expect Negroes as a group to make satisfactory progress in the public schools as now organized. That they do not make satisfactory progress is well known. Much of their lack of success is due to poor attendance and to unfavorable school and home conditions. These adverse social factors are found particularly in the South, where there are separate schools for the two races. But even in the North, where compulsory education laws obtain and where the same schools are attended by both races, the amount of retardation among colored pupils is far greater than among white. The psychological backwardness of colored children is everywhere paralleled by their educational backwardness. It would more nearly accord with all known facts concerning the intellectual ability of the Negro, if the elementary schools for colored children were so organized as to allow them an additional year for completion of the course. In a number of school systems for white children the grades are now so arranged that an additional year is allowed the slower third or fourth of the pupils. This arrangement for the slower white pupils should probably be made the basal plan for colored schools.

The content of the course of study for Negroes should be determined by social factors rather than by psychological. But in this connection it may be noted that the Negro, when compared with the white, seems to have relatively greater capacity to deal with the concrete, the tangible and the practical than with the abstract, the symbolic and the theoretical. He is highly capable in sensory and motor capacities and in native retentiveness; his shortcomings are logical or rational and more purely intellectual. He is well equipped for manual and industrial training and for acquiring the simpler skills. It is a common observation of teachers that colored children excel in handwriting and in rote memory work. It would seem that the nature of the mental equipment of the Negro lends sanction to the movement to render his schools less literary and "cultural" and more "practical" and vocational.

But since very able colored persons are found in every large group of Negroes, though the proportion of such individuals is much smaller than among whites, opportunities for advanced and professional education should be open to them. The widely held doctrine that the Negro's mental growth ceases at adolescence finds no sanction in experimental studies of his ability. And there is no reliable evidence that the variability of Negroes above and below their racial type is appreciably less than the variability of white men.

Psychological study of the Negro indicates that he will never be the mental equal of the white race. But the Negro in America is capable of great progress. Conditions in various small Negro republics, such as Haiti, Santo Domingo and Liberia, are frequently cited as evidence that the race is incapable of developing a high degree of civilization, and such arguments are not without their value. But in America the colored population is larger than in any of the Negro republics, and the progress of a group depends upon its size as well as upon its average capacity. The larger group will produce more individuals of great ability, and such individuals furnish ideas and inspiration for the whole group. And in America the Negro is in much closer contact with the white race than he is in the isolated Negro states. This contact gives him the advantages of white encouragement, achievement, example and control, and enables him to appropriate to his own use the products of white genius. Races or nations between which there is free intercommunication make greater progress than do isolated peoples, since the results of the ability of each race are more readily taken over and incorporated into the life of the other. It is therefore reasonable to expect the Negroes of America to reach a higher level of attainment than those of their race who are differently situated, even though the native ability of the Negro be everywhere the same.

SOME EARLY THEORIES REGARDING ELECTRICAL FORCES—THE ELECTRIC EMANATION THEORY

By Professor FERNANDO SANFORD

STANFORD UNIVERSITY, CALIFORNIA

SINCE our present electrical theories have arisen from earlier theories by modifications made necessary by later discoveries, any clear understanding of our present view-point makes it necessary to know the steps by which it has been attained. It is the purpose of this paper to discuss the opinions regarding the nature of electrical action which were held by some of the early investigators who were most influential in determining scientific opinion.

The origin of our knowledge of the attraction of rubbed amber for other bodies is lost in the obscurity of the past, but no attempt to explain this striking phenomenon in scientific terms seems to have been made until Dr. William Gilbert published his famous treatise, *De Magnete*, in 1600. Gilbert showed that the power of attracting other bodies could be developed in many substances besides amber; but he learned of no other property of electrified bodies except this attraction for other bodies. This is, accordingly, the only fact which Gilbert's electrical theory was called upon to explain.

Gilbert proposed a true physical theory to account for this fact. He definitely rejected any possibility of action at a distance, and assumed that electric and magnetic attractions must be brought about by means of some intervening medium. Thus he says:[1]

> For as no action can be performed by matter save by contact, these electric bodies do not seem to touch, but of necessity something is given out from the one to the other to come into close contact therewith, and to be a cause of incitation to it.

He regards the medium which is responsible for electric attraction as different from and as more attenuated than air or water vapor. Thus he says:[2]

> All bodies are united and, as it were, cemented together by moisture, and hence a wet body on touching another body attracts it if the other body be small; but the peculiar effluvia of electrics, being the subtilest matter of solute moisture, attract corpuscles. Air, too, (the earth's universal effluvium) unites parts that are separated, and the earth, by means of the air, brings back bodies to itself: else bodies would not so eagerly seek the earth from

[1] *De Magnete*, Mottelay's translation, p. 92.

[2] *De Magnete*, pp. 87-97.

heights. The electric effluvia differ much from air, and as air is the earth's effluvium, so electric bodies have their own distinctive effluvia; and each effluvium has its own individual power of leading to union, in its own movement to its origin, to its fount, and to the body which emits the effluvium. But bodies that give out a thick or a vaporous or an aerial effluvium when rubbed have no effect; for either such effluvia are diverse from humour (unifier of all things), or, being very like the common air, they become blended with the air and one with it: wherefore they have no effect in the air, and do not produce any movements different from those of that universal and common element.

And in the air the effluvium of electrics is very rare, and so it may more thoroughly permeate the atmosphere and yet not give it impulsion by its own motion. For were this effluvium as dense as air, or the winds, or fumes of burning saltpeter, or as the thick foul effluvia emitted with much force from other bodies, or as the air from vapourized water rushing forth as from a pipe (as in the instrument described by Hero of Alexandria in his book *Spiritualia*): in such case it would repel everything, and not attract. But these thinner effluvia lay hold of the bodies with which they unite, enfold them, as it were, in their arms, and bring them into union with the electrics; and the bodies are led to the electric source, the effluvia having greater force the nearer they are to that.

The theory that an invisible emanation of some kind was given out by electrified bodies was generally held for 150 years after Gilbert's time; but there was no general agreement as to how such an emanation could bring together bodies at a distance from each other. Gilbert, as indicated above, believed that bodies are held to the earth by some kind of pressure of the air, or, perhaps, by means of the moisture of the air. He accordingly attributed similar properties to the hypothetical atmospheres caused by electric and magnetic emanations.

The Rev. John Lyon, in his *Experiments and Observations on Electricity*, published in 1780, describes the different electrical theories with which he was acquainted. He says:

The first theory I shall mention is that of the learned F. Cabeus (1585-1650), who supposed that excited amber emitted effluvia from it, which expelled the neighboring air at small distances, and they made as it were a little whirlwind by the resistance they met with from the remoter air, which was not effected by the electric streams. When this subtle effluvia could not advance any further, by reason of the resistance of the distant air, he imagined they suddenly returned to the excited amber, and carried such light bodies with them as they met with in their way.

Sir Kenelm Digby, Mr. Boyle, Hartman, and others, supposed that excited amber emitted certain unctuous effluvia, which being cooled and condensed by the circumambient air, were deprived in part of their agitations, and shrinking back to the body from whence they issued, took with them such light substances as happened to adhere to their extreme particles at the time of their retractions.

The learned Gassendus approved of the foregoing theory, but he thought proper to add, that electric rays being emitted in several directions, intersected each other, and getting into the pores of light bodies, by means of their intersections, had the faster hold, and they drew with them chaff and straws, and other substances, in their returning to the amber from whence they were emitted.[3]

It will be seen that attraction is the only phenomenon thus far explained by means of effluvia. Nicolas Cabeus, who wrote his *Philoso-*

[3]These electric rays of Gassendus almost seem to have their modern counterpart in the "tubes of force" of some of the English physicists of the present generation.

phia Magnetica in 1629, and who is referred to by Lyon as F. Cabeus, was evidently the first to observe repulsion between electrified bodies. In Chapter XXX., page 139, of the *Philosophia* he says:[4]

I am convinced that this emanation attracts by setting the air in motion and that the air made to move in a whirl catches up the small bodies in the manner I have explained.

If a face of the amber be carefully prepared (i. e. by rubbing) and is then applied to iron filings, wood shavings or similar bodies, they will be drawn strongly to the amber, but when they reach it, they will fly back and instead of falling straight downward, they will be repelled to a distance of three or four inches. It is evident then that this motion of the small bodies is on account of the movement of the air which arises (in turn) from the emanation, by which also the bodies are projected to a distance. For if it were the propulsion of the small bodies as Gilbert says, with the emanation becoming strong near the amber, they would fly back to the amber and would not be projected, just as in the case of the magnet, iron never flies back and is not repelled on coming to the magnet. But since in this case the body subject to propulsion does fly back, it is evident that the movement is caused by some external influence, undoubtedly the air.

It is plain from the above quotation that Cabeus did not recognize repulsion as a true property of electrification. Nor was it so recognized by others until the publication by Otto von Guericke of his paper, *De Virtutibus Mundanis*, in 1672.

Von Guericke recognized what he regarded as a true repulsion of his electrified sulphur globe for light bodies in its vicinity, but his explanation of the phenomenon was rather metaphysical than physical. He definitely rejected the hypothesis of an attraction by means of an atmosphere of emanation because he found that his sulphur globe could transmit its attractive power to a distance of a meter or more by means of a linen thread. The importance of this latter observation seems to have been overlooked until it was re-discovered nearly 60 years later by Stephen Gray.

Von Guericke, as the title of his paper implies, undertook to describe the various corporeal and incorporeal powers which he regarded as inherent in the nature of physical bodies. Some of these he classed as moving powers, of which repulsion was an example, and others were called conserving powers, such as gravitation. Electric attraction was classed as a conserving power and electric repulsion as a moving power. Since these powers were supposed to be inherent in the bodies themselves, they were not dependent upon a surrounding medium, and hence were of the nature of action at a distance.

In a further discusison of the various theories of electric effluvia, Lyon says:

These theories had each their advocates in that age of Philosophy, in which they supposed that the effluvia emitted from an electric, returned to it again. After Sir Isaac Newton demonstrated the extreme subtility of the rays of light, and proved that several bodies might emit light copiously without any diminution of their weight: the doctrine of the return of effluvia was found unnecessary, and consequently was soon universally given up.

[4]Translation by Professor Jefferson Elmore.

This explanation of the abandonment of a belief in electric effluvia seems to have been influenced by Lyon's own hypothesis, which was that the light corpuscles of Newton's theory constituted the real electric fluid. Notwithstanding this explanation, the belief in an electric effluvium of some kind was retained for a long time after Newton's work on Light. In fact, Newton, himself, believed in some kind of an electric emanation. In 1675 he transmitted to the Royal Society his description of an experiment showing that a sheet of glass which has been electrified by rubbing on one side may attract light bodies to its other side, and he interpreted this as showing that the electric emanation was capable of passing through glass. He also, refers to the great tenuity of the electric emanation in two places in his *Opticks*. On page 315, he says:

> So also a globe of glass about 8 or 10 inches in diameter being put into a Frame where it may be swiftly turned around its Axis, will in turning shine where it rubs against the palm of one's Hand apply'd to it: And if at the same time a piece of white Paper or white Cloth, or the end of one's Finger be held at a distance of about a quarter of an Inch or half an Inch from that part of the Glass where it is most in motion, the electric Vapour which is excited by the friction of the Glass against the Hand, will by dashing against the white Paper, Cloth or Finger, be put into such an agitation as to emit Light, and make the white Paper, Cloth or Finger, appear lucid like a Glow-worm: and in rushing out of the Glass will sometimes push against the Finger so as to be felt.

Again, on page 327, in discussing the possibility of an all pervading ether, he says with regard to the objection of the necessary rarity of such a medium:

> Let him also tell me, how an electrick Body can by Friction emit an exhalation so rare and subtile, and yet so potent, as by the Emission to cause no sensible diminution of the weight of the electrick Body, and to be expanded through a Sphere, whose Diameter is above Two Feet, and yet to be able to carry up Leaf Copper, or Leaf Gold, at a distance of above a Foot from the electrick Body.

It seems likely that the proof that electrified bodies may retain their power of attracting other bodies for an indefinite time after being charged was one of the principal reasons for abandoning the hypothesis of a returning effluvium carrying light bodies with it. Probably the most important of these observations was due to Stephen Gray. In 1729 Stephen Gray found that many bodies, such as rosin, shellac, pitch, beeswax and sulphur, when once electrified might retain their attractive power for months, or even years, which seemed to show very clearly that electric attraction was not due to the return of the electric effluvium to its source, as Gilbert had imagined.

Gray also made another important discovery which was difficult to explain in terms of an electric emanation. He observed that a body may be given the power of electric attraction by merely bringing an electrified body near it. He performed this experiment with a ball suspended from the end of a cord more than 800 feet long, and showed that light bodies were attracted to the ball when an electrified glass tube was brought near to the farther end of the cord. One of his favorite experiments was to suspend a boy in a horizontal position by means of loops of hair or silk and to place a table on which were some scraps of metal foil just below his head. Then when he brought his electrified tube near the boy's feet the scraps of foil rose at once to his face.

Nevertheless, fifty years after the publication of the discoveries of Stephen Gray we find physicists still explaining electric attractions and repulsions by means of an electric atmosphere surrounding the charged body. The Earl of Stanhope, who did distinguished work in the field of atmospheric electricity, published an important work in 1779[5] in which he gave the most truly scientific explanation of electrical attraction and repulsion by means of an electric atmosphere to be found in the writings of any philosopher. Stanhope does not regard the electric atmosphere as consisting of a separate emanation from the charged body, but as made up of the particles of air which have become charged with the electric fluid of Franklin, probably by contact with the charged body.

Like Stephen Gray, Stanhope tried the effect of placing a charged cork ball electroscope under the receiver of an air pump and noting the distance of separation of the cork balls as the air was exhausted. He found that the cork balls which had stood 2½ inches apart in the air fell to a separation of less than a quarter of an inch when the atmospheric pressure was about ¼ inch of mercury. He concluded from this experiment that the force of repulsion between the cork balls was proportional to the density of the air between them. Then he says:

> From these Experiments, it appears, that, when Bodies are charged with Electricity, it is the *Particles of* (*circumambient*) *Air being electrified,* that constitutes the electrical Atmosphere which exists around these Bodies.
>
> Now, since an *Electrical Atmosphere* (whether *negative* or *positive*) consists of electrified Air; it evidently follows, that the *Density* of the Electricity of that Air, must be in some *inverse Ratio of the Distance* from the charged Body, which causes that electrical Atmosphere.
>
> That electrical Atmospheres do decrease *in density,* the more the Distance from the electrified Body is increased, is demonstrable by means of a proper Electrometer, in every instance.
>
> From these simple considerations, it is easy to reduce all the different *Phenomina* of electrical *attraction* and *repulsion,* to *one* plain and convenient Principle, derived from the very nature of a *disturbed electrical Equilibrium;* namely, to the elastic tendency of the electrical Fluid, to impel every Body, charged either in *plus* or *in minus,* towards *that Part* of its electrical Atmosphere, where its *natural electrical equilibrium* would be the most easily restored.
>
> From this simple Principle, it is evident, that Bodies which are charged with *contrary Electricities,* must tend to *approach* each other, whenever the skirts of their (*oppositely* electrified) *Atmospheres* interfere.
>
> From the same simple Principle, it is also easy to understand, why Bodies, that are charged with the *same kind* of Electricity, tend to *diverge* from each other.

[5]Principles of Electricity, etc., P. Elmsley, London.

Every Body that is electrified (whether *in plus* or *in minus*) has a constant tendency to return to its *natural State;* and this causes it to electrify, in a certain degree, *other Bodies* in contact with it, and the Air in its vicinity, in a manner similar to that explained above.

This explanation of electric attraction and repulsion was proposed long before the recognition of energy as a physical quantity; but it may easily be translated into terms of the principle that all elastic reaction to strain is directed to decreasing the potential energy of the strained system. If we substitute for Stanhope's elastic reaction of an electric atmosphere made up of charged air molecules an electric field of strain in an elastic ether, the principle here announced will enable us to explain, not only attraction and repulsion, but all the known phenomena of static electricity.

Twenty years before the publication of Stanhope's *Principles of Electricity* Aepinus had proved to his own satisfaction that charged bodies are not surrounded by an electric atmosphere of any kind. In 1759 Aepinus published his celebrated work, *Tentamen Theoriae Electricitatis et Magnetismi*, in which he stated his adherence to the general principles of Franklin's theory of a single electrical substance and attempted to develop a similar one-fluid theory of Magnetism. Aepinus expressed a firm belief that the electric fluid was wholly distinct from the ether of space, and maintained that it was confined to the limits of the electrified body and did not form an electrical atmosphere or effluvium extending into surrounding space. It is probable that it is for this reason that Aepinus is sometimes credited with being the principal founder of the theory of electrical forces acting at a distance. Thus, Whittaker, in *A History of the Theories of Aether and Electricity*, p. 48, says:

The theory of effluvia was finally overthrown, and replaced by that of action at a distance, by the labours of one of Franklin's continental followers, Francis Ulrich Theodore Aepinus.

The latter part of this statement seems hardly justifiable in view of Aepinus' own statement of his belief. Thus on page 7 of *Tentamen Theoriae* Aepinus says:[6]

I do not approve of the doctrine which assumes the possibility of action at a distance, for I hold as an indisputable axiom the statement that a body cannot act at a place where it is not; and if it should ever be proved that a certain attraction or repulsion does not altogether depend upon an external pressure or an internal impulse, then I think we have been reduced to such a position that we are compelled to conclude that motions of this kind are not produced by a physical force, but by spirits or other beings, as to which I cannot be induced to believe that this idea has any foundation in the world.

The arguments which led Aepinus to deny the existence of an electrical atmosphere seem to have been somewhat as follows: Since from Franklin's electrical theory all bodies upon the earth must be electrified,+electrification meaning that a body is more highly electrified

[6]Translation by Professor Jefferson Elmore.

than the earth and—electrification meaning that a body is electrified to a lower intensity than the earth, if charged bodies have an electrical atmosphere, then all bodies on the earth's surface should have an electrical atmosphere and by decreasing the capacity of an insulated body in the same electrical state as the earth it should be possible to increase the intensity of its atmosphere until it would become appreciable. Cavendish gives a similar reason for the same belief a few years later.

In 1771 Cavendish presented a paper to the Royal Society entitled *An Attempt to Explain Some of the Principal Phenomena of Electricity by means of an Elastic Fluid.* In the first paragraph of this paper Cavendish says:

> Since I first wrote the following paper, I find that this way of accounting for the phaeomena of Electricity is not new. Aepinus, in his *Tentamen Theoriae Electricitatis et Magnetismi,* has made use of nearly the same hypothesis that I have; and the conclusions he draws from it agree nearly with mine, as far as he goes.

On page 94 of his *Electrical Researches*, as edited by Maxwell, Cavendish gives his arguments against the existence of an electrical atmosphere as follows:

> That the attraction and repulsion of electricity extend to considerable distances is evident, as corks are made to repel by an excited tube held out at a great distance from them. That the electric atmospheres themselves cannot extend to any perceptible distance, I think, appears from hence, that if two electric conductors be placed ever so near together so as not to touch, the electric fluid will not pass rapidly from one to the other except by jumping in the form of sparks, whereas if their electric atmospheres extended to such a distance as to be mixed with one another, it should seem as if the electricity might flow quietly from one to the other in like manner as it does through the pores of any conducting matter.
>
> But the following seems a stronger reason for supposing that these atmospheres cannot extend to any perceptible distance from the body they surround, for if they did it should seem that two flat bodies whenever they were laid upon one another should always become electric thereby, for in that case there is no room for the electric atmosphere to extend to any sensible distance from those surfaces of the bodies which touch one another, so that the electric fluid which before surrounded those surfaces would be forced round to the opposite sides, which would therefore become overcharged with electricity, and consequently appear electrical, which is contrary to experience.

These papers of Aepinus and Cavendish seem to the present writer to furnish the starting point for that ether theory of electric attraction and repulsion which reached its extreme development in the writings of Faraday and his successors, but which seems for a time immediately following the work of Cavendish and Coulomb to have given place to the theory of action at a distance. At any rate, they mark the beginning of a rapid decline of the notion of electric atmospheres, though Stanhope's theory of the electrification of the surrounding air was published eight years after the presentation of Cavendish's paper to the Royal Society.

THE AGRICULTURAL LIMITS OF OUR POPULATION

By Professor E. M. EAST
HARVARD UNIVERSITY

RECENTLY Pearl and Reed[1] have shown that growth of population in any country is expressed by a portion of the curve of a logarithmic parabola having the formula $y = \frac{be^{ax}}{1-ce^{ax}}$, where a, b and c have postitive values. In developing this law of population increase, the authors have been guided by true biological premises, and have made the first original contribution to the problem of population since the time of Malthus. The fit obtained when the records of the United States Census are applied to this curve is truly remarkable, as indeed are the fits of census figures of other countries; and any student of population hereafter who does not give careful attention to the conclusions they have drawn, is treating his subject in a superficial manner.

The particular point in this paper to be discussed here is the major asymptote of the curve as applied to our own country. This gives the ultimate population limit of continental United States as 197,000,000, a figure so much smaller than has usually been predicted that it has aroused much comment. Doubtless Pearl and Reed realize how hazardous it is to predict. One who makes a prediction after a careful study of a situation is immediately bombarded with impromptu criticisms submitted by those who have made no such study, but who feel that in their infinite wisdom they have immediately thought of numerous variables left out of consideration by those against whom their criticism is directed. Thus it will be said that errors in the census figures will change the end result, that methods of agriculture will improve radically, that standards of living will be simplified, that new methods of utilizing energy will be found, that synthetic foods will be produced, that any one of a hundred things will occur which will make it possible for a much greater number of persons to be enlisted under our star-spangled banner than Pearl and Reed find to be probable under existing tendencies. Such criticisms are especially likely to appear on the subject of population, for a great many persons seem to take it as a direct personal insult when one suggests either the advisability of a population limit as a factor in national welfare or the possibility of a population limit as the result of natural laws. To limit

[1]Pearl, R. and Reed., L. J. On the rate of growth of the population of the United States since 1790 and its mathematical representation. Proc. Nat. Acad. Sci. 6: 275-288. 1920.

anything in the United States is blasphemy, though what the particular pleasure is in contemplating the country as an immense box of sardines, I am unable to discover. The authors would no doubt admit the possibility of certain changes in the present tendency for the population to increase. They would grant that for this reason the upper limits of our population are not to be set in 1920 with any high degree of accuracy. At the same time it could be shown, if space permitted, that criticisms of the type suggested above are not very cogent. They are the suggestions of the dilettante. The biologist realizes the improbability of new food products because of the fact that all our important foods were brought into use by prehistoric man. The geneticist is very conservative in his estimation of the prospects of a really great improvement in the domestic plants and animals. The chemist admits the possibility of synthetic foods as a laboratory stunt, but points out that as a practical scheme it is almost analogous to perpetual motion, since energy must be used up and man has never been able to approach nature in utilizing energy. The agriculturist points out the meagre changes in the art of agriculture which are the product of our civilization, and notes that those changes which have occurred are merely vehicles for exploiting a limited store of soil fertility at greater and greater speed. If there is any realm of activity wherein there is a small probability of radical future changes, it is agriculture; if there is any field wherein prediction for the future can be made from a study of the past with less likelihood of error, it is that in which agriculture is the major variant. Therefore a figure of 197,000,000 as the ultimate limit of population for the United States can not be cast aside for a *priori* reasons.

What the writer proposes to do in this paper is to show that the agricultural possibilities in this country are not so great as they are generally supposed to be, and that even if these possibilities were to be fulfilled wholly the population the country could support is not enormously greater than the figures Pearl and Reed have set. And naturally one has no good reason for saying the upper limits of food production will be reached because of population pressure. It is to be presumed that Americans will have sufficient foresight to adjust the birth rate to the death rate and to attain a stationary population without the compelling force of grim necessity. We shall not discuss the possibilities latent in new food products, in better cultivated plants and domestic animals, or in new methods of agronomy. They have been considered carefully, and it is our opinion that they are not important factors in the matter.

In an essay on population published in a previous issue of this journal,[2] the writer showed what a comparatively small amount of reserve agricultural land still exists in the United States from which to

[2]East, E. M. Population. Sci. Mon. 10: 603-624. 1919.

produce food for our increasing population—a population which is rising by leaps and bounds. Unfortunately our reference to rapid population increase has been misunderstood in various quarters. This misunderstanding was caused by our calling attention to Pritchett's calculation of our future population based on the supposed fit of our census returns to part of the curve of a third order parabola. It was obvious from its shape that this curve had no biological basis, and the absurdity of expecting 386 million people in the year 2,000 and 1,113 million in the year 2,100 was pointed out. The figures were used merely to bring out the terrific rate of increase maintained at the present time, and to emphasize the efforts necessary to provide food if this increase were to be maintained. The amount of reserve agricultural land not now in farms proved to be about 35 per cent. of the present farm area. Since in the nature of the case this uncultivated land must be of poorer quality on the average than that which has been cultivated in previous years, we are warranted in assuming that even less than 35 per cent. of reserve land remains in this country when considered on a productivity basis. These calculations were made carefully and were sufficiently accurate for the purpose for which they were used, viz., to show how rapidly our population was encroaching on our potential food supply.

Since this paper was written a detailed study of the "Arable Land in the United States" has appeared under the authorship of O. E. Baker and H. M. Strong, of the United States Department of Agriculture, as one of the papers in the 1918 Yearbook issued in 1919. These authors have made an extremely valuable investigation of the agricultural lands of the United States, and support their conclusions with adequate data. We wish to point out some conclusions as to the possible ultimate population of the country with their figures as the basis. We venture to make only two slight changes. The first change is to withhold permanently from farm use an additional 50 million acres of potential improved land to provide space for future cities, roads and railroads. The second change is a reclassification of the land, which, because of its arid nature or because of its topography, can never be used for primary food production. Baker and Reed have classed only 38 million acres out of 653 million arid acres as desert having no grazing value. But as a matter of fact about 200 million acres more are desert lands where the grazing value is negligible.

The final disposition of the lands of the United States, then, may be expected to be somewhat like this: improved land, 800 million acres; forest and woodland 360 million acres; range land and unimproved pasture 415 million acres; desert 238 million acres; cities, roads and railroads 90 million acres. One thus accounts for the 1903 million acres making up the total land area of the country.

Those who cast a distrustful eye on the 1103 million acres, 58 per cent. of the total land area of the country, which are set apart as land which must be permanently withheld from cultivation, are referred to the arguments given *in extenso* by Baker and Strong. The reasons are plainly set forth in their paper, and if the writers err they err on the side of optimistic conservatism. Their figures may have to be revised at the end of a few centuries, but it is more likely that they will be revised upward than downward.

In brief, 743 million acres of these lands are set apart because of natural irremediable conditions. They consist of arid lands having no possibility of irrigation, lands where the mean summer temperature is too low to grow crops, lands where the topography is such that cultivation is impossible, lands which are without natural soil fertility, and undrainable swamps. Nevertheless such lands, when the population pressure becomes sufficiently great, may be used to produce some food. The cheerful optimist, and we shall take on that rôle for the time being, may perhaps assume that there is the possibility of supporting one person per each 100 acres upon them—a total of 4 million people.

The 360 million acres of forest and woodland must be retained for a variety of reasons. In most cases their topography prevents their cultivation, so that they could not be used for farm lands even if no other obstacles intervened. But beyond this fact stands the opinion of meteorologists, that if this figure for a forest reserve be cut, a change in the rainfall and the temperature of the improved land would ensue such as to reduce its productivity much beyond that of any increased production resulting from the additional new lands. On the other hand, there remains the possibility of producing considerable amounts of both primary and secondary foods on these reserves without destroying their usefulness as forests and woodlands. When food becomes sufficiently scarce and the price in consequence becomes sufficiently high, these lands will be utilized. They will perhaps produce sufficient food to support one person for each 50 acres, giving an additional potential population of a little over 7 millions.

There remains, then, a potential 800 million acres of improved land for consideration. This figure is made up by adding together the 478 million acres in cultivation in 1910, 30 million acres of desert land which irrigation engineers believe may be irrigated, 60 million acres of swamps that can be drained, 82 million acres suitable for dry farming and upland pasture, and 200 million acres of tillable land which is now in woodland. The sum obtained is 850 million acres. But from this sum must be subtracted a parcel of 50 million acres to allow for the growth of cities, roads and railroads. 800 million acres of arable land are left. The question then arises; what potential population will this land support? It is a question that can be answered in a rough way by comparing the per capita acreage of cultivated land in foreign countries as compiled by the International Institute of Agriculture at Rome.

Before the war Germany cultivated 48 per cent. of her land area, France cultivated 45 per cent, Italy cultivated 48 per cent, and Belgium 49 per cent. It will be seen that these figures are fairly comparable with the 42 per cent. proposed for the United States as the sum total of her arable possibilities. Furthermore our comparison is fair in a historical sense, since these countries were over-populated as shown by the fact that they did not live within themselves agriculturally, and since our own country is made up of peoples from similar racial stocks and therefore may be presumed to have similar tastes, customs and abilities.

On the face of the returns, these countries were tilling the following number of acres per capita; Germany 1.15 acres, France 1.5 acres, Italy .98 acres, Belgium .57 acres. These figures, however, do not show the true state of affairs. For example, the total arable land of Belgium can not be compared with that of the United States. It is much too good. It is no more right to use her wonderful bottom lands as a standard than it would be to use the Nile overflow lands of Egypt where nature robs Peter to pay Paul and produces greater crops than anywhere else in the world. It is no more proper than to expect all the soils of the United States to come up to the production figures of the Mississippi Valley. Exclude Belgium and a fair comparison can probably be made if one is careful to make the comparison fair. These countries were not self supporting. Huge quantities of food were imported annually. We have not been able to obtain the complete returns for exports and imports from which to make an accurate accounting of the number of people actually supported per acre in such countries as France and Germany where both the standard of living and the efficiency of the agriculture is high. In Germany it seems to have been pretty close to 2.2 acres per man when all corrections are made. In France it was probably somewhat higher. Personally I believe that 2.5 acres per man is the limit that we may hope to reach in the United States if we cultivate our whole 800 million acres, if we keep up a reasonable standard of living, if we follow rather closely our present food habits, if we conserve carefully our soil fertility, and above all if we farm as intensively, as scientifically and with as little waste as the best farmers of Europe who have been under the necessity of perfecting their agriculture because of population pressure during the past half-century.

If this assumption be true, our 800 million arable acres will support 320 million people, a figure to be added to the 11 millions obtained by calculating the productivity of our grazing lands and forests. The maximum population the United States can support under any conditions conceivable to those of us who live at the present day, therefore, is 331 millions.

To be sure 331 millions of people is a right tidy little population. China is supposed to have about 300 millions, with a land area 600 million acres greater than the United States. Can we wish to be placed ultimately in an economic position less favorable than that of present day China? We should all answer, No! Is it, then, improbable that we shall use a little forethought before this time comes, and establish a birth rate adjusted to the death rate which will withold from us the economic pressure which she confronts at all times? If this be reasonable, is it not probable that Pearl and Reed's figures of 197 million, as the upper limit of the population that the United States will actually attain, are wholly just and proper?

The most optimistic of our population enthusiasts will criticize these figures no doubt. They will point at once to Japan as the shining example of efficient agriculture, an example that we ought to hold ever before us and strive to emulate. Japan, with a population of 52 millions in 1911, cultivated 18 million acres out of a total land area of 94 million acres. By an extraordinary use of fertilizers, which reached a figure of over 4.5 tons per acre over the whole cultivated area, exclusive of commercial chemicals, she was thus able to support 3 persons per acre. In reality the figures reported should not be quite so high, as Japan imported a very much larger amount of foodstuffs than she exported in the years just previous to the war. But with due allowance for imports Japan did actually produce food sufficient to support about 2.5 persons per acre of cultivated land. If the United States could do as well on her 800 million acres of arable land, our population might have a maximum limit of 2000 millions—a figure greater than the present population of the world.

Let us stop a moment and do a little more figuring before we accept this computation. The Japanese are small. Their army rations are only about one-half of ours. Their population as a whole gets along with less than half of the food per capita required by the people of the United States. Undoubtedly our own people are great wastrels because they have more to waste, and could get along with less if it were necessary; but it may be questioned whether Japan's crops would support more than 1.5 Americans per acre, even with a material lowering of the standard of living and a higher standard of efficiency for food utilization. Naturally it will be maintained by some that this difference in food consumption between the American nation and the Japanese nation is unnecessary. It will be pointed out that excess of body weight in one over the other is not over 25 per cent., and that for this reason a 25 per cent. difference in food production is all that can reasonably be demanded. But this is not the whole truth in the matter. Food habits are very ancient. Pearl has shown that the people of the United States did not reduce their food intake during the war though there was an urgent moral necessity that this should be done. Nevertheless during this period the people not only ate just as much, they even demanded their food in whatever expensive forms appealed to their tastes. Our contention is, therefore, that while a constant economic pressure maintained over long periods may modify our food habits, it will be just as difficult for us to cut our present ration as for the Japanese to cut the one to which they have become accustomed. And it does not appear that such established folkways will be materially modified in the comparatively short length of time which present indications allow us as the interval before we reach a close approximation of our population limit—i. e., the point where our population curve turns sharply toward the horizontal.

There is still another important modification of our computation to be made. We have an extensive system of agriculture in this country. Our yields per acre are comparatively low; but we farm more land per man than any other country. The Belgian, the most intensive farmer of Northern Europe, for example, cultivated 5 acres per man before the war; the comparative figure for the United States is 26 acres. Now we have calculated that the United States contains 800 million acres of arable land that can ultimately be put under the plow, but if we suppose that this 42 per cent. of the whole land area of the country can be made to produce the crops which Japan produces on 18.7 per cent. of her area we are making a grave mistake.

Japan cultivates a comparatively small proportion of her land area by a method built up in China, because she has found that she thus gets the greatest returns. She even goes so far in her conservation and utilization of soil fertility as to strip the surface soil from less productive areas for use upon her best land. Indeed it is wholly probable, as may be seen by a study of the relief maps of the two countries, that Japan has almost as high a percentage of arable land as the United States. But she has found that it does not pay to try to cultivate it all. We have considerable reason for supposing that Japan would not obtain a significant increase in her total production of foods if she cultivated 42 per cent. of her area instead of 18.7. If, therefore, her productiveness were measured in relation to the first percentage (42), she really would need 1.5 acres per man to support her population in terms of American food habits. At this rate, the United States could support only 530 millions on her arable land. Presumably this figure may be taken as the ultimate limit humanly possible for the country. That we shall ever reach this figure seems to the writer wholly absurd.

THE BEARING OF THE RESULTS OF MENTAL TESTS ON THE MENTAL DEVELOPMENT OF THE CHILD

By Professor FRANK N. FREEMAN

UNIVERSITY OF CHICAGO

IT is surprising to note how little the results of mental tests have been used as a basis for a critique of our views of the mental development of the child. These views have become traditional and are based upon data which were gathered before the present day era of mental testing had opened. The scientific facts upon which our current conceptions are based are exceedingly slender in comparison with the rich material which now awaits our formulation. It is probably no exaggeration to say that there is now available for interpretation ten times as much material bearing upon the age progress of the child in intellectual functions as was available ten years ago. I have attempted in this paper to make a survey of the most significant of this material and to examine critically our conceptions of intellectual growth in the light of it. In the examination of the data we should consider such questions as the following:

1. Age progress in particular intellectual functions.
2. Age progress in more general or composite intellectual functions.
3. The correspondence between this age progress and physical growth and development.
4. The relationship between the progress of the average or median child and the progress of those who are above or below the median.
5. The relation between the facts already mentioned and current methods of expressing the relationship between the individual of inferior or superior ability and the individual of median ability. This question deals particularly with the now commonly used I. Q. (Intelligence Quotient).
6. The nature of the differences in the intellectual capacity of children at different ages. This topic raises the question whether the differences are chiefly in amount of ability or whether there are also differences in kind. In other words, the problem is whether the child simply increases, through development, the powers which he already possesses, or whether he acquires new powers as he grows older. This topic is not included in the present discussion.
7. Finally, we may consider some of the practical bearings of the facts upon such problems as the grouping of the children in school.

Age Progress in Particular Intellectual Functions

We may introduce the topic of age development by examining some of the chief data which were gathered by earlier students of this problem. About 1900 Smedley made tests of memory on a large number of school children. He presented the results of this test in the form of a curve which represents the achievement of the child at each age from 7½ to 19½. The type of memory which was tested was a very simple one, namely memory span for digits. It consisted in requiring the child to reproduce a series of numbers which were spoken to him or presented to him visually. The curves for visual and auditory memory are shown in Fig. 1. From these curves the conclusion has been drawn that auditory memory ceases to improve between the ages of 13 and 14 and the visual memory between the ages of 14 and 15. In other words, memory develops rapidly until early adolescence and then practically ceases to improve. It is rather astonishing that so far-reaching a conclusion should have been drawn from an experiment with only one type of memory and that a very simple one. We shall see from the examination of the other progress curves that the age at which improvement ceases depends in a large measure upon the difficulty and complexity of the test which is used. It is quite unjustified to conclude that memory for narrative, or for expository prose, or for poetry follows the same course of development as memory for digits.

The difference in the age at which progress slows down or ceases is shown in the three examples from a still earlier investigator, Gilbert, whose report was published in 1895. A careful examination of Gilbert's results indicates that the age at which one function matures may be very different from the age at which another reaches its climax. Chart No. 2 shows the progress in discriminating differences in color. We see that this ability ceases to develop rapidly at 10 years. The break in development comes in the middle of the period of later childhood, between second dentition and adolescence. In the third chart is shown progress in the discrimination between weights, which Gilbert calls muscle sense. The development in this capacity apparently ceases at the age of 13, in early adolescence. Development in rate of movement, as tested by rapidity of tapping, (Chart 4), shows a break at the age of 13, but unlike the muscle sense continues its development after this break up to the age of 17. In another investigation of progress in tapping there is no such clear break at 13 as was found by Gilbert. Chart 5 from Bickersteth shows fairly continuous progress up to the age of 14½. We have thus already found a considerable variety in the time of maturing of various functions.

The following charts will illustrate further this variety in the form of progress of relatively simple functions. Chart 6 represents progress in a test which consisted in marking with a pencil a succession of dots. The speed of the dots was progressively faster so that the test passed from easier to more difficult stages. The progress in this ability shows no radical retardation from the age of 5½ to 15½, though there are minor retardations at 10½ and 13½. In general, however, the curve of the line of advancement is straight up to the age of 15½.

The next chart shows progress curves in three examples of another

Fig. 1. Age progress curves in memory span for digits presented visually and orally (from Smedley)

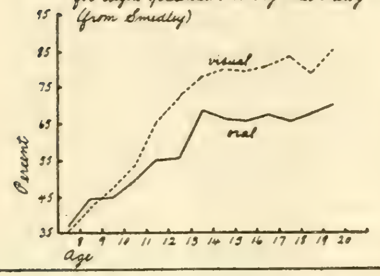


Fig. 2. Age progress curves in discrimination of color (from Gilbert)

Fig. 3. Age progress curves in weight discrimination (from Gilbert)

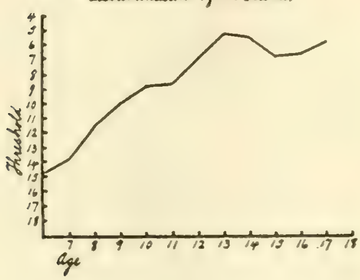


Fig. 4. Age progress curves in rate of tapping (from Gilbert)

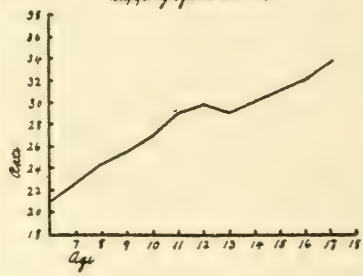


Fig. 5. Age progress curves of girls in rate of tapping (Bickersteth)

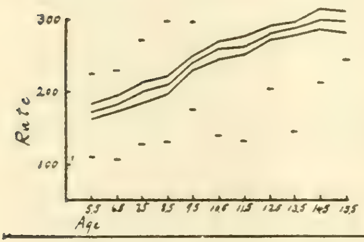


Fig. 6. Age progress curves of girls in marking dots on moving paper (Bickersteth)

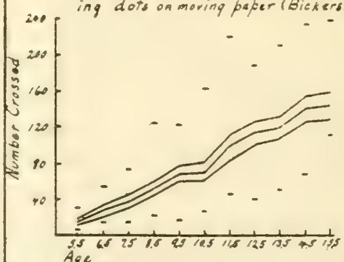


Fig. 7. Age progress curves of girls in finding and crossing letters and numbers in sequence (Bickersteth)

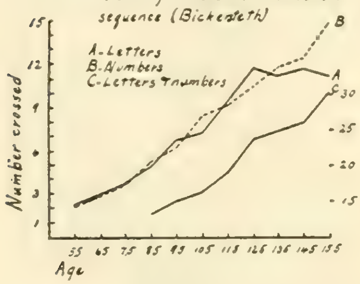
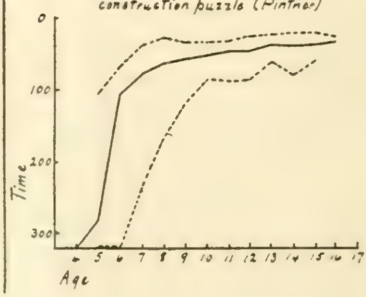


Fig. 8. Age progress curve in a simple construction puzzle (Pintner)



test. The test is given by presenting to the child a card upon which are arranged letters of the alphabet and numbers in irregular order. The problem is to cross out the letters of the alphabet or numbers in order. In the third form letters and numbers are mixed. We see that in two of the tests, namely crossing numbers and crossing numbers and letters combined, there is no let up in progress up to the age of 15½. There is a slight break at 13½ in the combination test but none in the number test. In the alphabet test, however, progress ceases at the age of 12½. There thus appear radically different forms of progress in the tests which superficially seem to be practically identical. It is impossible to predict where a break in progress will come on the basis of a knowledge of the general character of the test. It is equally incorrect to say that the break of progress in different tests will come at any common age.

A similiar variety in the ages at which ability culminates is seen in three examples from the performance tests given by Pintner and Patterson. The first of these is the so-called triangle test. It consists in fitting triangular pieces into an opening. It is an example of the form board test. The culmination in this ability comes at the age of 6, with very slight progress after this age. There is enormous progress between the ages of 5 and 6 (chart 8). Another form board test used by Pintner, on the other hand, shows this rapid progress at a different age. It is the so-called picture profile test in which the task is to place a number of blocks so as to form the outline of a face. The rapid progress in this test comes between the ages of 9 and 11, and the culmination is practically reached at the age of 11 (chart 9). Chart 10 shows somewhat more gradual advance with age, in which the most rapid progress comes between 5 and 9, slower progress between 9 and 12, and practically no progress after this age. This is the so-called picture completion test. A series of parts of a picture pasted on a board are cut out of a picture and mixed with a number of blocks on which other pictures are pasted. The task is to select the proper block from the collection and insert it in the proper opening in the large picture. The range of chances of correct moves is large and the scoring system is worked out in considerable detail. Progress is therefore represented in a more refined fashion than in some of the preceeding tests.

The examples thus far have been drawn from general mental tests, which measure somewhat abstract abilities. The same differences in age of maturing of different functions can be illustrated, however, from tests in school subjects. On chart 11 are shown three curves of advancement in reading from Gray's investigation. The continuous line shows advance in the rate of oral reading, the broken line in the rate of silent reading and the dotted line in quality of silent reading. It will be

Fig. 9. Age progress curve in a simple construction puzzle (Pintner)

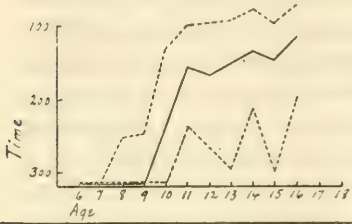


Fig. 10. Age progress curve in a picture completion puzzle (Pintner)

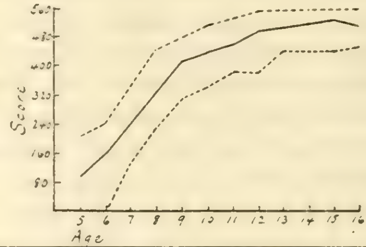


Fig. 11. Grade progress curves in reading (Gray)

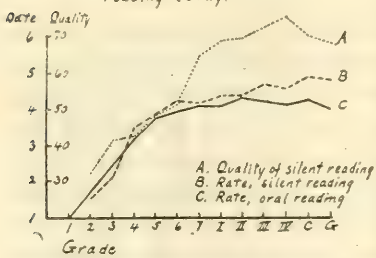


Fig. 12. Average age in the school grades

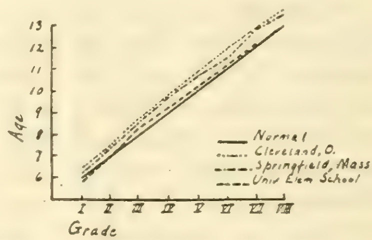


Fig. 13a. Percentage of children testing below age who reach or exceed those of same mental age who test at age, in nine single tests

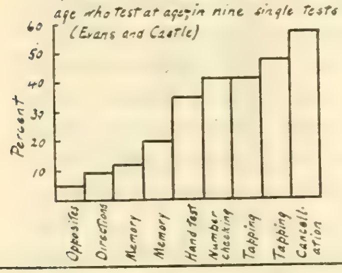


Fig. 13b. Diagram illustrating the relative effect of age on the scores of various tests shown in Fig. 13a, and in the Yerkes Point Scale, there used as basis for mental age

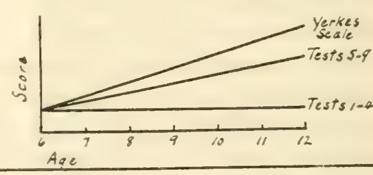


Fig. 14. Grade progress curves in simple multiplication and division (Judd)

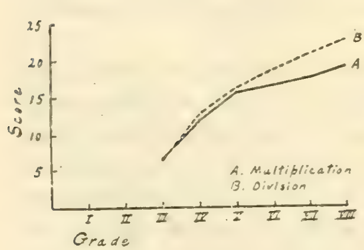
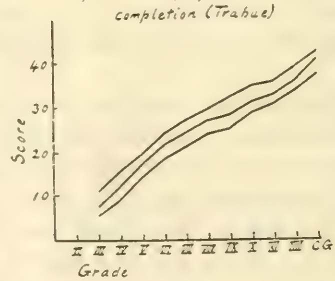


Fig. 15. Grade progress curves in sentence completion (Trabue)



seen that the progress in rate of silent and oral reading is relatively very similiar, although the rate of silent reading is above that of oral reading from the fourth grade on. The curve for quality of silent reading, however, takes a radically different course. There is marked and continuous progress up to and including the Senior year of the High School. It is probable that this progress would continue through the further two groups which were tested, namely college students and graduate students, if their attitude toward the test had been as natural as that of the younger pupils.

The question of technique in the interpretation of these tests arises from the fact that, unlike the preceeding tests, the results are grouped by school grades rather than by ages. If the pupils of successive grades were all of the same age, and if each grade represented an advancement of one year in age over the preceeding one, the curves would be based upon the same groupings. Neither of these conditions, however, obtains. The relation between age and grade may be illustrated by a chart showing the average age of pupils in successive school grades. On chart 12 is shown by the continuous line, the normal age for each school grade, assuming the pupils enter at six years and advance one grade each year. The next line above represents the average age for the successive school grades in the University Elementary School. It appears that in all grades except the first two the average age is somewhat above the normal. The other broken lines represent the same facts for Springfield, Mass., and for Cleveland, O. The average age in the public schools is considerably above that both of the normal and the University Elementary School for each grade.

Assuming that the results from school grades would be the same as results from age groups if the average age corresponded to the normal expectation, we may ask what effect this deviation of the actual from the expected may have upon age progress curves. In order to answer this question it is necessary to know whether the average score in a test would be raised or lowered by the fact that the average age of the grade is above normal. The question may seem at first sight ridiculous, but it ceases to be so when we consider that the pupils who are above the normal age in any particular grade are retarded because of backwardness in mental growth. Investigations have repeatedly shown that the younger pupils in the same grade may do better in certain tests than the older pupils in the same grade. In such a test, therefore, the excess in the average age of the pupils might be expected to lower the curve at the point at which it occurred. On the other hand, it may be true that in some tests the older pupils would do better than the younger pupils of the same grade. We might for convenience call this type of test a maturity test, and the type in which the younger pupils excel a brightness test.

Fig. 16. Grade progress curves for completion of sentences of varying difficulty (Trabue)

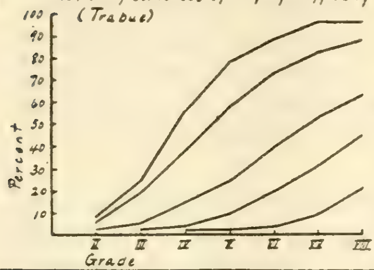


Fig. 17. Age progress curve in the Yerkes Point Scale

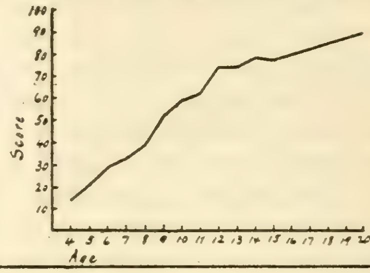


Fig. 18. Age progress curve in the Pressey Group Test

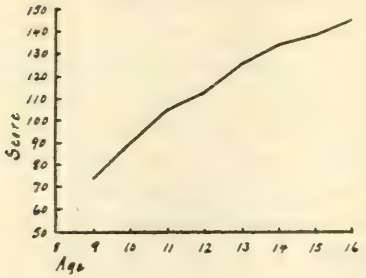


Fig. 19. Grade progress curves in Forms A and B of the Chicago Intelligence Test

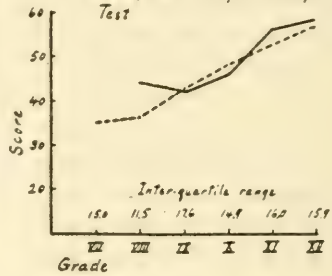


Fig. 20. Age progress curves in Haggerty's tests Delta 1 (A) and Delta 2 (B).

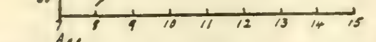


Fig. 21a. Hypothetical age progress curves in Intelligence (Woodrow)

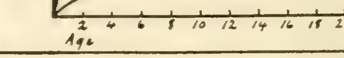


Fig. 21b. Hypothetical straight-line age progress curves

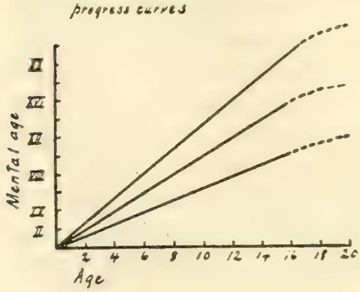
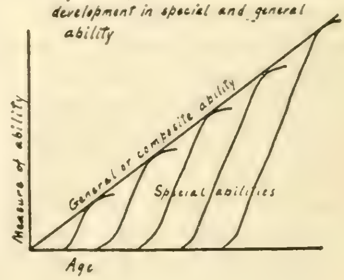


Fig. 22. Hypothetical relation between development in special and general ability



That there are such differences between tests is made clear by Chart 13a. In the upper part of the chart are represented the scores in a variety of tests given to a group of children. These children varied in chronological age, but were similiar in ability as measured by the Yerkes point scale. This group, homogeneous so far as their ability in this scale was concerned, were given nine tests. In order to compare the factors of brightness and of age in these nine tests the entire group of children was divided into two groups. The first consisted of all those whose mental age did not correspond to their chronological age. For the most part their ages were above the normal. In the other group the mental and the chronological ages correspond, that is, their mental advancement was what might be expected from their age. The relative standing of these two groups was thus compared in each of the nine tests. Each horizontal column represents one of the tests, the first column an opposite test, the second a directions test, the third a memory test, etc. The length of the column represents the percentage of the older children of the group who exceeded the median of the normal children. If the column reaches fifty per cent., as it does in the last two tests, it indicates that the two groups are equal. If the column is short it indicates that the older children are inferior to the younger ones. In the last five tests, which consisted in simple sensory and motor processes, the older children were nearly equal or fully equal to the younger ones, while in the first four they were markedly inferior. We may express these facts by saying that in some tests, physical maturity, as distinguished from brightness, is of little avail, whereas in others improvement accompanies to a much greater extent mere chronological age.

We may express the differences between these types of abilities by the figure chart 13b. The lines indicate the relative degree of advancement we may expect in a test from mere physical maturity. Thus we see that in the Yerkes scale and in tests 5 to 9 the factors of maturity and of brightness have about the same relative influence, while in tests 1 to 4 the factor of brightness outweighs that of maturity in comparison to both the Yerkes scale and tests 5 to 9.

To come back now to our interpretation of the grade progress curve, we may say that if the test in question depends largely upon physical maturity the curves which represent it will be higher in intermediate grades, and in some cases in the grammar grades, than would be the same age progress curve. If the test is one of brightness however, it is probable that the curves would either not be raised or would be slightly lowered by the excess age of children in these grades.

Since the above was originally written both an age and a grade progress curve in the same test have become available for the Haggerty test, Delta 2. These curves are shown in Fig. 20, B and C. The age progress curve is practically a straight line while the grade progress is more rapid up to Grade VI and then decreases. The form of the grade curve suggests that success in this test depends largely on maturity. From the third grade to the fifth the number of over age, dull, pupils increases, while the number of under age, bright pupils decreases. After the sixth grade the number of over age pupils decreases rapidly and the number of under age pupils nearly holds its own. There is one serious difficulty in the interpretation of these data, however. The superiority of the grade progress curve is much greater than can be accounted for by the preponderance of over age pupils in the grades and the assumption that the score depends chiefly on age. For example, the average age of eighth grade pupils in two cities, Cleveland and Springfield, Mass., is 13.66 years and 13.53 years respectively. The score for year 13.6 according to the age norms would be about 95, but the score for grade VIII is 120. Since the results come so far from fulfilling the legitimate expectations in this respect, then, we may well be hesitant in drawing the natural conclusion which is suggested above from the form of the curve, particularly since the younger children of a school grade have been shown repeatedly to make a higher score in tests of this sort than do older pupils. The question of the relation between age and grade progress curves must be left open to further investigation.

We may then use these grade progress curves to represent roughly progress with age but must bear in mind that they may be somewhat distorted. Another illustration from school subjects is given in chart 14 which represents grade progress in simple multiplication and division as measured in the Cleveland Survey. While there is continuous progress in division to the eighth grade, there is a marked break in progress in multiplication at the fifth grade. Thus in two of the operations in the same school subject we find the progress curves representing different periods of maturing.

Age Progress in General or Composite Functions

Progress curves which have been shown up to this time represent development in fairly specific mental functions. We may compare with these a number of curves which represent somewhat more complex functions or composite functions. The first one, shown on chart 15, is not greatly different from those which we have already been shown. It represents progress in ability to complete mutilated sentences as taken from the study of Trabue. The sentences are so arranged as to advance from very easy to difficult. This makes possible a wide range of scores and gives an opportunity for pupils of little ability and also for pupils of much greater ability to be faithfully represented in the score. The progress curve on this test is accordingly very different from that which was obtained in most of the preceeding examples. It represents an almost uniform rate of progress from pupils in the second grade to college graduates. This means that the development in the ability which is required in this test is practically uniform. The facts here represented suggest very strongly the view that the form of progress in which there is rapid gain within a small range of ages, followed by little gain, is due to the fact that the test is of such a character as to measure only a given degree of difficulty, or given level of ability, in the function which is measured. It suggests that if a test were so designed as to give opportunity for all ranges of performance in a function, the curve would show more continuous and extended advance.

That this hypothesis is a reasonable one is indicated by the next chart, No. 16, in which curves for several individual sentences of the Trabue test are given separately. The upper curve obviously represents an easy sentence, since the ability to pass it develops early. The lower curves represent successively more difficult sentences. We have here then a succession of progress curves in the same function, which take radically different courses, and represent development at widely different ages. It is obvious that a marked development at a particular age distinguishes it from the others, not in a marked advance in the function as a whole, but rather in what we may call a particular cross section of it, or particular degree of capacity in it. Progress in a function as a whole is uniform and extended over many years.

Similiar uniform and extended progress is represented in the scores of four point scales. A point scale is usually similiar in organization to the Trabue scale in that it includes materials of widespread range in difficulty. An individual's score is made up of the sum of the points which he is able to make in all of the tests which he can pass. These scales, in addition, go one step further in including tests of a variety of sorts of functions. In the first record of progress in a point scale, namely the Yerkes scale, shown in Chart 17, the progress is continuous and uniform up to the age of 12. From that point forward to the age of 20, there is further uniform progress, but at a much slower rate than that below the age of 12. If we reason from this alone, we should conclude that there is a break in mental development at the age of 12. It is quite possible, however, that break in progress is due to the fact that the scale does not furnish as great an opportunity to individuals of the upper degrees of ability as to those in lower ranges. That this supposition is correct is indicated by the fact that progress in the Pressey test, chart 18, and the Chicago Intelligence Test, chart 19, follows a uniform course beyond the age of 12. In the Pressey test this uniform progress is carried as far as age 16, and in the Chicago test to the senior year of the high school. Some allowance should probably be made in the case of the Chicago test for the selection of the brighter pupils in the later years of the high school. This factor, however, is probably not responsible for the great difference found between this test and the Yerkes test.

Additional evidence that progress with age as measured by composite tests follows approximately a straight line within the ages during which growth is continuing is to be found in the norms from the Haggerty point scale, shown in chart 20. The irregularities in the curves are readily explained. The falling off in progress in A at 10 years is doubtless due to the fact that this test is too easy for this grade. Likewise the low score in B at age 8 is due to the difficulty of the test for 8 year old children. The acceleration in B at the age of 15 years is probably due to a selection of the brighter children at this age.

Hypothetical Growth Curves

We may now make an attempt to generalize upon the facts concerning intellectual growth which are represented in the preceeding charts. We may first consider the question as to the general form of the development curve. The fundamental question which arises here is whether development preceeds in general at a uniform rate or whether it is more rapid at one period than at another. Disregarding the question whether there are minor accelerations or retardations in rate, the first question to be considered is whether growth in general is more rapid in the early period of childhood or later on, or whether the progress follows some other course. The widespread view on this matter is represented in the upper curves of chart 21a. This view has been given some support from the analysis of the results of the Binet scale. The particular curves here shown are taken from Woodrow. They represent intellectual growth as being very rapid in the earliest years and becoming progressively slower until it practically ceases at the age of 16. A different conception is represented in chart 21b. According to this conception, progress is comparatively uniform in rate from early childhood to maturity. The limit of progress, furthermore, comes at least somewhat later than the age of 10. Again the same point must be made as was mentioned in the comment on the Yerkes scale. When progress appears to cease at a given age, it is not safe to conclude that this cessation is actual unless we are sure that the tests give an opportunity to superior degrees of ability. There is reason to believe that the Binet tests do not do so, and that therefore the conclusion that progress ceases at 16 is not justified. At what age progress does show marked slowing down we cannot at present say. In all probability it continues with considerable rapidity to the age of 20.

The further discussion of the validity of these two conceptions of age progress is so bound up with the question of individual differences and of overlapping ability of succeeding ages that it can be best taken up after presentation of data upon this matter. We may add, however, a chart which represents a view of mental development which is in harmony with the facts already presented. The figure representing this view is shown on chart 22. On this chart is indicated the relationship between general intellectual progress or composite progress, represented by the straight line, and progress in a series of particular capacities or in narrowly defined measures of general capacities or functions. Such a conception reconciles the superficially contradictory facts shown in the preceeding charts. In some of these, progress seemed to be confined to particular ages while in others progress is spread over a wide range. The view here suggested is that progress in general or composite functions is widely extended, but that this general progress is contributed to by increments of ability in narrow functions or in different applications of a function coming at definite stages of maturity.

A word may be said in explanation of the apparent difference between this picture of the progress curves in particular abilities and the curves taken from separate sentences of the Trabue test. In the former chart the individual curves for more difficult sentences are progressively lower on the chart. In the present chart the curves representing the scores in more difficult tests mount successively higher. The difference is simply one in the mode of representation. In the earlier chart the height of the curves represented the absolute score in the different sentences and the more difficult sentences are therefore lower on the chart. On the present chart the height of the curve represents the degrees of ability indicated by the score, and it is therefore greater in the case of tests of greater difficulty.

Relation of Age Progress to Individual Differences

We have thus far been dealing with average or median progress from age to age or grade to grade. It is well known, of course, that the absolute ability at succeeding ages represented by such median or average curves stands for comparatively few individuals. The range in ability above and below such medians or averages, or the knowledge of the fact that there is such wide range is to so great an extent common property that it is not necessary to dwell upon it. A few illustrations may be given of the extent of this individual difference and we may then pass to certain more particular and less generally known aspects of the matter.

On chart 23 are shown distribution curves in ability in the Trabue scale for selected school grades. The breadth of the distribution is illustrated by the fact that there are pupils in the second grade who get as high a score as pupils in the eighth grade. There is a considerable number of fifth grade pupils who do as well as college graduates. Further illustration may be found on some of the charts from the study of Bickersteth. See, for example, the results of the tapping test, shown on chart 5. The extreme cases are represented by the short lines at the upper and lower parts of the chart. Thus we see that there was a thirteeen year old girl whose tapping rate was below median for the fifth year, and that an eight year old girl made a score equal to a fifteen year old norm. Similar wide ranges appear in the dotting test, shown in chart 6. A further illustration may be taken from results of the picture completion test, chart 10. The dotted lines on this chart include the middle half of the various age groups. We see, for example, that an individual at the upper limit of the middle half at age eight made a score equal to the median at age 10, and equal to the individual at the lower limit of the middle half at the age of 13, five years later. Such facts as this mean, of course, that there is as

Fig 23 Distribution of scores of five groups in the Sentence Completion Test (Trabue)

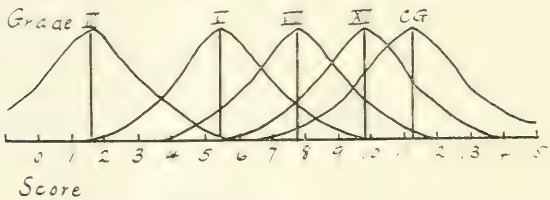
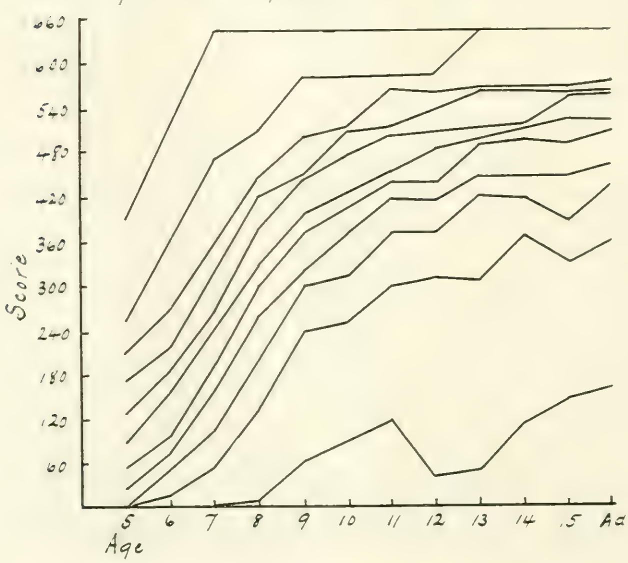


Fig. 24. Age progress curves of ten percentile groups in picture completion test (Pintner)



much overlapping in ability in tests of a general character as we have become familiar with in the case of tests of school subjects.

The question which particularly concerns us here is the bearing of these individual differences upon the form of age progress or, in other words, the relationship between progress from age to age of individuals of different degrees of ability. Does the individual at the lower part of the scale advance by the same stages as the more able individual, or is the form of his progress different? Illustrations which have already been shown suggest that the form of progress in the case of individuals of differing ability is similiar but that their progress is at different levels. This relation is more clearly shown on chart 24. We have here shown ten progress curves, each one representing a given level of ability. These curves are obtained by dividing the individuals of each age group into ten equal sub-groups and finding the scores of each of these smaller groups. It is remarkable that these curves are practically uniform in showing a break in progress at the age of 9, and another somewhat less pronounced break at the age of 11. The test from which this table was made is the picture completion test. It thus appears that whether an individual is of low or high ability he comes to the culmination in his development at practically the same age. This means that insofar as there is a break in the general curve of progress we may expect to find this break at the same point in the lives of different individuals. This is a remarkable and somewhat surprising fact of individual differences. Before adopting it with entire confidence, we should have further evidence of the same sort as that which is here represented, and also a record of the progress of individuals through a succession of years such as will be suggested later, but our present data seem to warrant the conclusion stated above.

The second problem regarding individual differences in their relation to age progress may perhaps be best discussed from the point of view of one of the well known devices in mental testing. The device is a method of expressing the relation between the ability of individual and the ability of the group. In the earlier period of the use of age scales this relationship was expressed in the form of the difference between mental age and chronological age. If the child was able to pass tests equivalent to the ability of the 10 year old child and if he was actually 12 years of age his intelligence was expressed in terms of two years' retardation. It appeared after a time in the experience of those who used the Binet scale that this method did not represent equally the retardation or advancement of children at different ages. Two years' retardation at the age of 6, for example, was found to be more serious than two years' retardation at the age of 12. In fact, it was found empirically that one year's retardation at 6 was about equivalent to two years at 12. The degree of retardation or advancement then came to be expressed in the form of a ratio of mental age to chronological age rather than in the form of the difference between mental and chronological ages.

It is obvious that this practice, and the theoretical basis for it, have bearing upon our conception of intellectual progress. The explanation which has been commonly accepted, and which is perhaps the most natural, is that the rate of progress is continually diminishing. This view is represented on Woodrow's chart already referred to (Number 21a). It may readily be seen how this form of progress would give the basis for the Intelligence Quotient. Compare, for example, the position of the normal individual represented in the middle curve and the moron represented in the next lower curve in relation to one another at the ages of 6 and 12. The six year old moron is practically at the same level of ability as the four year old normal child. The twelve year old moron, on the other hand, is at practically the same level as the eight year old normal. Thus the ratio between the mental ages of the individuals remains constant, which is what we should expect.

There is another condition, however, which would give the same constant intelligence quotient, and which would permit the hypothesis that the rate of progress is uniform rather than decreasing. That condition is illustrated in chart 21b. This assumes that the progress lines of various individuals of differing ability are straight and that they diverge in the upper ages. The consequence of this would be that the range of distribution of the individuals in successive age groups would become greater. Take again, for illustration, the comparison between normal and low grade individuals at ages of 6 and 12. The low grade individual at age 6 is equivalent in ability to the normal four year old, and the low grade individual at age 12 is equivalent to the normal eight year old. The ratio remains constant.

We thus see that the problem of the intelligence quotient involves two conditions rather than one. It depends upon both the form of progress and the spread of distribution at successive ages.

In support of the view that the rate of progress is a diminishing one, the fact that there is more overlapping in the scores of adjacent ages in the upper age levels than in the lower ones is sometimes cited. Thus, if we compare the percentage of the 5 and 6 year old pupils who pass the six year old tests in the Stanford Revision of the Binet scale we find that the average difference is 23 per cent. If, again, we compare the standing of the 10 and 12 year old children in the 12 year old tests, the difference is nearly the same, namely 26 per cent. This means that in the tests that are used in the Binet scale there is more overlapping between successive age groups in later than in earlier ages. It is clear that this increase in overlapping in the latter ages is the justification for the use of the Intelligence Quotient with the Binet Scale.

The cause of this difference in the overlapping at different ages has been assumed, as has already been said, to be due to diminution in the rate of mental development. It might equally be due to the increase in the range of distribution of the individuals of the higher ages. Our next problem then is to determine what the actual cause is, and whether this cause pertains to all tests, so as to determine whether the method of expressing intelligence by the Intelligence Quotient is universally appropriate.

With reference to the question whether age progress follows a straight line or a negatively accelerated curve, numerous progress curves which we have before us give some evidence. The general fact is that narrowly specialized functions give a curve whose rise is slower in the later ages than at some earlier age or succession of ages. On the other hand, a test of a more composite nature, which offers the opportunity of a wide range of scores, gives something nearly approaching a straight line progress. We cannot determine what the type of progress is in the Binet scale since it is not scored in absolute units, but in terms of mental age. The whole scale is standardized in age terms and therefore cannot be used directly to indicate the type of age progress. This is the reason why resort has been had to the indirect method already mentioned. The burden of evidence seems to be that a composite test like that of the Binet scale ordinarily gives straight line progress provided a sufficiently wide range of scores were possible.

We may then examine the other possible explanation of the fact that the Intelligence Quotient is valid when applied to the Binet Scale, assuming for the moment that it should give a straight line progress if scored in absolute terms. The other possible hypothesis is that increased overlapping in the upper ages is due to an increase in the range of distribution of the individuals. We may examine a number of cases in which the range of distribution has been calculated. Reference may be made to charts No. 5, 6, 8, 9, 10, 15, 19, 24. In this fairly comprehensive group of tests there does not appear to be any general tendency to increase in the range of distribution of scores in the upper ages. It seems legitimate, therefore, to eliminate this as a cause of increased overlapping in general, and in the Binet scale in particular.

The conclusion to which we are forced, if these inferences are correct, is that the Binet scale is an exception to the majority of composite tests, in that it actually does give decreasing of rate advancement in the later years. This inference is strengthened by the fact that the Yerkes scale, which applies a method of absolute scoring to some of the Binet materials, gives a decreasing rate of advance beyond the age of 12. That such a form of development, however, is to be regarded as characteristic of intellectual life in general is not to be concluded. It is due, in this case, as evidence seems to warrant, to limitations of the Binet scale in the upper ranges of difficulty.

This conclusion has bearing upon the tendency which is being manifested to apply the same method of reckoning intelligence by means of the Intelligence Quotient to scales in general, since there seems good warrant for the belief that neither a diminishing rate of advancement nor increased spread of distribution is characteristic of the scales which give sufficient range of difficulty at the upper levels, up to the period of middle adolescence at least. It is very doubtful whether the Intelligence Quotient is to be generally applied. It seems likely that it might turn out that the earlier difference between chronological and mental age may be more generally applicable.

A few supplementary topics may be discussed very briefly.

Correspondence Between Physical and Mental Development

A survey of the curves of growth in special and general functions seem to give little ground for the theory that widespread and general crises or stages in mental growth correspond to particular stages or transitions in physical development. The two prominent turning points in physical growth are second dentition, occuring at about eight years, and adolescence, beginning, roughly, at about twelve years. Particular functions show rapid growth at certain ages, and these stages in growth come at very similar ages in different children; but cases can be found of rapid development occuring at practically any age. It is simply necessary to choose an appropriate mental process, or a test of appropriate difficulty, in order to find rapid development at any point. Composite or general curves show very little tendency to break at any particular age. If there is any such tendency it is comparatively slight, and is more likely to come in the neighborhood of the year twelve than at any other time. This may be interpreted, probably, as due to some general disturbance resulting from physiological and instinctive changes rather than to any fundamental and deep-seated effect of growth changes upon intellectual capacity.

These conclusions are, of course, limited to intellectual capacity, which is the function measured by these tests. No implication at all is intended with reference to emotional attitudes, instincts or interests. This may very likely be much more closely related to stages in physical growth than are intellectual capacities.

Practical Application of the Above Conclusions

It is clear, in the first place, that the child passes through fairly clearly marked stages when his progress is measured by his achievement in narrowly defined capacities, or by tasks of definite degrees of difficulty which are examples of general functions. Thus the child's ability in color discrimination or pitch discrimination, in oral reading or adding or subtracting, and perhaps as well in certain aspects of the content subjects—history, geography, science not yet defined—culminates at specific ages. Training should obviously be adapted to these periods of culmination.

Just how this adaptation should be worked out is not quite clear. Take pitch discrimination as an example. Should training be emphasized during the period when the function is developing rapidly or should it await the time when the development of the function culminates? It is quite possible that this question must be answered differently for functions which develop relatively spontaneously, such as sensory discrimination, and those in which specific school training is a much larger factor, such as facility in the number operations. We do not know without more scientific experimentation on this point, how far down the culmination in particular school abilities may be pushed, nor do we know what the relative length of the period of training would be at different ages. In the case of the school subjects the facts of age progress are complicated by the training factor.

The results of mental tests throw some light on the urgent problem of grouping pupils in classes. If pupils are grouped according to their absolute ability children of different ages and of different stages in the development of their mental functions will be put together. This is well shown in chart 21. In presenting this chart Pintner suggests that such a grouping may be desirable. It is very questionable, however, whether it is so. Such a grouping brings together pupils who are unlike, not only in their general social attitudes and instinctive development, but also children who are at different stages in the development of particular intellectual functions. The traditional method of grouping which brings together children of about the same age, makes it necessary, on the other hand, to handle in the same class pupils of vastly different absolute ability. The difficulties of this procedure are evident to every teacher. The only satisfactory solution is to group together pupils who are alike both in stage of advancement and in absolute ability. When the numbers are too small to allow the number of groups which this arrangement involves it is necessary to meet the situation by individualizing instruction as much as possible.

Do the facts indicate that there are clearly marked crises in general intellectual development, or that there are ages at which a culmination in a sufficiently large number of particular functions occurs simultaneously, to warrant, on the basis of intellectual development alone, an administrative division of the school into units? The writer does not believe that they do. It is quite possible that such a division is justified on other grounds. When the pupils arrive at a given stage of maturity, they may be prepared for a different form of organization, such as more extensive departmentalization, or more specialization, simply because they have reached such a level of maturity as fits them for an objective task of a given difficulty or complexity. But this would not imply either having arrived at such a level suddenly or ceasing to progress beyond it. Furthermore the necessity for a new type of organization, such as is represented in the Junior High School, may arise from the acquisition of new interests and social attitudes, quite apart from intellectual ability. The introduction of a new form of organization, then, is dictated, in all probability, not so much by clearly marked stages in general intellectual development, as by the broadening out and specialization which follows the pupil's mastery of the common fundamentals of his education and by the necessity of a different type of management which results from the pupil's new social attitude.

THE PROGRESS OF SCIENCE

THE WASHINGTON MEETING OF THE NATIONAL ACADEMY OF SCIENCES

The annual meeting of the National Academy of Sciences was held at the National Museum in Washington on April 25, 26 and 27, with an attendance of about seventy of the some two hundred members and a scientific program of forty papers. The programs always maintain high scientific standards, but the different papers vary in interest, being sometimes discussions of new advances of concern to all and sometimes technical accounts of special investigations. In recent years an evening address of general interest has been arranged for the annual meeting, which was given this year by the Prince of Monaco, who came to the United States to receive the Agassiz medal conferred upon him last year by the academy

In his address, Prince Albert described his oceanographic investigations for which he built and equipped four yachts, the *Hirondelle* I and II, and the *Princess Alice* I and II. The first *Hirondelle* of 1885 was a schooner of 200 tons and the second *Hirondelle* of 1911 is a steel steamer of 1,650 tons. With these yachts he had explored the sea from the Canaries to Spitzbergen. Apparatus had been devised for sounding the depths of the ocean and the upper air. In his voyages extensive explorations had been carried out, including oceanic soundings to a depth of 20,000 feet, and drag-net catches to a depth of 18,000 feet. Prince Albert also referred briefly to his explorations of the caves of southern France and northern Spain, which have brought to light a series of mural paintings by the men of the Old Stone Age. To house the collections of his sea and land explorations he has erected two museums, one at Monaco for ocean life and one at Paris for early human remains and works of art. At the annual dinner, President Walcott in awarding the Agassiz medal, told of the desire expressed by Sir John Murray, on his visit to this country, to leave a fund to commemorate Alexander Agassiz, which took the form of the Agassiz Gold Medal for "original contributions to the science of oceanography"; and Dr. W. H. Dall, of the Smithsonian Institution, described the scientific researches of the Prince of Monaco in the investigation of ocean currents and ocean life, including voyages in his especially equipped yachts from the Azores to the Arctic. Other medals of the academy were presented as follows: To Dr. Charles D. Walcott, secretary of the Smithsonian Institution and president of the academy, the first award of the Mary Clark Thompson Medal for distinguished achievement in geology and paleontology; to Dr. P. Zeeman, of Amsterdam, Holland, the Henry Draper Gold Medal for eminence in investigations in astronomical physics; to Rear Admiral C. D. Sigsbee, U. S. N., retired, the Agassiz Gold Medal for eminence in investigations in oceanography; to Dr. Robert Ridgway, the Daniel Giraud Elliot Gold Medal for his studies of the birds of North America; to Dr. C. W. Stiles, the Gold Medal for eminence in the application of science to the public welfare, in recognition of his work on the hookworm disease.

Dr. Albert Einstein, to whom Columbia University last year awarded the Barnard medal on the recommendation of the National Academy of Sciences, was present at the meeting. He was welcomed by President Walcott in the following words:

It is a happy privilege to greet you on behalf of the National Academy

PRESIDENT HARDING, PROFESSOR AND MRS. EINSTEIN AND MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES AT THE WHITE HOUSE of Sciences. The academy rejoices to bring its tribute of homage to the brilliant and penetrating mind which has so greatly enriched the philosophy of ultimate truth. We congratulate you on the universal appreciation of your investigations which has outrun and overleaped the limitations and barriers associated with nationalities and with the times. To men everywhere your name, in association with the abstruse subject of your investigations, has become a household word. We welcome you to our scientific meetings and especially to the social hours which intervene, during which the members of the academy hope to have the pleasure of meeting and learning to know you as a friend.

In reply Professor Einstein in substance said:

It gives me great pleasure to meet here so considerable a part of the scientific investigators of America and to become personally acquainted with them. I thank you for your friendly invitation and for the very hearty reception which has been accorded me. The appreciation of my scientific work, which has just been expressed, embarrasses me. When a man after long years of searching chances upon a thought which discloses something of the beauty of this mysterious universe, he should not therefore be personally celebrated. He is already sufficiently paid by his experience of seeking and finding. In science, moreover, the work of the individual is so bound up with that of his scientific predecessors and contemporaries that it appears almost as an impersonal product of his generation. The fact of this close spiritual association leads me to the last point that I have upon my heart to say. Our perturbed time has through the action of political misfortune partly impaired that community of labor that is so important for science. I should like to express the hope that the field of activity of scientific men may be reunited and that the whole world will soon again be bound together by common work.

ELECTIONS BY THE NATIONAL ACADEMY OF SCIENCES

At the business session of the academy the president, Dr. Charles D. Walcott, presented his resignation, but at the earnest request of the academy, he consented to serve the remaining two years of his term. The resignation of the foreign secretary, Dr. George E. Hale, was accepted with regret, and with the expression of high appreciation of his able work in that office. Dr. R. A. Millikan was elected foreign secretary, to complete the unexpired term of Dr. Hale. Dr. Hale was elected a member of the council, and Dr. Raymond Pearl was reelected.

The following were elected to membership:

Frank Michler Chapman, American Museum of Natural History.

William LeRoy Emmet, General Electric Company, Schenectady, N. Y.

William Draper Harkins, University of Chicago.

Ales Hrdlicka, United States National Museum.

Arthur Edwin Kennelly, Harvard University.

William George MacCallum, Johns Hopkins University.

Dayton Clarence Miller, Case School of Applied Science.

George Abram Miller, University of Illinois.

Benjamin Lincoln Robinson, Harvard University.

Vesto Melvin Slipher, Lowell Observatory.

Lewis Buckley Stillwell, 100 Broadway, New York.

Thomas Wayland Vaughan, United States Geological Survey.

Donald Dexter Van Slyke, Rockefeller Institute.

Henry Stephens Washington, Geophysical Laboratory.

Robert Sessions Woodworth, Columbia University.

Foreign Associates

William Bateson, John Innes Horticultural Institution, Merton Park, Surrey, England.

C. Eijkman, University of Utrecht, Holland.

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MME. CURIE IN HER LABORATORY WHEN ENGAGED IN HER STUDIES OF RADIUM

MME. CURIE'S VISIT TO AMERICA

Mme. Marie Sklodowska Curie, accompanied by her two daughters, is spending five weeks in the United States. Representing France and Poland, the high intellectual achievement of women, and at the same time science which transcends the limits of nationality and of sex, she has received a welcome commensurate with her services and her distinction. In view of the widespread accounts of her work and of the honors conferred upon her, it is only necessary here to join in the universal expression of welcome and of admiration.

In her first address, which was made to the students of Vassar College, Mme. Curie expressed the value of research in pure science to the general welfare, the recognition of which will be greatly forwarded by the universal interest taken in her visit: She said:

> We must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of its direct usefulness. It must be done for itself, for the beauty of science, and then there is always the chance that a scientific discovery may become, like radium, a benefit for humanity. But science is not rich; it does not generally meet recognition before the material usefulness of it has been proved. The factories produce many grams of radium every year, but the laboratories have very small quantities. That is true of my laboratory, and that is why I am very grateful to the American women who wish me to have more radium and are giving me the opportunity to go on with my work.

SCIENTIFIC ITEMS

We record with regret the death of Henry Platt Cushing, professor of geology in Western Reserve University; of George Frederick Wright, the geologist, professor emeritus of the harmony of science and religion at Oberlin College, and of Albert Cable Hale, formerly secretary of the American Chemical Society.

At the recent meeting of the American Chemical Society at Rochester, Professor Charles F. Chandler and Dr. William H. Nichols were elected honorary members of the society.

The American Philosophical Society has elected members as follows: Herman V. Ames, Philadelphia; George David Birkhoff, Cambridge; John J. Carty, Short Hills, N. J.; Frank M. Chapman, New York; Henry Crew, Evanston, Ill.; Benjamin M. Duggar, St. Louis; John Marshall Gest, Philadelphia; Charles Homer Haskins, Cambridge; Lawrence J. Henderson, Cambridge; J. Bertram Lippincott, Philadelphia; Hideyo Noguchi, New York; Thomas B. Osborne, New Haven; Charles J. Rhodes, Philadelphia; Vesto M. Slipher, Flagstaff, Ariz.; David White, Washington.

The trustees of the estate of the late John W. Sterling, to whom the residue of the estate was left in the interest of Yale University, have established two additional Sterling professorships at Yale; one of these is to be assigned for the present to mathematics, one to physiological chemistry. Professor Ernest W. Brown, of the department of mathematics, has been assigned to one of these professorships, and Professor Lafayette B. Mendel, professor of physiological chemistry, has been assigned to the other. Four Sterling professorships have now been established, the other two being the new professorship of education recently filled by the appointment of Frank E. Spaulding, formerly superintendent of public schools in Cleveland, Ohio, and the new professorship of chemistry recently filled by the appointment of Professor John Johnston, formerly secretary of the National Research Council. Each of these professorships has an endowment of about $225,000.

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MME. CURIE AT THE TIME OF HER ARRIVAL IN THE UNITED STATES

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