MAN *and the* EARTH

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PREFACE

IN this book I have endeavored to set forth certain reasons why there should be a change in the point of view from which we commonly regard the resources of the earth. As a teacher of Geology, I have seen that there is a complete lack of understanding in our communities as to the duty we owe to our successors in their use of these limited resources. In this regard our conduct is like that of children who take the good that comes to them with no thought of the hereafter. This attitude of men as regards the future of the material values of the earth notably contrasts with that they hold to the moral and political future of their kind. A large part of their thought and endeavor goes to that group of problems, but practically none at all to the immediate questions that relate to the material foundations on which all the higher development of the life of their kind has to rest. It is with some hope of directing attention to this neglected field of inquiry that I have written this book.

It will, perhaps, be noted that the statements concerning the mineral and other material resources of the earth are not supported by statistics set forth in these pages. They thus lack the apparent authority which such a presentation would have given them. It would have been a matter of no great difficulty to have carried out my original plan and to have filled many pages with such matter. The truth is, however, that although the earth's stores of value to men can be estimated in general terms there is as yet no sufficient basis for accurate quantitative reckonings. Thus while we can clearly foresee that the store of coal is certain to be so far exhausted within two or three centuries that it will have no considerable place in the arts, we cannot estimate the amount of this fuel with anything like statistical accuracy. Thus it is that the statements in this book should be taken as the judgments of an observer who has endeavored to inform himself as to the resources of the earth of value to men, who is confident that in the general terms in which these opinions are stated they have value as guides to conduct.

Several of the chapters of this book, in all about one-fourth of the whole, have been published in the "International Quarterly." I am indebted to Mr. Richardson, the editor of that journal, for permission to repeat them substantially in the form in which they there appeared.

N. S. S.

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I

EARTH AND MAN

THE situation of man with reference to the material resources of the earth deserves more attention than has been given to it. Here and there students of the mineral deposits of certain countries, especially those of Great Britain, have computed the amounts of coal and iron within limited fields and estimated the probable time when those stores would be exhausted; but a general account of the tax that civilization makes on the fields it occupies and a forecast as to their endurance of the present and prospective demand on them is lacking. It is evident that such a fore-looking should be one of the first results of high culture. We may be sure that those who look back upon us and our deeds from the centuries to come will remark upon the manner in which we use our heritage, and theirs, as we are now doing, in the spendthrift's way, with no care for those to come. They will date the end of barbarism from the time when the generations began to feel that they rightfully had no more than a life estate in this sphere, with no right to squander the inheritance of their kind.

To see our position with reference to the resources of the earth it is well to begin by noting the fact that the lower animals, and primitive men as well, make no drain on its stores. They do not lessen the amount of soil or take from the minerals of the under-earth: in a small way they enrich it by their simple lives, for their forms are contributed to that store of chemically organized matter which serves the needs of those that come after them. With the first step upward, however, and ever in increasing measure as he mounts toward civilization, man becomes a spoiler. As soon as he attains the grade of a hunter he begins to disturb the balance of the life about him and in time he attains such success in the art that he exterminates the larger, and therefore the rarer, beasts. Thus when our *genus homo* comes into view, elephants of various species existed in considerable numbers in all the continents except Australia. Its first large accomplishment appears to have consisted in the extermination of these noble beasts in the Americas, in Europe, and in northern Asia. There is no historic record of this work, but the disappearance of the elephants can be well explained only by the supposition that they went down before the assault of vigorous men, as has been the case with many other species of large land animals.

So long as men remained in the estate of the hunter the damage they could do was limited to the destruction of the larger beasts and the birds, such as the moa, that could not fly. Prolific species, even of considerable size, such as the bisons, if they were nimble and combative, seem to have been able to hold the field against the attacks of primitive hunters. While in this station the tribes of men are never very numerous, for their wars, famines, and sorceries prevent their increase, which, under the most favorable conditions, is never rapid among savages. As soon, however, as stone implements begin to be replaced by those of metal, man begins to draw upon the limited stores of the under-earth, and with each advance in his arts the demand becomes the greater. In the first centuries of the iron age the requisition was much less than a pound each year for each person. Four centuries ago it probably did not exceed, even in the most civilized countries, ten pounds per capita each year. It appears to have been at something like that rate when the English colonies were founded in North Amerca. At the present time, in the United States, it is at the average rate of about five hundred pounds per annum for every man, woman, and child in the land, and the demand is increasing with startling rapidity. It seems eminently probable that before the end of the present century, unless checked by a great advancement of cost, it will require a ton of iron each year to meet the progressive desires of this insatiable man.

Of the other long-used metals and other earth resources the increase in consumption is, with slight exceptions, as notable as in the case of iron; within a generation, mainly because of the use of the metal in electrical work, the need of copper has augmented even more rapidly than that of iron and the gain in the requirements is going on with exceeding speed. So, too, the demand for the other base metals long in use, zinc and tin, has been in nowise lessened by the more extended use of iron and copper; they are ever finding new places in the arts and a larger demand in the markets. As regards the so-called noble metals, silver and gold, the demand from the beginning has not been distinctly related to use, but to unlimited desire. Men have always wrested all they could of them from the earth or from each other, with little reference to the profit they won in the process. There has been of late something like a halt in the production of silver, except when it comes as a by-product, because it has generally been abandoned as a standard of value; but taken together the production of these precious metals has in modern times increased about as rapidly as that of iron. It is likely, however, that they will in time become of no economic importance.

As regards the earth's resources in the way of fuel — coal, oil, wood, petroleum, and peat — the history of the modern increase in demand is as evident and menacing as in the case of the metals. When the American English colonies were founded, coal had hardly begun to come into use in any country. It is doubtful if the output of the world amounted at that time to one hundred thousand tons, possibly to not more per capita of the folk in Europe than a pound, or about the same as iron at that late period in the so-called "iron age." At the present time the total production of Europe and North America amounts to an average of at least two tons per each unit of the population, and the increase goes on at a high ratio. Petroleum, practically unknown to the Occidental peoples until about half a century ago, has, with wonderful rapidity, become a necessity to all civilized and many barbaric peoples; the increase in the rate of consumption is swifter than that of any other earth product. Timber and peat, the primitive resources for light and heat, are the only earth products for which the demand has not greatly extended in modern times; it appears, indeed, to have shrunk in most civilized countries with the cheapening and diffusion of coal, due to the lessened cost of mining and of transportation.

The increase in the tax of the earth's resources is seen also in the very great number of substances which were unknown to the ancients, or disregarded by them, but which now find a large place in our arts. A comparison of the demands of three centuries ago with those of our day is interesting. In, say, 1600, when men were very much alive to the question of what they could gain, there were only about twenty substances, other than precious stones, for which they looked to the underground realm. Clays for the potter and bricklayer, whetstones and millstones, iron, copper, tin, gold, silver, lead, sand for glass, mica, coal, peat, salt, and mercury make up all the important elements of this list. At the present time, we more or less seriously depend on what is below the ground for several hundred substances or their immediate derivatives which find a place in our arts. Petroleum alone has afforded the basis of far more earth products than were in use at the time of the discovery of America. It gives us a large number of dyes and a host of medicines. It is indeed likely that the products immediately derived from the mineral oils exceed all those obtained from the earth at the time of Columbus — and each year brings additions to the demand.

The advance in needs of dynamic power, in modern times, has been even greater than in ponderable things. Even two centuries ago, the energy available for man's work was mainly limited to that obtained from domesticated animals. The wind served in a small measure through the sails of ships and of windmills, and there were water-wheels, but the average amount of energy at his service was certainly less than one horse-power per capita. At the present time it may safely be reckoned that in the United States and in European countries on a similar economic basis, the average amount is at least ten times as great, and the present rate of increase quite as high as in the case of mineral resources. It is true, that, so far as water is concerned, this increase in the demand for energy in the arts does not come as a tax on the store of the under-earth, as it is obtained through solar energy which would otherwise be dissipated in space. But the use of falling water as a source of power, though rapidly increasing, does not keep pace with that of coal, which is obtained from a store which is in process of rapid exhaustion, one that cannot be relied on for more than a few hundred years to come: — if the world keeps the rate of consumption with which it enters the twentieth century it will be exhausted before the twenty-third.

The problem of the underground store of wealth, though as we shall see on more detailed examination it is very serious, is not so immediate or menacing as that afforded by the question of food supply. As far as man is concerned, the supply has to come from two sources — the tilled soil and the waters, especially the sea. While it is possible by a widely extended system of fish culture greatly to increase the amount of food derived from the waters, experience does not warrant the supposition that the supply from this source can be manifolded. The life of the oceans, as of the primeval lands, is already packed to the utmost point. We cannot hope to double the number of edible fishes without reducing the number of their enemies or of the other creatures which compete with them for subsistence. Neither of these things can we at present see the way to do. It is to the soil, to the tilled soil alone, that we are to look for the body of the food that is to feed man for all the time he abides on this sphere.

In the life below man the relation of the creatures to the soil had been beautifully adjusted. The plants, by associated action, formed on all the land surfaces, except in very arid regions, a mat of roots and stems which served to defend the slowly decaying rock against the attack of the rain-water. This adjustment is so perfect that in a country bearing its primeval vegetation the eroding of the soil is essentially limited to what is brought about by the dissolving action of the water which creeps through the earth and there takes the substances of the rocks into solution; very little goes away, in suspension, in the form of mud. In these conditions the slowly decaying rock passes very gradually to the sea; for a long time it bides in the soil layer where, with the advance in its decomposition, it affords the mineral substances needed by the plants that protect it. Thus until man disturbs the conditions of forest and prairie the soils tend to become deep and rich, affording the best possible sustenance to the plants which feed in them. In their normal state they represent the preserved waste of hundreds, or it may be, thousands of feet of rocks which have gradually worn down by being dissolved in the rain-water that creeps through them.

As soon as agriculture begins, the ancient order of the soils is subverted. In order to give his domesticated plants a chance to grow, the soil-tiller has to break up the ancient protective mantle of plants, which through ages of natural selection became adjusted to their task, and to expose the ground to the destructive action of the rain. How great this is may be judged by inspecting any newly ploughed field after a heavy rain. If the surface has been smoothed by the roller, we may note that where a potsherd or a flat pebble has protected the soil it rests on top of a little column of earth, the surrounding material having been washed away to the streams where it flows onward to the sea. A single heavy rainstorm may lower the surface of a tilled field to the amount of an inch, a greater waste than would, on the average, be brought about in natural conditions in four or five centuries. The result is that in any valley in which the soils are subjected to an ordinary destructive tillage the deportation of the material goes on far more rapidly than their restoration by the decay of the underlying rocks. Except for the alluvial plains whereupon the flood waters lay down the waste of fields of the upper country, nearly all parts of the arable lands which have been long subjected to the plough are thinned so that they retain only a part of their original food-yielding capacity. Moreover, the process of cropping takes away the soluble minerals more rapidly than they are prepared, so that there is a double waste in body and in the chemical materials needed by the food-giving plants.

There is no question that the wasting of soils under usual tillage conditions constitutes a very menacing evil. Whoever will go, with his eyes open to the matter, about the lands bordering on the Mediterranean, will see almost everywhere the result of this process. Besides the general pauperizing of the soils, he will find great areas where the fields have prevailingly steep slopes from which the rains have stripped away the coating down to the bed-rock. In Italy, Greece, and Spain, this damage has gone so far that the food-producing capacity of those countries has been greatly reduced since they were first subjected to general tillage. There is no basis for an accurate reckoning, but it seems likely from several local estimates that the average loss of tillage value of the region about the Mediterranean exceeds one-third of what it was originally. In sundry parts of the United States, especially in the hilly country of Virginia and Kentucky, the depth and fertility of the soil has in about one hundred and fifty years been shorn away in like great measure. Except in a few regions, as in England and Belgium, where the declivities are prevailingly gentle, it may be said that the tilled land of the world exhibits a steadfast reduction in those features which give it value to man. Even when the substance of the soil remains in unimpaired thickness, as in the so-called prairie lands of the Mississippi valley, the progressive decrease on the average returns to cropping shows that the impoverishment is steadfastly going on.

In considering the struggle which men have to make in the time to come in order to maintain the food-giving value of the earth, it is well to keep in mind the fact that the battle is with one of the inevitables — with gravitation, which urges everything ponderable down into the sea. What we know as soil is rock material on its way to the deep, but considerably restrained in its going by the action of the plants which form a mat upon it. All the materials which go into solution naturally pass in that state on the same way; thus whatever we do, we cannot expect to effect anything more than a retardation of the process to that point where the decay of the bed-rocks will effectively restrain the wasting process, so that the loss may be made good. It is indeed not desirable to arrest this passage of earth material to the sea. So far as that passage is here and there effected by natural processes we find that, in time, the soil loses its fertility because the necessary mineral constituents are exhausted. Thus in the case of the coal-beds, the swamp-bottoms in which the plants grew did not have their materials renewed by the decay of the underlying rock and so were in time exhausted by the drain upon them and became too unfertile to maintain vegetation. The preservation of the food-giving value of the soil as used by civilized man depends on the efficiency of the means by which he keeps the passage of the soil to the sea at a rate no greater than that at which it is restored by the decay of the materials on which it rests.

Some of those who have essayed a forecast of the future of man have felt that the prospect was shadowed by a doubt as to his permanence. Seeing, as we do, that the life of this earth is characteristically temporary, the species of any geological period rarely enduring to the next, it is a natural conclusion that our own kind will share the fate of others, and, in a geological sense of the word, soon pass away. Closer attention to the matter leads us to believe that the *genus homo* is one of those exceptional groups, of which there are many, which have a peculiar capacity for withstanding those influences which bring about the death of species. There are a number of such forms in most of the classes of animals, creatures which have existed, it may be, from palæozoic times, perhaps for fifty or more million years, so little changed that the earliest of them seem as nearly akin to the latest as are the diverse species of mankind. Man has been upon the earth certainly for two geological periods. He withstood the colossal accident of the last glacial epoch. He is by his intellectual quality exempted from most of the agents that destroy organic groups. So we may fairly reckon that he is not to pass from the earth in all foreseeable time, but is to master it and himself for ages of far-reaching endeavor. The limits set to him are not those set by the death of his species, but by the endurance of the earth to the demands his progressive desires make upon it.

We have already glanced at certain of these limitations in the future development of man in the extent of his present and increasing demands on the resources of the soil and the under-earth; before going further, let us consider what is the probable number of men that will have to be provided for, say, within three centuries to come — a future as remote as the past of our American history. At the present time the human population of the earth is somewhat variously estimated at from thirteen to sixteen hundred millions, for the reason that the reckoning of the number in China and Africa is uncertain. It is most likely near the higher of those figures. The gain in three centuries has probably been at an average rate of near a million a year, and, at the present time, is very much greater. So far as we can see, this increase has been altogether among the peoples who have attained to the condition of civilization, with the consequent partial exemption from pestilences and the evils of chronic war.

As the control of modern conditions extends, either by the spontaneous development in the retarded peoples, as in China, or by the conqueror's hand, as in India and Egypt, we may reckon that the rate of this growth in population will increase. There is indeed danger that with Africa and China modernized, the rate will, by the end of the present century, be many times as great as it is at present. In a word, we may estimate that in a historic sense very soon the world will be near its food-producing limit. As to the numbers of our *genus* who will be demanding subsistence at the time when the ultimate of the earth's sustaining capacity is attained, no very precise determination can be made, yet a fair general idea of it may be had by considering the existing conditions in certain of the best-known regions. Thus in Europe it is evident that an increase of one-half in the existing total cannot be accomplished without a great and practically inconceivable reduction in the standards of life of the people. The evidence of diminished birth-rate, as in France, leads to the conclusion that an unusual decrease in that rate will occur before there is any considerable abasement in the conditions of the folk.

In North America, the soils of the first order, those easily appropriated and affording large returns to tillage, have already been generally occupied. Further subjugation will have to be gained either from forested areas of the second and third class, where the soil will give relatively low returns to labor unless it is brought up to more than its natural fertility by a care which we are at present indisposed to give lean fields. Thus developed there are land reserves on this continent now in upland forests which may afford subsistence to twice or thrice the existing population. In this reckoning no account is taken of the large unoccupied areas in northern Canada, which, it is claimed, are well suited for permanent tillage. There is as yet doubt whether this district, owing to the limited range of the crops which can be grown in the very short summer, and the tax of the long-continued winters, will prove well fitted for the continuous uses of civilized man. Should they be found thus serviceable, we may add enough to the store of immediately available land to subsist from twenty to fifty million people.

In South America, the unoccupied lands which can be brought to use without engineering work appear to be sufficiently extensive to maintain in the tropical and sub-tropical conditions of that continent a considerably greater population than can be supported by the soil of North America. It is not unlikely that these tropical available lands could be made to support four of five hundred million folk at a standard of living quite as high as that now attained in India or China. By far the greater part of this population will dwell within the tropics, a region evidently unfitted for the development of what we esteem as the higher kind of man, but he will there have a fair share of the earth.

In Africa the conditions are very like those of South America. There is a very large area of tropical land which is scantily occupied by peoples of the lower sort. These folk, however, differ from the aboriginal peoples of the American continents in that they are fitted by nature for agricultural labor and can readily be made to work in an efficient way. Under the control of the masterful European states Africa is likely to afford room for a population of not less than five hundred million, of whom the greater part will necessarily be of the negro and Arab stocks, and this without reckoning the lands which may be won by engineering work from the deserts or the morasses.

In Australia and the islands of the Pacific realm, there is relatively little unused land which can be turned to account; in the humid tropical areas the population is generally well adjusted to the resources, and in the arid the opportunities for extended irrigation are not very great. It seems questionable whether room can be made in these lands for more than an additional fifty million folk.

There remains to be considered the great continent of Asia. In this ample realm, we find the population of all its fields south of Siberia in general pressed up against the limits of the soil resources. There is some room for gain in the region of the Twin Rivers and the Kahnates, but it is doubtful if without very extensive engineering work place can be made for another hundred million folk in the valleys which drain to the Pacific and the Indian oceans. The Arctic slope of the continent is the only field where there is an extensive unoccupied area which has conditions that promise to support a large additional population. The value of this district for the uses of civilized men cannot well be estimated with the information concerning it which is now in hand: it is subjected to the same, or even more, doubt than that of the country of northern Canada. The greater part of it lies, like much of the land in sub-arctic Canada, in the region of permanently frozen sub-soil, only the upper foot or two sharing in the brief summer, so that the soil cannot be watered from below. That much of it is fertile and will for a time produce crops of small grain, roots, and forage is evident; but it all is afflicted with a long and very rigorous winter when water for man and beast has to be obtained by melting ice or snow, and the consumption of the stored food is very great. Moreover, there seems to be an insufficient supply of coal to serve even for domestic purposes, and in many parts of the country the resources from the natural timber are insufficient to meet such needs. Except where peat occurs, it is likely that the people will have to resort to the practice of burning the dung of their domesticated animals, and we know from the experience of western Russia how fatally and swiftly the fields are exhausted by this practice. Those only who are very optimistic will be disposed to reckon on an increase in the population of Siberia that will add one hundred million to the total of the Asiatic continent.

The foregoing glance at the conditions of the lands which are now open to the increase in population which has to be expected within two or three centuries may be taken approximately to show that, at most, there is enough to admit of something like a doubling of the present numbers; and that without any considerable engineering work in lands not now available for tillage a total of somewhere about four thousand million can be supported in tolerable comfort. The question arises as to the additional food-giving capacity of the earth which may be won by means of engineering and other scientific work, as in irrigating arid fields or draining those which are excessively watered, or by improving the methods of fertilizing soils now in use.

It is impossible, with the present lack of information, to determine accurately how extensive is the field which may be won to tillage by the work of the engineers: this winning from the excessively arid lands will be done by irrigation, and from the morasses, the fresh-water swamps, and the marine marshes by drainage. In Europe the larger part of the land thus winnable has long been brought to use; it is not likely that an increase of ten per cent. in the food-giving capacity of its soils can, by any such means, be realized. In the less-developed continents the gain is likely to be much greater. Thus within the limits of the United States the writer has estimated that the fields improvable by drainage, in the manner already applied in Holland, would add to the tillable ground of the country an area somewhat exceeding one hundred thousand square miles in extent, with a food-giving value about four times that of the State of Illinois, wherein the soil would be far more enduring than that of any upland district. The complementary process, that of irrigation, promises to afford yet larger gains. Including the area of the South and the Middle West where the system would greatly increase the food-giving value of the soil we may reckon the possible enlargement from it would be even greater than that afforded by a complete drainage of the morasses. Taking the continent of North America as a whole, it seems probable that the existing capacity of its soils for feeding men may be doubled by the work of the engineer, through his skill in watering and unwatering its deserts and morasses.

On the other continents the opportunities for winning good land from arid deserts are probably less than in North America, yet the possible gain is such that we may reckon that when his great work is done, the engineer will have recovered land enough to feed the existing population of the earth. In Africa there is the magnificent problem of the Nile, a river which wastes to the sea in its annual floods water enough to fertilize tenfold the desert that it now makes fertile. There is the valley of the Twin Rivers of Asia, where a realm once fertile has become a waste by the loss of its irrigation works. There are in all the great lands vast areas of lakes, swamps, and marshes awaiting the skilful labor which has won Holland from the sea. The largest opportunity of profit is in such brave combats with the incomplete work of Nature.

The problem of how we are to maintain the fertility of the soil when the earth is taxed by a population thrice as great as it now supports, depends upon our ability to restrain the excessive rapidity with which tilled soils pass to the sea, and our ability to restore to the land the materials which the cultivated plants remove. We shall find that both these needs are fairly to be met by the resources of modern science; the first by a proper control of the movements of water from where it falls upon the land to its station in the ocean, and the second by a resort to the ocean and the under-earth for the materials to renew the fertility of the ground when it is exhausted by cropping. There is much to do in order to make the earth fit to bear the life to come, but there is every reason to believe that our science is ready for the task and that within two centuries of peaceful endeavor we may prepare the place for it. Some of the steps of this preparation will be considered in the following chapters of this book.

II

THE FUTURE OF POWER

ALL the progressive desires which characterize modern civilization call for an ever-increasing share of the energy to be applied to the arts; from an economic point of view it is this feature which most clearly separates the culture of our time from that of the ancients. The Greek of the best estate had only the strength of a few domesticated animals and of slaves to help him to his large share in the world's goods. The pauper of our time is incidentally, but most effectively, helped by a retinue of mechanical servants, who give him the profit of perhaps a hundred fold as much energy as ever contributed to the welfare of an Athenian gentleman. This change has come about in very modern times, and is now in the prowess of its development; it is evidently to increase to the point when all the sources of power will be utilized to somewhere near their possible capacity, and the individual or the state of the century to come will have success in proportion to the dynamic energy that may be controlled. Therefore the first question in our effort to forecast the conditions of men concerns the possibilities of increasing the supply of power applicable to the arts.

A glance at the facts shows us that all the dynamic energy at the command of men comes more or less directly from the sun. To the idealist's advice, "Hitch your wagon to a star," the practical man might well retort that all our wagons are necessarily tackled to the particular star that does the work of this sphere. All that work, from the trifling share of brain and pen that writes these words to that which sways the winds and sends the waters in their streams, is celestial energy, practically all derived from the sun, energy which is held upon the earth by the air and set upon the diverse work we behold. We see this the more clearly upon the contrasted state of the moon, where for geologic ages there has been no work done because there is no air to entrap the heat and turn it to the varied tasks which it performs upon the earth.

The energy that is at work upon the surface of the earth, except the trifle from its depths derived mostly from volcanic outbreaks, comes immediately from the sun. The greater part of it is speedily sent forth again into the spaces. Only a little is for a time detained in the water that it has lifted into the air, or upon the lands, or mayhap for years in the bodies of animals and plants, or, exceptionally, for geologic ages, in the incompletely decayed remains of organic life which are buried in strata. The sources of energy available for mechanical power have to be from one or another of these stores derived from the sun. The most immediate of them, that which is the nearest to the source of power, is the wind; next in order the water, which has been lifted by solar heat to high levels on the land, and is on its gravitational journey back to the seas; then the waves of the sea, a possible, but in an economic sense improbable, source of power. Then again there is the timber of our forests, and, the last in this series, the buried organic remains, which give us access to ancient solar energy in the form of coal, mineral oils, and gases. Outside of this field of power derived from the sun, there is another source of some importance to be found in the tides, due mainly to the gravitative attraction of the moon, which promises in time to be locally serviceable to man. We shall now glance at these several resources with a view to estimating their prospective utility.

The largest share of solar energy which we have a chance to capture and turn to account in our arts is that embodied in the winds. There are as yet insufficient data for computing the quantity of this power that can possibly be won for our service, but it certainly amounts to very many times as much as is now won from all the other sources now utilized by man. This source of power was the first to be used — at the outset in the sails of boats — but it has as yet afforded little help in the arts. The winds have ground much corn and pumped a deal of water, but, except in sails, they have not helped us much. The difficulty arises from the great variations in the speed of the air currents and the long periods in which the movement is so slight that they afford no effective power whatever, together with other periods when their speed is likely to be destructive to any machinery large enough to win much value in any state of their motion. It seems likely, however, that the method of the storage battery, with the cheapening of its cost and the increase of its efficiency, which may reasonably be expected in the near future, will enable us so to husband the energy afforded by windmills that they will serve for constant uses. It may also be possible to find a more direct way of utilizing this source of power by using the variable work of windmills in pumping water to a height whence it can be made to give a constant supply to water engines. As it is, this oldest servant of man is still among his useful helpers; the sails of mills and ships are together more numerous than any other machines by which he hitches his economic wagons to the stars, and in time they are likely to yield more power than all other devices.

The next largest source of solar energy is that obtained from falling water. Until less than a generation ago water-power had a very limited application, for the reason that it had to be utilized at or very near the point where it was obtained — and it could be carried by wire-rope belts for a distance of not more than a few hundred feet. With the method of turning the energy of falling water into electricity and thence back to dynamic power it is now possible to send that force a hundred miles from the point where it is obtained and with the improvements that are constantly making, it seems likely that the distance to which it may be conveyed will in time become practically unlimited. In no other case has the use of any source of power been so speedily extended. A glance at the rapidly developing situation will show us that this source of energy promises to effect very great changes in the seats of industries and consequently of population.

It is evident that the amount of water-power available in a country depends on three factors: the amount of rain, or melting snow; the average height above the sea of the field on which it falls; and the extent to which the flow of water is or can be evenly distributed throughout the year. This is a complex equation, one not easily solved, yet in a rough way it enables us to determine much as to the future of accessible power and thereby forecast the success of communities, so far as that success depends thereon. Thus in Europe we see that certain streams radiating from the Alps, such as the tributaries of the Rhone, the Po, and the Rhine, which are fed to a great extent by melting snows and have great natural reservoirs in the lakes through which they flow, are well placed in relation to this source of energy. So, too, with the streams of Sweden and Norway, which come down rapidly from a great height and are likewise, for various reasons, of fairly uniform discharge. Thus when coal becomes impossibly dear because of the approaching exhaustion of the limited store, as will surely be the case within three centuries, these favored regions will be the seats of manufacturing, which will pass from its present stations where it depends on fuel.

On the whole North America is, as regards its possible water-powers, more favorably placed than any other continent. The amount of falling water is less than in South America, perhaps less than in Africa, but the distribution is better for the needs of man. In all the glaciated district which occupies near one-half of its surface, natural storage is provided by the porous water-holding nature of the drift deposits and by the lakes that by the tens of thousands occupy these glaciated fields. This glaciated district of North America is, indeed, the richest part of the world in streams fitted to drive wheels. We seek in vain elsewhere for any region of this kind comparable to the area on the eastern side of the continent between the Arctic circle and the Ohio and westward to the centre of the great continental valley, from the upper Mississippi and the Ohio to the Mackenzie River. The southern Appalachians also afford a field abounding in streams fitted to be sources of power, deficient only in storage, which is partly supplied by the forests and by the deep coating of decayed rock which, in a measure, acts, as does the drift, in the manner of a sponge to detain the water on its way to the sea. In the plain region of the Middle West, we have a broad field where the streams, because of their slight fall, can afford little help to man's arts. But again in the eastern face of the Cordilleras, from the Arkansas River northward to the Arctic circle, the rivers, though of scanty flow, promise great value in the way of power; and fed as they are by melting snows, their discharge, at least in their lower reaches, is fairly steadfast. In the central region of the Cordilleras there is as far north as the Canada line a wide belt of country where the rainfall is very small in amount. We find little power value in the streams, but on the western slope facing the Pacific Ocean, and increasingly from California northward to Alaska, there is, for its width, a noble body of power awaiting the call to use. It is this store combined with the mineral resources of the Cordilleran field, together with the quality of its people, that is to give the States of this region their dominance in the Pacific realm.

As to the water-power of the other continents, it may be said in general that while it is certain to be a vast advantage to many wide fields, it is rather narrowly limited in value by the lack of possibilities of storage, combined with a bad seasonal distribution. Of the regions which promise much, we may note the eastern face of the Andes for the greater part of its length, the high country of eastern Brazil, and, with some limitations, all the country from the La Plata northward; in Africa, certainly the valley of the upper Nile, that of the Zambesi, and, on a basis of imperfect knowledge, the great valleys of the Congo and of the Niger; as a whole this continent probably ranks next after North America in its water-power sources. In Australia the prevailing aridity of the region makes the value of this resource relatively small, yet in ratio to the food-yielding resources of the land it is considerable. The greater islands of the Malayan archipelago are, because of their prevailing high rainfall, fairly well placed for power. So, too, are the isles of the eastern coast of Asia; the Philippines are, for narrow lands, fairly rich in opportunities for water mills; in Asia there is the promise to the future of its peoples of a vast profit from this source of help.

On the mainland of Asia the most important district for water-power is to be found in the southern versant of the Himalayas, where streams of fair volume and permanence descend from a great average height to the lower open country. This condition continues around the eastern side of the central Asiatic mountain systems, affording in the interior of China similar opportunities to those of India. On the Arctic slope of the continent the rivers, though of less flow than those discharging to the South and East, will afford a large amount of power. Below the headwaters in the Arctic slope of Siberia the rivers descend gently, and though of large volume, they are not likely to be of great value to the arts. As a whole, the share of available water-power in Asia, in proportion to its area or the food-giving capacity of its soils, is probably less than in any other of the continents except Australia. Yet even in Australia there is the promise of a vast profit from this source of help.

Considered as a whole, the rivers of the earth promise, with the aid of the engineer, to afford far more dynamic help to the arts than all that now serves them. Moreover, this help will be from sources of continuous supply and not like that from coal, in the way of speedy exhaustion. And further, the full utilization of the streams, as sources of power, because it involves the process of holding back the flood-waters, will in a considerable measure aid in diminishing the speed with which the soil passes to the sea, while the water, after it has been used to turn the wheels, may, to a great extent, be made to serve the purposes of irrigation. The increase in the use of this source of energy will probably not continue to be very rapid until the supply of the fossil fuel aproaches exhaustion; from that time on it will necessarily be speedy, until all this group of resources is completely applied to the arts.

The other source of power originating beyond the earth is the tide produced mainly by the moon's attraction. This movement of the sea probably not exceeding in the central parts of the oceans a rise and fall of more than a foot or so, is in many places accumulated on the shores to a great height. There are many thousand miles of coast line where the average swing of the waters amounts to ten feet or more, and along hundreds of miles of shore it exceeds twice that amount. The total energy involved in the tidal movement is so large that if all of it could be turned to the uses of man there would be a supply ample for the needs of all the hosts which the soil could sustain with the best husbanding. Unfortunately, we can conceive of no convenient means whereby this power which the sun and moon expend upon the earth can in any great measure be applied to industries. The tide-mill, which appears to have been designed in England some centuries ago and to have been brought to this country in the colonial period, is a simple device consisting of a dam with wheels so arranged that they are impelled by the water as it enters or leaves the embayed space. The energy thus attained may be very considerable; it would not be costly at many places to win a maximum of several thousand horse-power. There is, however, the serious difficulty that the energy thus obtained is irregularly distributed, the maximum arising twice each day at mid-tide and falling to nothing four times each day at the time of low and high tide. There are yet other irregularities in the difference between spring and neap tides, as well as the daily alteration by about an hour of the maxima and minima of the risings. The result is that there have never been more than a few hundred tide-mills at any one time in operation, and these have been limited to such uses as grinding corn. With the development of steam-power, they have gradually passed out of service, so that it is doubtful if there be a score of them now in operation in North America. It is, however, possible that with the development of an efficient storage-battery system the powers obtainable from the tides will be greatly increased. In the time, but a few centuries remote from the present, when the need of replacing the power derived from fuel is great, the tide is pretty sure to afford a most valuable resource to all the countries about the northern parts of the Atlantic and Pacific oceans where the range is great and the sites for mills numerous.

It has often been suggested that power could be obtained from the motion of the sea waves. There is no question but that the energy involved in the surges is great, for in an ordinary storm the pressure of their stroke on the cliffs may amount to as much as ten thousand pounds to the square foot, or about that in an ordinary low-pressure boiler; but the exceedingly intermittent and variable nature of this action, together with the difficulties of maintaining any machinery which can render it serviceable for the arts, makes it unlikely that it will be utilized save in the last extremity of need.

There is yet another way by which we may find access to solar energy, one which is even more direct than any of those already described: we may reflect those rays by mirrors or refract them by lenses and thereby concentrate their heat. There is an ancient story — surely no more than myth — that Archimedes contrived to do this so effectively in the siege of Syracuse that he set fire to ships. In an extremity for lack of power there is no doubt that we could with some profit resort to this system. In those parts of the earth, in low latitudes, where the sky is rarely clouded, about a hundred square feet of mirrors would for some hours each day afford energy equal to a horse-power, but, as was just said, it would be a state of extreme and unforeseeable need that would bring this method into any considerable use.

This is true also of a project, once much discussed, of utilizing the central heat of the earth. It exists in such ample stores that if we could draw upon it, there would be power for all the conceivable needs of man for a million of years to come. But there is no conceivable way in which it could be brought to general use. Where there are hot springs of large volume it would be possible to turn them to service, but such opportunities are so exceptional as to be of no importance. It has also been suggested that it might be possible to bore down into the earth to a sufficient depth to heat water much above the boiling point; but, save near volcanic centres and certain other very exceptional places, this scheme is quite impracticable. The average increase in temperature is only about 100 deg. Fahr. for the mile of descent, and at less than three miles down the pressure would speedily close the pipe. Thus we see that the earth's vast inner store of energy cannot be of avail.

We come now to the energy derived from the sun, which can be won to use by burning the carbon which is locked up in organic matter; in the timber of the forests; in recent peats, or their equivalents; in beds of coal, and in those curious carbonaceous products of animal remains, petroleum, and burnable rock gases. As for the wood of the forests, it is everywhere an ephemeral source of supply. When the earth is as fully peopled as it is likely to be in the twenty-third century of our era, there will be no forests save those that may be preserved in order to insure the flow of streams. At best, and with the utmost economy, it requires about an acre of woodland to meet the needs of each civilized person in high latitudes — as much as is required for his food. With the crowding which now exists in most developed countries, this resource can have no value as a source of power.

The most recently formed of the fossil fuels, the peat deposits, which, in practically all cases, have been formed since the last glacial period, are of much more value as a source of power than is commonly reckoned. They occur in all the humid regions beyond the tropics; and, in general, are best developed in the glaciated districts. Data to determine their extent are lacking, but from certain observations in New England, it seems likely that the available widely scattered deposits of that district may be reckoned as having a total area of at least five hundred square miles, with an average depth of ten feet, the deposit having about the heat-giving value of ordinary coal contained in a bed of that area and rather less than half that thickness. Northward, on this continent, to the Arctic circle, the beds of this material are found in even larger proportion to the area. Probably the one-hundredth of the surface of the continent is similarly conditioned. The aggregate of this store is vast, amounting in volume to perhaps as much as all the coal beds, and in heat-giving value to perhaps one-half of those deposits. There are certain serious difficulties connected with the utilization of peat which have greatly limited its value in the arts and for a century or more have diminished its use as a fuel. When it is taken from the bogs it holds about half its weight of water, which is only slowly and partly dried away, and when the material is dried it is very bulky in proportion to its heat-giving power. A host of processes have been invented for drying and compressing the crude peat, but experience has shown that in the United States this cannot profitably be undertaken at the present price of coal. There is, however, the possibility that in many places the substance can be used without other treatment than drying for the manufacture of fuel gas, and this gas can then be burned for making electrical power. In such a way this store of ancient solar energy may become immediately available in the arts. In any event it remains a reserve on which the people of the future may draw in the ever-advancing need of power.

We turn now to the deeply buried deposits of carbon, coal, petroleum, and rock gas which have been the basis of the economic side of our modern civilization. It is well to begin this part of our inquiry by noting that the formation of these stores of fuel depends on the action of organic creatures in taking carbon from the carbonic acid gas of the atmosphere and storing it in the earth. This task is effected by the plants, which each day take some million tons of carbon from the air to shape it in their forms. The greater part of this element goes back to the atmosphere on the death of the creatures it has served; some part of it is taken into the bodies of animals who are not able to obtain carbon directly from the inorganic realm. This, too, normally passes straightway back to the air by the processes of decay. In some part, however, the remains of plants and animals are deposited under water in such conditions that the carbon they hold is not quickly combined with oxygen and thus delivered into the air, but stays until it forms a bed of humus or peat and is buried in the sea bottom or in the beds of lakes beneath deposits of clay, sand, or limestone; then, if it be the remains of plants, it may change to coal, and if it be animal waste, to petroleum or rock gas.

The passage from the state of peat to that of coal is gradual: with the escape of a certain part of the more volatile compounds of carbon in the form of gases and with the increasing pressure of the overlying rocks and the added heat, we have at first lignites; then brown coal; then in time bituminous; later, anthracite coal, and finally, at the extreme point of the series, graphite — an essentially unburnable form of carbon. In these changes of vegetable matter there is no considerable production of oil, and the gases which are formed do not seem to be preserved in the rocks. In the decomposition of the animal remains buried in strata there is no coaly substance produced, but if the conditions be favorable the free carbon of their bodies is combined with hydrogen, forming hydrocarbons in the form of the varied petroleum group and the commonest and most useful natural gas. This burial of carbon in the form of plant and animal remains in the burnable form suited to make coal, oil, or gas is exceptional; by far the greater part that enters the earth finds its way there in union with lime, magnesia, or other elements under conditions which do not admit of its being used as fuel. Probably of each ton of inhumed carbon so much as the hundredth part becomes a possible source of heat for the uses of man.

The amount of fossil fuel is not only small but evanescent. The beds of coal are always formed on the land; they have rarely been buried to the depth of more than a few thousand feet and are generally in process of rapid destruction by erosion. Oil and gas, being from the remains of marine animals, are usually found in rocks that obtain deeper burial and that occur more widely, but these substances are easily driven out by heat, and when the beds containing them are even moderately heated they are sent forth to the air. Moreover, the pressure of the gases on the rocks is constantly so great that they are always eager to escape from their prison, and are likely to expel the oil with which they are mingled. Thus it comes about that the fields of oil and gas are much more narrowly limited than those containing coal.

As a whole the combustible carbon in the forms of peat, coal, oil, and gas constitute the least important of the several great sources of energy which are at the command of man. They are not only exhaustible, but form a store that cannot be expected to endure the drain made on it for more than three or four centuries. We now know that the coal beds of any great value are essentially limited to the regions beyond the tropics, and practically to the regions north of 30 deg. north latitude. The reason for this is that the equatorial districts have always been the seat of such high temperature that peat, the first stage of coal, could not accumulate there to any considerable extent, and so the coal-making process did not have a chance to begin. The store is effectively limited to the northern parts of North America and of the Eurasian continent. Of this accumulation the share of Europe will be substantially exhausted by the end of the present century: indeed, if the present increase in the demands upon it continues, this exhaustion may come within sixty or seventy years. This does not mean that all or nearly all of the coal that lies beneath the surface will have been used, but that much of the store is now so deeply buried by the down-folding of strata that it is not in existing economic conditions available. That which remains will serve only when the needs are desperate and are far beyond what can be met by the other sources of power and heat.

In northern Asia, especially in China, there are very extensive deposits of coal. The Chinese empire probably has a store larger than any other except that of the United States, a resource which, in combination with the cheap labor of that country, is certain to play a large part in the economic development of the lands about the northern Pacific realm. So far as the world is to depend on coal as a source of power, there are but two districts that will have a chance to attain a large and enduring success; these are the fields of western China and that of North America east of the Mississippi and south of the St. Lawrence, and these areas, vast as is the store of fuel they contain, are not likely to meet the demands made upon them in the next three hundred years. With rare and local exceptions their beds of coal are much more easily accessible because they require less deep mining than those of Europe or Asia, so that they will probably be exhausted long before those of England and Belgium come to an end.

The other burnable materials of the under-earth, rock, gas, and petroleum, will certainly not endure the demands made on them for nearly as long as will the coal deposits. The rock gases are a peculiarly evanescent store. Experience has shown that the fields which have been developed are not likely to afford a profitable supply for more than two or three decades. These fields are of seldom occurrence, none of considerable value having been found in Europe. The conditions of their formation indicate that they may not be expected to exist in the other continents to the extent that we find them in the central valley of North America. They are formed in vast quantities from the decomposition of organic matter, and in every coal bed in the transition period from peat to the bituminous a considerable part of the carbon combines with hydrogen to produce them; but for some reason that is not yet clear this gas is never in any considerable quantity retained in the coal-bearing strata. Now and then it is found in quantities great enough to originate those well-known unhappy explosions of mines which so frequently occur, but in these accidents the burning gas is small in quantity and of itself not the cause of the damage which is brought about by the fired coal dust that is shaken into the air. Now and then we may note the gas escaping from the newly broken face of the coal, showing that it is held, under pressure, in the mass; but, as above suggested, it passes from the strata to the upper air about as rapidly as it is formed. But when the rock gas is developed from animal remains near a bed of porous rock with a covering of dense material, the gas then finds lodgment in the interspaces and may gather a pressure of a thousand pounds or so to the square inch. When the beds containing the gas are penetrated by the drill, the discharge takes place so rapidly that a few years suffice to drain a large area. This source of energy is certain to be less enduring than any of the others to which man can turn.

The petroleums, when first brought into use, were supposed to afford a basis for industries as extensive and as lasting as the coal deposits. Time has shown that while these accumulations are in some places, as at Baku, in vast quantities, none of the so-called basins which are now drawn upon are likely to withstand the drain for a half-century to come. Inasmuch as the rock oils are formed from decomposing animal matter, there is reason to believe that they have been very generally produced in all marine deposits abounding in fossils; that is, in nearly all beds formed on the floors of the ancient seas at some distance from the shores. It is tolerably certain that if we had access to all this oil, it would in amount many times exceed in energy-giving value all the other existing stores of fuel. Unfortunately, the rock gases are abundantly formed along with the oil; and by their accumulated pressure force the fluid to the surface, where it is broken up and dispersed. Consequently while there is probably a large amount of petroleum beneath the sea floors quite inaccessible to man; the amount at his disposal beneath the lands is small. In western Europe there is, in an economic sense, no petroleum. In North America, the fields probably now fairly well known are limited to the Mississippi valley and possibly the country to the northward as far as the Arctic circle, southern Texas, New Brunswick, and to a belt on the coast of California. The Baku, or Caspian district of Russia, is the only part of the old world where large amounts of oil are well known to exist, but it is likely that other fields will be disclosed in Siberia and in China. Like discoveries are to be reckoned on in Africa, Australia, and South America, but it is not at all likely that any of them will exceed North America in their yield, and it is evident that the oil of this continent will probably not outlast the present century.

It is to be noted that while the native petroleum of the world can be no more than a temporary source of energy in the forms of heat and light, oil of like quality can be produced in vastly larger amounts from certain carbonaceous shales which plentifully occur in various parts of the world. One of these formations, perhaps the most extensive, is that of the Ohio valley and adjacent districts in the east and north. Here we have a set of beds averaging more than a hundred feet in thickness which, over wide areas, will yield to distillation probably about one-tenth of its mass in oil, paraffin, and related substances; it affords the range of chemical properties which make our rock oils the source of so many substances necessary in the arts. From this deposit, but one of the many that are found in various parts of the world, we may look for a store of energy which may be drawn upon long after the beds of coal have been consumed. This oil and other burnable materials will be won at a much greater cost than where they are obtained from wells, in the fluid state; but the by-products of the distillation to which the rock is subjected will probably be as valuable as those afforded by the natural oil. The present writer has computed that the oil which may possibly be had from the Ohio shale above mentioned will in volume much exceed the amount of water contained in Lake Superior. This estimate cannot pretend to accuracy, but it may serve to indicate the amplitude of this source of material serving for a wide range of needs.

While the beds which may be distilled in order to obtain petroleum and its related products are very extensive and widely distributed, we cannot, with certainty, look to them as sources of power in most parts of the world, until the coal beds are effectively exhausted. As a source of illuminating oils they are likely to be resorted to extensively in the immediate future and to serve this use for centuries. It may be that the gas engine, that group of contrivances which seems likely to displace the engine of Watt, will be so developed that petroleum distilled from bituminous shales will be an economical source of power.

Viewed as a whole, the forecast for the future of power with the world peopled to its maximum of food-giving resources, is favorable. While coal and natural oils and gases are essentially temporary resources, not to be considered available for more than three or four centuries to come, they constitute but a small part of the offerings of nature on this sphere. The falling waters, the winds, and the tides are great and permanent sources of supply from which the crafty mind of man will be certain to win his needs for all his time. These sources of supply he will supplement with the oils obtained from the above-mentioned carbonaceous shales, and from the same source he will seek for dye-stuffs, medicaments, and the host of petroleum products which are now regarded as mere by-products. For all we dare reckon of the future the great stores of solar energy are sure to be at the service of our kind, as many as the earth can feed; and this in far larger share to each individual than we now demand.

III

THE EXHAUSTION OF THE METALS

IT is evident that the economic side of human advance, as well as the greater part of the contriving foresight which characterizes it, depends upon the qualities of materials men turn to account. The story of adaptation of substances to desires did not begin with man. It is common among the bees and ants and divers other insects. We see it in the nests of birds, in the hotbed in which the brush turkey lays her eggs. These contrivings generally relate to utility alone, yet often the sense of beauty guides the construction so that the æsthetic as well as the utilitarian motives appear to exist in the minds of many highly developed animals, and readily lead to the adaptation of outward things to the needs of the body and the mind.

It is interesting to note that the utilitarian motive is much less developed in the mammalian ancestry of man than in the insects or the birds. A distinct sign of it can be found only in the group of rodents, as in the beavers, but this order lies far aside from the series of animals from which our kind came up. It appears pretty certain that except possibly for the occasional use of a stick or stone as a rude tool wherewith to break a nut, or a huddle of branches placed in the fork of a tree to serve as a nest, none of our prehuman ancestors met their advancing needs by the use of the materials that might have served them. As soon, however, as the critical point between the brute and man was passed by, the new creature entered upon a realm in which the qualities of things were to satisfy its progressive desires and in the process enlarge its intelligence.

At first sight, there does not seem to be much difference between the way the monkey and the lowlier man use the stick or stone to serve their immediate needs; but while the ape gives no evidence of judgment in any act, in the lowliest man judgment and constructive endeavor always appear to enter. The roughest stone tools used by the most primitive toiler are chosen with reference to shape and endurance. They are shaped with rude but advancing art, so that they may better serve their need, and speedily the æsthetic motive leads the man to endow them with beauty. Each of these early and simple conquests of nature leads to a sense of the powers of the outer world, so that even the lowliest savage becomes an inquirer in a true sense, a man of science exploring the world with his imagination of things possible, and verifying his conjectures by experiment.

This is not the place to set forth what little we know by the study of primitive tribes and our own children concerning the steps by which man won his way to the earlier conquests of the material world;

how at every step in the earlier inquiry he was, by his exuberant fancy, continuously and irresistibly led away from the path of science into the wilderness of superstition, and how in the Greeks and their successors the better way was continued and affirmed. For our purpose we need see only that the truly experimental science of the savage and his barbarian successor led him afield, and that with the emancipation from superstition the possible extension of his excursions has become, so far as we can see, almost limitless. What concerns us now is the extent to which our civilizations have become dependent on the resources of the earth for their support or advancement, and how long the sphere is likely to endure the tax upon its store which the increasing numbers of mankind and their ever-growing demands are certain to make.

Putting aside, for the moment, the vast range in minor substances, such as precious stones as well as the other minerals which do not support any important part of the functions of civilization, we find that the conditions essential to the maintenance and advance of civilized man are those relating to two fields of utility, one being the development and application of energy, the other the construction of vessels for the purpose of retaining and transporting substances. The last-named of these groups was the first to find a large place in the arts; long before men had managed to gain any access to natural forces they had learned to use the gourds, baskets, skin bags, vessels of pottery or hollowed wood for a great range of needs. The existence of the household and growth of economic foresight depend upon the invention of such retaining vessels. This application of materials must always remain the most fundamentally important.

This history of retaining vessels shows that a successful and highly developed social economy is possible when they are made of baked clay, and, incidentally, of cloth. The best days of Greece and Rome did not know the can or barrel. In the time to come when, with the earth taxed to its utmost to support the population which may be expected with the abolition of pestilences and war, it will be possible, though not convenient, to dispense with the use of wood and metal for domestic and transportation uses, and to return to the classic earthenware. There is plenty of material to meet all possible demands for this purpose; clay suitable for such uses is found practically everywhere, and the amount of fuel necessary to bake it is relatively small. We may, therefore, regard the evils arising from the exhaustion of metals for this purpose as entirely evitable. As we shall see below, this limitation on the demand may, in a few centuries, be a matter of considerable consequence.

Of the supply of metallic substances needed for the generation and application of power, we find that in the present state of our arts there are two of cardinal importance, viz.: iron and copper, half a dozen of secondary yet great utility, lead, zinc, tin, mercury, gold, and silver, and a number of others, such as nickel, which though most useful in the arts, do not materially affect the course of civilization. If any of these metals, except iron and copper, were by some accident to be transmuted to-morrow, it would be temporarily most inconvenient, but the world would in a generation or two adjust itself to the loss without serious hindrance to its activities. If gold were to disappear, we should for a time have grave trouble in our traffic, but its use is essentially a matter of custom and we should have to undergo only a change in that regard. In the disappearance of the secondary metals, mercury would probably be the most serious loss, for it would be hard to replace it in our thermometers. Next to mercury, lead would be the most difficult to dispense with, for the reason that its qualities of weight and softness fit it as no other substance for use in small-arm projectiles. But as war will surely disappear, and hunting also, in the bettered earth of the future, we could contemplate these losses of quality with no great regret.

Seeing, as we do, that the mainstays of our existing civilization among the metals are iron and copper, let us note in what ways they are necessary and what are the conditions of demand and supply that may be anticipated. First, as regards iron, it may be said that almost from the beginning of its use it has been adopted as the prime metal of civilization. It is not unlikely that men gained their first notions concerning the properties of this metal through experiments with the masses of it that had fallen from the sky. These are so far pure that if heated and beaten they would disclose properties which would lead an intelligent barbarian to researches. He would easily see the evident likeness of these meteorites to many forms of iron ore, and with his skill already acquired in smelting the ores of copper, zinc, and tin, and in the simple furnaces that served him in such work he would readily find his way to producing the substance which, more than any other, has afforded his successor the means of dealing with nature.

More than any other metal, iron, and its slightly modified form known as steel, affords the combination of qualities needed in the application of power. It is at once hard, rigid, flexible, and tough, and has these features through a considerable range of variations which may be readily induced; in the form of pig-iron it is meltable at a temperature easily attained even in primitive furnaces, and can then be cast in moulds; in another variety it can when heated be shaped as desired to an engine-shaft, a sword, or a watch-spring. Not the least of its values consists in its cheapness; even with the primitive smelting apparatus, the cost of a pound of iron, because of the plentiful distribution of the ores and the ease with which they were mined, was probably not more than a fifth of the cost of a pound of the earlier used bronze. At the present time, the average costs are in the ratio of about twenty to one. As regards the relative utility of the two materials, the difference is in a far greater measure in favor of iron. A civilization in the age of Athens at its prime, or of India in the time of Christ, is possible with no more effective instruments than bronze affords. But it is doubtful if the Roman culture and conquests could have been shaped without the use of iron, and it is certain that our modern states, so far as they depend on their command of energy, could not have developed, and perhaps cannot be maintained, without the use of iron or some other metal that is thus fitted to serve in acquiring and applying power.

If we had now to reorganize our culture on the basis of iron at the ancient or even the lower modern cost of bronze, we should have to abandon much that might be termed necessary to our economic life; the most of our railways and steamships would be too costly for the services they render, great and seemingly indispensable as these are. A like reduction would have to be made in all our instruments by which we attack the resources of the earth, those of soil as well as mine. It is easy to imagine the shearing of our comforts and luxuries, and even of necessities, which such a change would involve. It is evident that the means of culture, which the well-conditioned laborer now has in larger measure than the prince of a thousand years ago, would be vastly reduced by such a change. Let us see whether such a need of readjustment is to be reckoned on in the centuries to come.

Iron, as is well known, is a very widely diffused element. In combination with oxygen and other substances it is found in most rocks. Because of the high specific gravity of the earth it is often stated that this metal must superabound in the deeper parts of the sphere; but there is no good reason for this notion, for the volcanic materials which presumably come from at least fifty miles below the surface, though they contain iron, do not indicate that the interior is peculiarly ferriferous. It is, moreover, not improbable that the infalling of meteors composed in large part of this metal has in the course of geologic ages considerably increased the store of it in the outer part of the sphere.

Because the oxides of iron are rather soluble in water containing CO^2, carbonic acid gas of common phrase, and because all the water moving or in the crust contains enough of this gas to give it solving capacity, iron oxides undergo a continuous process of dissolving and are thereby diminished in the soil or porous rocks and concentrated in the lower strata. In this way they are gathered in deposits below the decaying vegetation of swamps; they replace limestones that lie near the surface and sometimes come to form true veins. In most instances these processes of concentration do not go on at great depths beneath the surface, but are limited to the levels where the rain-water has a chance to penetrate; usually much less than half a mile down. Thus, although there are probably instances where beds or veins of iron ores may be found at the deepest levels at which we may hope to win them at practicable cost, say at a depth of two miles or so, it may be assumed that the supply of the metal will have to come from less than half that distance below the surface. In this regard, the occurrence of minable deposits of iron ore differs from that of the other important metals, the most of which, though likely to be richest at no great depth beneath the surface, continue in the rocks downward indefinitely beyond the limits where they may be won.

Though the available iron ores are, as a whole, not to be reckoned on in great depths, and the store is thus much limited, their generally bedded nature and the great horizontal extension which comes from this arrangement afford an abundance of the material found in no other metalliferous deposits sought by the miner. The total amount of these minable iron ores, when their exploitation began, probably much exceeds all the other mineral deposits, excluding coal, that have been sought in the earth. The amount of these iron ores still available is very great, doubtless many times, perhaps twenty-fold, as great as has been won to use. Yet we see already that on the continent of Europe the fields long in service are beginning to be exhausted. Great Britain has practically consumed its store, which a century ago seemed ample. Essentially all the supply for its furnaces is now imported. The supply from the Mediterranean, that promised to be inexhaustible, cannot endure for many decades to come. The same is the condition of the ore districts of central Europe; at the rate of the increasing demand they are not likely to afford a source of supply a hundred years. There remain extensive deposits of rich ores in the Scandinavian peninsula and in fields on the confines of Belgium and France which have hardly begun to be drawn upon, yet it is evident that at anything like the present rate of increase in the consumption of metallic iron the European sources of its ores are not likely to endure for a century.

In North America, the conditions are more promising for a long continuance of iron production than in Europe. In the region east of the Appalachians, including New England and the maritime provinces, the originally rather scanty stores of the metal have, save in Nova Scotia, proved unprofitable sources of supply. It is evident that they may be left out of account in any reckonings of a large nature. On the Pacific slope, though our knowledge of the matter is less complete, it appears unlikely that the deposits have any considerable value in relation to the world-needs. In the central district of the Cordilleras of North America the scanty evidence as yet gathered seems to indicate the promise of considerable bodies of iron ore, but the greater part of them lie far removed from coal of a quality suited to the operation of smelting, and, therefore, to be available, save for local use, only when the price of the metal is far higher than at present.

The best-placed field for the production of iron in North America or, save that in northern China, in the world, is in the central section of the Mississippi valley, mainly between the great river and the Appalachian system of mountains and northward beyond the great lakes to the head-waters of the streams flowing into Hudson's Bay. As a whole, this area is not only exceptionally rich in iron ores, but the deposits lie near enough to coals of a quality suitable for smelting them.

Save as before mentioned, in China there is clearly no other region in the world where the physical conditions are, on the whole, so favorable for the cheap production of the metal and its ready transportation to the principal markets; it is a question, however, if the store will supply the demands of the future.

The more important iron ores of the central trough of North America may be roughly divided into two geological groups — those of the region to the north and west of the upper Great Lakes, and those of the region south of the Ohio. The Great Lakes group mainly consists of deposits contained in the older rocks, those which have been greatly altered by chemical changes, so that the original oxides of iron, probably once bedded, have been dissolved and reconstructed, with the result that they are now accumulated in masses of limited area of exceptional richness. When, some twenty years ago, these ores in the region about the shores of Lake Michigan began to be extensively developed, it was generally believed that the field was practically inexhaustible, that it would withstand for centuries any demand that could reasonably be expected. At the present time good judges are reckoning the longevity of these mines by decades. A conservative view of the situation is that at anything like the present output of the ores the existing production cannot be maintained for fifty years. It is true that there is much unexplored territory hidden from the eager and keen-eyed scouts who have traversed the wilderness about the developed mines, but it seems altogether improbable that discoveries of unknown fields will be found sufficient to tenfold the known ores of this region between the Great Lakes and the Arctic circle. The geological features of the region make this reckoning almost certain; add to these considerations that the demand for these ores is rapidly increasing, and we are forced to the conclusion that this, the most promising field discovered in the last century, and, most likely, all things considered, the best ever to be found, will not continue its production for a century to come.

A similar story is to be told concerning the ores south of the Ohio, those which in Alabama, Tennessee, and southwestern Virginia, in the time of the swiftly developed iron industry of the Birmingham district, promised to revolutionize in future years the industry of this country. The greater part of these deposits are bedded, mostly in the upper part of the Silurian system of rocks. Those beds belonging in the Clinton period consist of limestone which has been converted into iron ores by the downward leaching of the surface water, carrying iron oxides in solution in the manner before noted; when this carbonated water comes in contact with lime it lays down the iron oxide it contains, takes up lime, for which it has a greater affinity, and goes on its way. In this manner, in the course of time, all of the bed of limestone to which the rain-water finds access is converted into siderite, a carbonate of iron and lime in which the proportion of iron to the other materials is rarely greater than thirty per cent. The further access of water and air to the deposit will in time remove a considerable part of the remaining lime and effect other changes which bring the mass into the condition of limonite, brown ore, or hæmatite red ore, in the more concentrated forms of which the proportion of iron may be increased to from forty to sixty per cent. of the mass.

The bedded Clinton ores of the southern states have very generally been tilted by the mountain-building processes which have operated in that region, so that we have the deposits appearing at the surface, the beds plunging downwardly, and after the miner has followed them for, say, 1,000 feet on the slope, he is several hundred feet below the surface. When a bed of ore of a given thickness was discovered that in shallow pits yielded iron at the rate of forty per cent. or more of metal, the natural mistake was made that the deposit could be followed downward with like richness as far as mining skill could carry the openings. Experience has shown that as soon as the workings are extended much below the zone of movement of the rain-water the beds are found in their original condition of limestones; so that in place of a workable belt of some miles in width the limit of profit is within a few thousand feet of the surface. The result is that the expectations concerning the Clinton field of the South which seemed to most observers, even to those who were fairly well informed, to be inexhaustible, have to be greatly reduced — in such measure, indeed, that the resources which were expected to endure for centuries cannot safely be reckoned on for more than half a hundred years. It may be conjectured by those who find comfort in mere possibilities that we know so little of the under-earth, even in our own relatively well-known land, that these reckonings are vain, and that surprises await us in the way of discoveries undreamt of. The uninstructed only will be inclined to make such guesses. It is a fact that all the iron fields of this country of sufficient extent to have a wide-reaching importance have been known for thirty years or more. Later knowledge has only defined their bounds. It is in a high measure improbable that within the limits of the United States any new fields of notable value remain to be discovered.

We know much less of the iron resources of the other continents than of Europe and America. The only other known field in any of them which promises a yield of general importance is that in China, where over a wide area there is evidence of iron ores along with good coal for smelting, and under conditions of climate and of labor which promise a cheaper product than has been obtained in any other district. This combination of resources is one of the several features which give the present struggle between Japan and Russia a world-wide meaning, for on their control depends in large measure the economic mastery of the Pacific Ocean. They are very soon to make China the manufacturing centre of that realm. The state that commands the mineral stores of that kingdom may find its way to master the world even more effectively than did Rome in her time.

As for the other parts of Asia and the continents of Australia, Africa, and South America, relatively little is known of their resources in the way of iron, save that owing to the prevailing lack of coal deposits fit for use in blast-furnaces, the ores here and there abundant cannot generally be made to serve except at much higher prices of the metal than now hold. As for the eventual product of these lands, we may make a rough reckoning in the assumption that, area for area, they are no richer, and probably less rich, than Europe and North America. If we accept the conclusion that the iron ores of those lands are not likely to continue to be sources of large and cheap supply beyond the present century, we may fairly assume that the world, as a whole, will not have access to the metal at anything like the present cost in terms of labor which prevail at present.

It is not to be supposed that the iron age will suddenly pass away; its passage doubtless will be gradual. The deposits other than those of China which can produce iron at the present low labor cost will almost certainly be exhausted within one hundred years. Those of China may last for a similar term after they become the centre of a large industry. Then the cost of production will gradually increase as the lower-grade ores and those remote from coal come into use. In the end we shall have to resort to concentrating processes by which the iron ore is separated from the rock in which it is disseminated as grains. This upward grade in cost means a downward grade in the utility of the metal in the service of man. Finally, it may be some centuries from now, but surely, we shall be forced to economy in the use of the metal such as was exercised by folk two hundred years ago, when, save for what went down at sea, or rusted back to earth, none of it was lost to the arts. In this stage, when it becomes again a precious metal, iron may continue to be the helper of man for an indefinite period, but its power for help will be greatly diminished.

In the case of copper the outlook is much the same as with iron. The sources of supply are very much rarer and the total amount of the metal in the crust of the earth is probably not the thousandth part of that of iron. Athough it has been the object of close and well-guided search through North America, and of innumerable essays in mining, there are no deposits of any importance now worked in the region east of the Rocky Mountains except on Lake Superior, and in the western district there are but two limited fields of considerable production, or even of much promise, within the bounds of the United States. And yet the Cordilleran system in North and South America is the region in which this metal appears to be most generally diffused and to exist in the largest aggregations. On the other continents we find a like sparsity of copper-bearing ores of the economic value of the present sources of supply. Only the Spanish mines of Europe are the seat of a considerable production; no

Asiatic or African fields comparable to those of Lake Superior, Butte, or Arizona have been found, and in South America the only successful mines are in the central district of the Cordilleras. It appears that the supply of copper will be reduced to a point where its service to the arts will be seriously limited before there is a like reduction in the supply of iron. In the last-named metal there exists a considerable leeway in the saving that will be made in scrap material as soon as the price rises to, say, fifty dollars per ton; because of the present relatively high price, about two hundred dollars per ton, there is no savable loss in copper.

We can look upon the approaching exhaustion of the sources of copper supply with less apprehension than in the case of iron, for the reason that, useful as the metal is in manifold ways, it is not indispensable or even very necessary in our arts except in the transmission of electric power, and even then substitution is possible. Save for this use the economic world could soon adjust itself to the loss of this once indispensable metal.

Turning now to the question of the possible substitution for iron and copper, we find ourselves in face of the interesting problem of aluminum. This metal is in form of silicates, the base of all our clays, and of the feldspars from which they are mainly derived, as well as of many other common mineral species. Owing to the abundance of these materials, the amount of aluminum accessible to man provided he breaks up its union with silicon, which needs to be done because the substance is never found in the metallic or unoxidized state, is perhaps some thousands of times as great as the iron contained in the concentrated form of beds or veins. Every clay bank is a possible source of the material. Great sections of the stratified rocks are in part composed of it, and all the feldspathic massive rocks, such as the typical granites, contain a like store of the metal.

In its qualities aluminum is admirably adapted to serve the greater part of the needs now served by iron and copper. It is relatively very light, but for its weight admirably strong, rigid, tough, and elastic; it is a good conductor of electricity; it does not oxidize or rust as readily as those metals. It meets practically all the uses of the constructive arts; it is better than steel for the greater number of them. In the hulls of ships it would spare a large part of the weight in the hulls and machinery, and would greatly increase the cargo-carrying power. We readily see that an aluminum age would carry us almost as far beyond that of iron as we advanced when that metal replaced bronze in the mechanic arts. Why, then, as we have learned how to separate this admirable substance from its union with oxygen, may we not extend its use, thereby dismissing all fears that our successors of the centuries to come are to lack a fit share of the metals necessary for economic success?

To comprehend the economic situation of aluminum we have to note that though the metal has long been known and a great deal of experiment has been devoted to cheapening the cost of producing it, an inevitable difficulty in obtaining it from ordinary clays is encountered in the firmness of the grip which the atoms of silicon have upon those of the metal in the compound. To pull these units apart and to send those of silicon on some other errand than a union with the aluminum atoms, requires an amount of energy in the form of heat and a combination of the ores with other materials very many times greater than is required to do like work with the oxides of iron. The result is that so far as this process has yet attained, the cost in terms of power incurred in making a ton of aluminum is, under the most favorable circumstances, very much greater than in the case of a like amount of metallic iron. It may be granted that future improvements of the process of winning the material will much reduce the cost of its production. The fact that within fifty years the market price of aluminum has been reduced to about one-tenth of what it was favors this supposition. Yet we have to bear in mind the fundamental difficulty that it requires many times as much energy in the form of heat to part the other atoms from the metal as it does in the case of iron, and that so far as we can see the work has practically to be done in electric furnaces on a small scale and with steps that entail a large amount of labor. He would be a confident man who, on the basis of computation, looked forward to a time when aluminum could be economically produced on a large scale for less than two hundred dollars per ton.

To bring the cost of aluminum down to, say, ten times that of pig-iron, and to produce it on a scale in any important measure to compete with iron, even at double its present price, it will be necessary to reduce the cost of electric power to a small fraction of the present cost of production. This can probably be done, for there are innumerable places where great water-powers are unused which can be turned to this account at a cost, perhaps, not more than one-tenth of what it would be if won from coal. This, however, will meet but a part of the difficulty, for the aluminum-bearing ores rarely occur in such quantity and purity that they may be directly used in a furnace, and in this condition are much less extensively developed than those of iron. Moreover, we do not as yet know how to win them from ordinary clays. Thus with any methods now conceivable we have to reckon that while aluminum is likely in time to take the dominant place now held by iron, it will do so at a cost in terms of labor far higher than what men now pay for their capital metal. Nevertheless, the difference is not likely to be so great that the mechanical foundations of our economic civilization will be endangered.

As for the other metals now in use, gold is of most popular interest. Its place in the public mind and in the peculiar work of measuring exchanges is no gauge of its essential value. The metal has not a single property that makes it necessary in the mechanic arts, and its special delegated work in measuring values could be accomplished by other agents. In the course of the present century it may be necessary to seek other means of effecting such measurements. There is a large quantity of gold accessible in this world at about the cost in terms of labor which exists at present. The metal is very widely diffused not only in the earth, but in the waters of the sea as well. The processes of mining it are constantly increasing in efficiency and decreasing in cost per unit of the material won. There is little doubt that these changes, by adding to the store of gold beyond the needs of civilization, are even now depreciating the metal, and the effect is shown in the rise of prices of things for which it is exchanged; a rise which in face of lessened costs of production can only be accounted for by the excessive supply of the agent of exchange.

As the use of gold in ways that lead to its loss is not extensive, the gain in the world's store of it is going forward so rapidly that, considering the contributions from the land alone, it seems likely that we shall, within a few decades, contrive some other means of measuring values than by the ancient device of balancing them against a substance of which the supply is excessive.

Should the much-talked-of method of winning gold from sea-water by any contrivance prove economically successful, the increase in the stock of the metal might quickly become so great as to break down its value as money. The effect would be speedier than that attendant on the increase in the quantity of silver in the world's store due to the development of the Comstock and other American mines about twenty years ago. Fortunately for the convenience of man, it seems unlikely that a process of obtaining gold from sea-water at a profit will be contrived. While we have little trustworthy information concerning the supply of this gold, or the state in which it exists in the ocean, it appears unlikely that it ever amounts to more than about five cents' worth in a cubic metre, and there is no way known in which it can be won at anything like that cost.

Silver, the noble companion of gold in the work of measuring the goods of men, is now a forlorn element, a very pauper among the metals. At any price at which it can be produced, it is valueless in the arts. What station it retains is due to sentimental considerations which are likely soon to pass away. In a century, save for its use for fractional currency, it is likely to be quite neglected; it is, therefore, not necessary to consider the question of its supply in the time to come.

Lead, as before noted, has its largest use in small projectiles — it is to be hoped an evitable use. It is, however, serviceable as a basis for various solders and as an agent in joining sections of metal pipes — as well as for making an objectionable group of paints. If war is to be continued for a century to come at the rate of the past century, it is likely that the stores of lead ores will be seriously trenched upon. Although it occurs in very numerous areas, in many countries, and in a great variety of geological formations, it is rarely found in extensive deposits, so that the mines producing it are generally soon exhausted. Thus fifty years ago there were seats of large production east of the Mississippi or near its banks; at the present time the amount produced in that region is insignificant. Moreover, until the recent fall in the price of silver, lead has been largely a by-product obtained in mining the more precious metal under conditions which would not otherwise have admitted of its being mined.

Tin has a singular place in the mechanic arts; it is but little used by itself, but serves mainly to give a coating to iron, thereby preventing rust. The distribution of this metal is peculiar. So far, though the search for it has been well carried on, it has been found in profitable quantities only in Eurasia and the Australian realm. It occurs here and there in the Americas, but it has never rewarded continuous mining. The evidence is clearly to the effect that it cannot long be supplied in quantities or at a price which will render it serviceable in the arts. It is not likely that it will hold its place through this century.

Zinc is possibly more important than tin; it serves a variety of uses as sheet metal as well as a coating of iron to avoid rusting; it is also in an oxidized form of decided value as a paint, but in all these services to the arts it is replaceable by other metals. The distribution of its ores is wide and their abundance considerable. They are found to a great extent in veins which hold their contents of the metal in the extreme depth of mining work. The general conditions point to the conclusion that this substance is one of the last of the underground values to be exhausted. Yet, as it is mainly to be won as a by-product of silver, lead, etc., the duration of the supply is probable dependent upon the production of these metals.

Among the minor metals of special and important value, irreplaceable in the arts so far as we can see, there are few which give the forecaster concern. Mercury is imperatively needed in mirrors and in a wide range of scientific instruments such as thermometers and barometers, as well as in the processes of amalgamation by which the greater part of the gold supply is won from ores. This metal is scantily and peculiarly distributed. There are less than a half-dozen places in the world where it is known to occur in sufficient quantities to repay the miner, and none of these deposits give promise of long endurance. It is, indeed, likely that the first important deprivation to be encountered in the approaching exhaustion of metallic stores will be of this substance. A like apprehension is due in the case of platinum. This metal is peculiarly necessary to thc chemist, as it alone has the needed resistance both to heat and acids, such as is required in a large part of his laboratory experiments, as well as in some processes of manufacturing. Thorium, which serves in the manufacturing of the "mantles" of incandescent lamps, as well as sundry other substances needed in particular arts, are about as unpromising for the future as those above noted, but they need no further mention because it is likely that they may be replaced, or, at the worst, the deprivation will not be serious if they are lost to the arts.

Of the earth substances which afford other than metallic products, the number is so great that they cannot all be considered here. Perhaps the most important of these, for it touches on a host of common arts, is sulphur, which, as is well known, finds its most important use as sulphuric acid. This substance comes to our hands from two sources, in the shape of the yellow mineral of the name, and, in larger share, from what is familiarly known as iron pyrite. To one or the other of these sources we have to turn for the acid which is indispensable in a host of the arts that are linked in the chain of our economic civilization. It is even more indispensable than any of the metals except iron. What, then, is the chance of its supply being maintained?

The future of the supply of sulphur is tolerably certain. In all active volcanic districts there is a constant expulsion of sulphur vapors which form deposits that after the period of activity can be mined; in this and yet other ways the supply of the mineral in the native form is provided. Again, and more importantly, it is produced from iron pyrite, a compound of sulphur and iron. This pyrite is of very general occurrence in the form of distinct veins and as crystals of the material scattered through rocks of all ages; the facts, in a word, point to the conclusion that of all the earth products which are useful in the arts, sulphuric acid will be one of the last to be exhausted.

Nitrates, the source of nitric acid and the basis of gunpowder and hardly second to sulphur in importance, rest on a more unstable basis of earth resources than any other. They exist in certain very limited fields as nitrate of soda, which can readily be converted into nitrate of potash, " saltpetre." These nitrates are very soluble, and the chance of finding them in commercial quantities, except in recent deposits formed in desert countries, is small. The situation, however, is hopeful for the reason that the greater part of the air is composed of nitrogen, and though we have not learned how to convert it into serviceable form, we may trust our good helpers, the chemists, to learn how the bacteria do the work, and apply that or some other method to the task.

There are many other earth substances helpful to man in his present economic estate, and many others will find their place in the arts. The substances that have been mentioned in this incomplete review are, so far as we can discover, the most important for the continued success of human endeavors. Some of these, as, for instance, the radium group, come just now trooping out of the dark — out of the great mystery of this seemingly commonplace world. What share they are to have in human events is not clear; yet because of our considerable knowledge of the materials of the earth which exist in notable quantities we may fairly reckon that the discoveries which await us are of rare elements and combinations, not, in many instances, likely, because of their small quantity, to prove of great economic value.

Beneath all these reckonings is the ancient question as to the transmutability of the elements. Shall we be able in time to find some way by which one of them can be transformed into another? To this there is, as yet, no final answer, but all our knowledge points to the conclusion that even if an atom be actually changeable in nature, such is the persistency with which it clings to the shape in which we find it that it is idle to hope for conditions where the alteration can be accomplished in a way to serve our needs. We have to accept the hypothesis of unchangeable elements as a basis for our economic concepts of the earth and be thankful for the large gifts they bring, confident that the spirit of man may win his needs from the great store.

IV

THE UNWON LANDS

BY far the greater part of the food now at the service of man is derived from lands which have been easily subjugated, needing only the axe and the plough to fit them for use. Probably not more than five per cent. of the area of tilled or pastured fields has been won by the devices of the engineer from the arid deserts or those sterilized by an excess of water. In Asia, from immemorial time, considerable regions have been irrigated; much irrigation also has been done in Africa and along the north shore of the Mediterranean; a fair beginning has been made in North America. But probably not the fiftieth part of the lands which can be bettered by the application of water now going unused to the sea has been brought to the service of man. The conditions are the same as regards the areas which are over-watered as they are with the excessively dry lands, though the distribution of the fields is different. The process of drainage has been essentially limited to northeastern Europe; only here and there and in a relatively small way has it been applied elsewhere. The share of these inundated lands which has been won to tillage is even less than in the case of those which are excessively arid. From these two groups of fields we are to find the source of the food for a large part of the increase in population which we may expect in the centuries to come. We shall now note the conditions of the reclaimable arid deserts, reserving our glance at the swamps and marshes for the next chapter.

All arid deserts owe their lack of rainfall to the existing distribution of the seas in relation to the lands, to the direction of the winds and the ocean currents they impel, and the position of mountain ranges in relation to their movement. It is a safe general assertion that these wastes are, in a geological sense, temporary, having been at various times in the past well watered and likely to be so again in the course of the unending geographic change to which the earth is subjected. Thus in the arid district of the Cordilleras of North America — the so-called Rocky Mountains — it is clear that a time of great rainfall during the early Tertiary period was followed by long-enduring drought. This was succeeded by a return to humid conditions of the glacial epoch, and, finally, the existing state of scanty rainfall was established. The Sahara and other arid regions exhibit like evidence of alternations of wet and dry ages. There are some reasons for supposing that, on the whole, the continents are at present more than usually arid.

During the periods of considerable rainfall, say above twenty inches per year, the streams somewhat rapidly bear away to the sea all the broken-up rock which is dislodged by weakening processes. The soil which represents so much of this rocky matter as is not taken into solution creeps down the slopes on which it lies and is carried away by the streams. These, normally, have their beds on the firm-set rock. When the rainfall decreases to less than twenty inches the precipitation is apt to be limited to rain-storms of torrential nature — the so-called cloud-bursts — which detach the weakened fragments of stone from the highlands and bear them to the valleys where the small and inefficient streams are unable to convey the *detritus* onward to the sea. The result is that the valleys become filled up with débris, often, as in the Cordilleras, to the depth of thousands of feet.

Even in the most sterile deserts there is some rainfall. It is, indeed, doubtful if in any part of the world the precipitation is, on the average, less than three inches per annum. Although this is quite insufficient to maintain any plants, it is enough to bring about the chemical changes necessary to prepare the earth substance for their uses. The result is that all deserts, however barren they may be, have incipient soils which need but water to become surpassingly fertile, rich beyond the best of those developed in ordinarily humid climates. We see this in the familiar phenomena of the so-called alkali deserts, where the ground is often encrusted to the depth of an inch or more with a coating of a varied nature composed of lime, potash, soda, etc., just such materials as plants need, but there present in excessive quantities. In fact, the desert soils, if they are not mere blown sands, are so rich in the soluble mineral substances that, when at first irrigated, they are, for a time, unfit for tillage, and required to be subjected to successive inundations, so as to leach out the excess of what serves as food for plants. Many experiments in irrigation have been hastily abandoned because those in charge of the work found that for all their toil and pains the well-watered fields would bring no returns because they were surcharged with richness.

It is worth while to look for a moment more clearly at the conditions which lead to the formation of an "alkali" coating in arid lands, for it tells us much of value as to their conditions. The important facts are these: When the rainfall is very small in quantity, say less than ten inches in a year, there is little of that circulation of water through the soil which under ordinary humid conditions brings about a constant removal of the dissolved mineral substances through the springs to the open streams. When, by a chance rain, the desert ground becomes soaked with water, the dry air quickly evaporates what of it is upon the surface, leaving the mineral materials it contained. When the deeper-lying water is drawn up to the surface to replace that which has been vaporized, it in turn goes away, and its load is continuously added to the coating. The process is essentially like that of a lamp wick when the fluid is taken into the air by burning and its solid contents left as a coating at the point where it is vaporized.

In desert countries this excess of soluble materials extends throughout all the earth to which the water penetrates. Commonly the process of irrigation does no more than reduce the store to the point where it does not injure plants to the depth to which their roots descend, say for a foot or two downward; below that level the original condition remains. The result is that whenever the amount of water applied to the field is not sufficient, the evaporating process draws the fluid from the lower level and the field becomes again excessively charged with soluble mineral matter; it may, indeed, form anew an alkali crust. Thus in Egypt, when an effort was made to reduce the amount of irrigation water to a share which on ordinary soil would suffice for the nurture of crops, the result was that the surface again became covered with the crust and the crops perished. The facts show that the amount of water needed by desert soils is considerably greater than that required for successful agriculture on fields supplied directly by the rainfall.

So far as the arid deserts of the world can be irrigated they will afford, as experience makes plain, a group of opportunities for agriculture such as are not found in regions of the greatest natural fertility dependent on the chance of rain. In taking account of these peculiar advantages, we have first to note that, given the suitable temperature, the crop-giving value of a soil is in proportion to the amount of sunshine and the supply of water furnished at the time required for the growth of plants. When the needed water comes directly from the sky, the sunshine is interrupted, and if the rainfall is ever so little delayed beyond the critical time when the plants need it, their growth is hindered. It may be roughly estimated that at the rate of growth in an irrigated desert, such as we find in Utah, the yield of an acre, owing to these advantages, is likely to be about twice as great as in a like area in a humid district such as Illinois. In the more fertile portions of the tropical and sub-tropical regions irrigation often makes it possible to raise three crops a year where but one could be assured by the direct rainfall.

The permanence in the fertility of irrigable soils, in a measure impossible to attain in those of ordinary character, is brought about by two features in their history. The first of these is that owing to the controllability of the supply of water the washing of the soil into the rivers can be entirely avoided. The second is that owing to the large amount of soluble mineral matter in the sub-soil, it is easy to restore the waste brought about by cropping, by deeper tillage, or by the disuse of irrigation for a short period, so as to allow the sun to draw up the lower water with its store of plant food in the manner just above described. As possessions of the race, the redeemed deserts are of far more value than the richest naturally well-watered fields. They are likely to afford sustenance to man long after the soils lying on steep slopes have gone away to the sea. Turning now to the question of the irrigable desert lands, let us note the conditions in which they occur and, as far as possible, the extent to which they may be won to tillage.

Although the most arid deserts have some rainfall, often enough if it were properly distributed to nurture certain crops, it may be accepted as a general fact that only under peculiar conditions can effective irrigation be obtained by storing the water that falls within the limits of the tilled country. The supply has to be found in streams which arise in districts having a larger precipitation and flow toward the less-watered lands. Sometimes, as in the valleys of the Cordilleras and of many other prevailingly arid mountainous regions, the source of supply may be in the nearby uplands, where the winter's snow is preserved into the summer to fill the torrent beds by its melting. Again, as in the case of the Nile, the Twin Rivers of Mesopotamia, or the Colorado and many rivers of the Cordilleras, the stream flows from a region of considerable rainfall to one of much less precipitation, so that the desert may profit by climatal conditions quite unlike its own. It is in this state of affairs that we find the largest opportunities for irrigation at the least cost of the necessary engineering work.

As to the amount of tillable land that can be won by irrigation from the arid districts, only a very general estimate can as yet be made. It is, however, evident at a glance that only a small part of the arid deserts of the several continents afford enough water at the command of the engineer to make irrigation possible. Thus in Asia, the whole of the central high-lying arid field is essentially waterless as is the Arabian peninsula. The most promising fields for the development of the method are in the drainage of the Caspian and the Aral dead seas and in the valleys of the Euphrates and Tigris. Irrigation to supplement the rainfall in somewhat arid fields is extensively applicable in China and in Siberia, and has already been greatly developed in India. It is not probable that extensive new conquests can be made from the true deserts of Asia, but much can be done to recover the ground in Persia and elsewhere which, anciently irrigated, has in modern times been allowed to return to its wilderness state. The valleys of the Euphrates and the Tigris, once the seat of a great population, form the most tempting field in the world to the irrigation engineer. It seems likely that, next to the Nile, here will be found the greatest opportunity to win the bread of a people from what are now mainly sterile fields. If the irrigation of the whole of Asia should be brought to the condition in which it has been developed in British India, there is reason to believe that there would be an increment of the food supply sufficient for the support of an additional population on that continent amounting to somewhere between two and four hundred millions — the greater part of the increase being in western China.

Europe has no deserts, and the considerable local systems of irrigation are intended to do no more than supplement the rainfall. This work is as yet imperfectly carried out; many extensive regions on the

Mediterranean face of the land well suited to this auxiliary method have never had their streams turned to account. The Aryan race, in general, for all that it takes its name from the plough and is characteristically soil-tilling, shows no native sense of the use of water on the land. It is only when folk of this race have come in contact with people bred in desert conditions, such as the Arabs, that they have ever much concerned themselves with projects for leading streams upon the land. It is, perhaps, due to this lack of race experience that we owe the slight development of irrigation in Europe and among the descendants of its stocks in other lands. If the Semitic folk had come to mastery, the fields of this world would doubtless be much better watered than they are under Aryan control.

Africa has, in the Nile valley, the field where the most important conquests from the desert can be made. The conditions of the problem are so interesting that they demand especial treatment and have, therefore, been made the subject of a separate chapter. Save for this part of Africa, no other large field of desert appears to be irrigable. The remainder of the Sahara, in the later Tertiary time well watered, is doomed to sterility until the climatal equations are again subjected to one of the many revolutions which have dried up realms to deserts and turned once waterless wastes to green pastures. The other valleys of the continent appear from the imperfect accounts of them to be unpromising regions for the work of the irrigation engineer. Where, as in parts of the extreme

South, the country is so arid as to need artificial watering, there are no streams of sufficient volume to serve large areas.

In Australia, because of the prevailing arid character of the greater part of the surface, there are no very extensive areas whereto water can be brought; yet the southern and eastern faces of the continent afford some considerable fields where the process is applicable. From the general conditions of the country it seems likely that the food-yielding capacity of this land may be more than doubled by the systematic distribution of its scanty rainfall — scantier than that of any other continent. At best, however, this realm is for its area the least hospitable of all to man. It is doubtful if with all the resources of engineering skill it can be made to support, in the present scale of subsistence of its folk, more than one hundred million people.

It is in the Americas, particularly the northern of the twin continents, that we find the most numerous and extensive fields which can be won from desert conditions to fertility. The reason for this is to be found in the long mountain system which borders the Pacific Ocean from Alaska to Patagonia; though it is interrupted in the Isthmus of Darien, it is so nearly continuous that it may be regarded as one chain of elevations — by far the longest in the world that has a like unbroken nature. This belt of elevations lies across the general course of the winds with the result that in North America they serve to bring about the principal rainfall on the western slope of the ranges, and in South America to fix it mainly on the eastern side of the barriers. The actions are not quite as simple as here stated, for there are sundry local complications arising from details of the air currents and the height of the ranges, but for our purpose these details may be neglected.

The result of the condition, due to the systems of the winds and of the mountains, is that South America has a relatively narrow belt of arid land extending along the greater part of its western shore. In this section the natives, before the Spanish invasion, had developed a certain limited amount of irrigation. The conditions do not permit any extensive use of the method, for the streams crossing this arid belt are few and small. Moreover, the total area that could under more favorable conditions be watered is too limited to have any general importance. South of the southern tropic on the eastern slopes of the Andean ranges, there is an extensive district which, though not an arid desert, is, after the manner of the great plainland of North America on the western side of the Mississippi valley, in need of irrigation to make it suitable for agriculture. Within the tropics the continent has a climate of a humid character, so that artificial watering is not necessary to give it fertility, though in many parts of this district it would by avoiding the seasonal droughts much increase the returns of the fields. Thus, although South America has, with the exception of Europe, which is really but the western fringe of Asia, the smallest proportion of arid deserts of any of the great lands, it is likely to be in time the most extensive field of that form of irrigation which is used to supplement the rainfall where it is scanty or seasonably ill distributed.

North America affords the most numerous and varied opportunities for the application of irrigation of any continent. No single valley has the possibilities of the Nile, but the aggregate flow of the many rivers which can be turned to account much exceeds that of the African stream, and the fields to be won are, save those of Mexico, all well beyond the tropics and, therefore, much better suited to the habit of our Germanic people than the Nilotic valley. In Mexico, the streams that may be used for irrigation purposes are of small volume, few of them deserving the name of rivers. Owing to the fact that the Spaniards from their contact with the Moors long ago acquired the custom of irrigating, their descendants and the Indians with whom they have mingled have brought the system of artificial watering nearly to perfection, with slender possibilities of further development.

Within the limits of the United States there are four great valleys where the conditions lend themselves admirably to irrigation, and numerous other lesser drainage systems where there are large but rather local possibilities of its application. These greater areas are those of the Rio Grande, the Colorado, the Arkansas, and the upper Mississippi. Of these, the Rio Grande is the least important; moreover, the water belonging to it is already so far led upon tilled fields that no considerable extension of the process is possible without extensive storage of the scanty floods in reservoirs — a doubtful resource in this valley, for the reason that the evaporation in the very dry climate is so great that most of the impounded water goes away to the air. In the Colorado River we have the most important stream that traverses the really desert section of the Cordilleras. In its conditions of supply and its journey from the mountains of Colorado to the sea, it more nearly resembles the Nile than any other great stream of this continent. In the high country where it has its source, the melting of the abundant snows affords a large flow during the summer season. In part, this water is available for fields above the Grand Cañon, but in larger share it, so to speak, belongs to those of the lower, extremely arid, desert of Arizona. It will be no small engineering feat to divert the tide of this river from the gorge through which it flows and to lead it upon the fields which are waiting the chance to bear the marvellous crops that sunshine and water will bring upon their rich soils. Yet it seems quite practicable to do this work, and the returns from some million acres of irrigated land will repay the cost.

In the upper Arkansas River we have a stream discharging into the Mississippi system of drainage which has its head in the same highlands as the Colorado and, like it, is nourished by the melting snows.

The opportunities of irrigation from this stream are less than in the case of the Colorado, yet they are more readily available than in the case of that river. The fields they will win to fertility, already in part watered from its stream, are not completely arid, so that the ditches have but to supplement the rainfall. The ground to be won lies on the great western plain which, next to the mountains from New Mexico northward, has a precipitation which just grazes the amount necessary to support a scanty pasturage, but is scarce half what is necessary for tillage.

By far the most important field for irrigation in North America is that of the upper Missouri and its numerous branches. In this system of valleys from the Platte upward to the head-waters of the streams, the rainfall, though sufficient in quantity, is not so seasonably distributed as to make agriculture safe. There is, even in the summer season, water enough in this system of rivers to supply the addition required for the crops on some million acres. In this valley there is, moreover, a remarkably good chance to store water by means of reservoirs. In common with the other streams of the arid parts of the Cordilleras, there is a lack of lakes such as make the vast opportunity of the Nile, but there are many instances where the streams pass through narrow cañons with a broad area of plains above the gorge affording excellent sites for water-retaining dams. The general structure of the Cordilleras makes these conditions very common, but in the excessively arid and hot regions of New Mexico, Arizona, and Nevada the small size of the streams and the very dry, hot climate make the process of retaining water generally impracticable. In the cool, and relatively humid, climate of the upper Missouri, where standing water is sealed by ice for six months of the year and the air is not very dry except in the growing season, it is profitable to retain the spring floods for summer use.

On the Pacific slope of the continent the opportunities for the irrigation of arid lands, except that afforded by the Colorado, are relatively small. The greater part of what can be done there is in the way of supplementing the rainfall. In the drainage of the Oregon River there are some fields of arid desert which may be, in part, won to tillage by its abundant waters, and by irrigation projects, at present beyond the limits of the practicable, but well within the possibilities of the centuries to come, when the whole of its head-streams may thus be diverted to the enhancement of the food-giving resources of this region. Southward along the coast numerous streams may thus be used for the enlargement of the tillage area or for the betterment of the agriculture where else it would be but scanty.

It is, as yet, impossible to estimate with any approach to accuracy the amount of arid land in the United States which can be won to the uses of man by irrigation. It seems evident, however, that, including not only the free flow of the streams which can be thus turned to account, but also the possibilities of retaining the waste water in reservoirs, there will be a gain in the food supply sufficient to provide for the needs of something like fifty million people. Besides this gain from the fields, which otherwise would be absolutely useless to man, we must count the great enhancement in the food-giving value of vastly more extensive areas where irrigation will be used to extend the yield now obtained from land which is accounted fertile. Nearly the whole surface of this country is under-watered in the growing season and is, moreover, liable to severe droughts which limit the yield of crops. It is a safe general statement that the average returns from the soil would be at least one-third greater than is now obtained, provided the farmers were able to supply their crops with water at the critical time of their growth. With forage crops the yield would be at least doubled by such a provision. We have proof of this in all our agriculture which has attained to the intensive state: thus in all high-grade market-gardens it is found advantageous to supply water, even by steam pumps, so that the need of the plants may surely be met. By the use of this means the production is doubled in quantity, and a certainty of returns assured. Although here and there this higher stage of tillage has begun in this country, the economic conditions do not yet justify it on a large scale or in ordinary fields devoted to the production of the great staples. Within a century, however, we may expect to see the process attain a great development, and to become a characteristic feature of our agriculture, with a gain in soil products which will near double the capacity of the land for sustaining man.

In the fully developed state of the earth we may expect that most of its land-waters will no longer flow to the sea but will pass back to the air by evaporation from irrigated fields. The effects of this process will be manifold and altogether advantageous. It will enhance the yield of all those regions where the rainfall is not so adjusted as to fit the needs of crops, say, at least, nine-tenths of the total area. It will very greatly increase the returns from the leaner soils where moisture is abundant, say on about half the surface of the lands, for there is little of the earth where with sun and water a fair yield cannot be obtained. In this estate of earth and man we may fairly reckon that the sphere will begin to escape from the danger which attends the excessively rapid passage of its soil materials to the sea. The disintegrated rock will, save in the districts of mountainous slopes, remain long enough on its journey to give its full value to vegetation. Moreover, in proportion to the development of irrigation, the yield of crops will become less variable. This is a most important point, for at present there is a very serious waste of human endeavor due to the lack of uniformity in return for a given amount of labor applied to tillage. This variation may, indeed, be termed the primal curse of agriculture. If it be removed that form of toil will enter into a new realm — that of a true art.

The probable gain from the subjugation of the land-waters to the needs of man is not only to be found in the hundreds of millions of people who may thereby be fed, but in the better order of the earth for the uses of man, and in his bettered adjustment to its conditions.

V

LAND FROM THE WATERS

WHEN, in the process of building the continents, their surfaces are lifted above the plane of the sea, they normally became dry land, and, unless too arid, are fit for the uses of those flowering plants on which man depends for food. There are, however, a number of accidents which serve to retain a covering of water on these fields so as to make them unsuited to the uses of the higher plant life. The land may rise irregularly, leaving depressions on its surface which become lakes. Like depressions may be formed by the downward-sinking areas, by the process which geologists term folding. Again, glacial action, by the irregular wearing of the rocks or the curious irregular heaps of débris it leaves on the surface, creates a multitude of hollows, forming lakes, until they are converted into peat bogs. Yet again, in humid countries mosses and even reeds may by their matted vegetation hold the rainfall as in a sponge, so that even hillsides become mantled with the boggy covering. Still further, the sea-shores have the amphibious zone of the tides, half land and half water, where the two "elements," as the ancients termed them, strive for mastery. The result of these conditions is that, when the critic man comes to survey the lands and judge them in general very good, he has to note that much of their fields has not effectively escaped the primal realm of the waters — that there is still much for his arts to mend.

It is surprising how large a part of the what-we-call land is so far occupied by water as to make it in its natural state unserviceable for agriculture. In the tropical regions these areas of bog and lake are least extensive; in that realm occupying probably not more than ten per cent. of the area. But in higher latitudes and in proportion as we approach the poles a greater part of the field is permanently inundated, so that from the parallels of 40° to the limits that climate sets on agriculture somewhere near one-fourth of the land area is in its primitive condition unsuited to the uses of man and has to be won to his service by the devices of the engineer.

In Europe, because of the antiquity and high grade of its culture, the process of winning the inundated lands to use has already gone very far, so far, indeed, that in ten centuries the aspect of the land has been greatly changed. Thus in Great Britain, at the time of Alfred the Great, near one-third of the area of the island was beset with marshes or with lands of the bog type. These impenetrable swamps appear in large measure to have formed the boundaries of the separate little kingdoms of the Heptarchy, and to have been even more effective barriers than the open sea. The redemption of these lands probably began in Saxon times, if not earlier, but it appears to have gone forward slowly until the reign of James I, when the population of England began to press upon the means of subsistence and the work of draining the fens was rapidly carried on. As an adventurer in this business Oliver Cromwell, it is said, had his first clash with his sovereign. Along with others he had an important drainage concession from the crown, one that was peculiarly favorable for the reason that a Dutch company had failed in the same undertaking. When Cromwell was successful and in a position to profit largely by his success, the impecunious Charles I appropriated a considerable part of his rightful gains. It is not unlikely that this action of the king had in the end to do with his discovery of the important fact that "he had a joint in his neck."

In Holland this process of reclaiming inundated lands has been carried much further than in any other country. When agriculture began in this region about the mouth of the Rhine, probably not one-tenth of the land now tilled was fit for that use. What was not covered with morasses lay beneath the level of the tide. In some fifteen hundred years the stout-hearted folk have made the most signal conquest ever effected by man in this winning of a state from the waters of sea and land. Work of the same nature and hardly less extensive has been done all along the lowlands which border the North Sea and the Baltic. Thus the fields of northeastern Europe, in Great Britain, Ireland, the

Low Countries, north Germany, and Scandinavia, which now support the agriculture of at least thirty million hardy people, have been won from bogs, marshes, and the bottom of the sea — areas which in America, save in a local and unimportant way, have been quite overlooked.

The task of winning land from the waters which has been so well done in northeastern Europe and, in some measure, throughout that so-called continent, is by no means completed. Even in Holland there are great works still under way which some time during the present century will make yet further additions of hundreds of square miles won from the shallows of the sea to its tillable fields. In Russia there are vast areas awaiting the drainage engineer to bring them to the service of man so that they may yield the food for millions of people. Even in Italy, that most ancient seat of high tillage and of crowded population, there are extensive projects for reclaiming inundated areas now under discussion. These facts show us that in the reserves of land to be won before the world is fully peopled, we have to reckon largely on the parts of it which are to be reduced to service by drainage. This reckoning is hard to make, for the reason that outside of Europe scarcely any attention has been given to the problems of drainage, so that but an approach to the truth is attainable.

First let us note that the most extensive of the inundated lands is the sea floor, and that from its shallower part next the land the important gains of Holland have been made. The conditions which permit such winning are very common along most sea-shores; an embayed area of shallow water, where the tides have a considerable rise and fall, and where the winds are constant and strong enough to serve for pumping, is always available; but the bottom of the area to be drained must afford the materials for a fertile soil as it, in fact, very generally does. It is not imperatively necessary that the shallows lie on the shores of a tidal sea so long as windmills close set by the margin of the area to be drained will serve to lower and keep down the water; there then is only the simple question of time and cost to bring the dyke's area into tillage.

The conditions of embayed waters of no great depth, and bottoms that will be fertile when drained are normally found about the mouths of the larger rivers. The reason for this is that a recent geological accident, the newest of all having a world-wide effect, consisted in a general rise of the sea to the extent of some hundred feet, due to the upward movement of a portion of the deep-sea floor. The gain of the sea on the land led to the flooding of the valleys of the greater rivers for a long distance upward from their ancient mouths; forming such great reëntrants of the sea as we have well preserved in the admirable examples of the Chesapeake and Delaware bays. In many cases these drowned valleys have been so far filled in with delta deposits, as in the case of the Mississippi, that the alluvial plain again projects out into the sea as at its mouth and at the Nile; more commonly there is an embayment, as in the case of Mobile Bay. In any event this inundated valley is certain to have more or less extensive areas of shallow water which, as in Holland, may be drained and turned to cultivated fields.

Besides the land won from the sea by the plants which develop the marine marshes in the higher latitudes, we find in the tropics a group of trees known as mangroves which have an even more swift and effective method of capturing land in shallow embayments. These trees are fitted to grow in salt-water silt, submerged it may be by some feet at high tide. They have long runner-like branches which, as they grow, extend outward and downward into the water of the bays until they touch the bottom, where they take root and form new crowns and stems which in like manner send their runners further seaward. In this way a mangrove swamp will speedily close over a shallow bay even if it be some miles in width, covering it with a dense low forest. While the trees are thus marching outward, their seed, long cylinders in form, with grapples at their lower ends, catch on the bottom as they drift away from the plant that bore them, rapidly grow to the surface of the water, and found new plantations. Beneath the very dense growth of the mangroves the scouring action of the tides and waves is arrested and a rapid deposit of plant and animal remains takes place, so that what was sea bottom is soon lifted to the state of a fresh-water swamp. As there are numerous varieties of mangroves in the tropical regions, some of which, as in Florida, extend their range to several degrees further toward the poles, the area they occupy and the land they have won from the sea are alike great. There is no basis for a reckoning as to the extent of their work, but it is evident that in the aggregate these fields must amount to some tens of thousand square miles, all of which have been brought by these remarkable plants into the state where the engineer may easily complete the work of converting them to the uses of man.

Although the basis for computation is imperfect, it may fairly be reckoned that in this debatable ground of the shore zone now occupied by mud flats, marshes, and mangrove swamps, there is a reserve of land awaiting such work of improvement as has been done in Holland, amounting to an aggregate area of not less than 200,000 square miles of land which with a fully peopled earth will be brought into tillage. As this land is of rare fertility and enduring to the tax of cropping beyond that of any upland fields, it has a prospective value as a human asset far beyond an equal area of ordinary ground. They are likely, in time, to afford the food for several hundred million people.

Turning now to the areas of the continents which are occupied by the fresh waters, as in swamps and lakes, we find a more extensive set of fields for reclamation than on the sea-shore belt — and a much greater variety of problems for the work of the drainage engineer. First we will consider the clearly limited group of areas which lie along the great rivers, where the annual floods render the land untillable. The higher parts of these alluvial plains where the annual inundations are such as to prevent tillage are easily dealt with by ordinary dykeing, and have been thus improved in all the great valleys of long-occupied countries. Yet there remains along the larger streams of Africa, the Americas, and northern Asia aggregating several hundred thousand square miles of naturally fertile land still unwon to use. A rough reckoning of these areas which gives only approximate results, indicates that the possible winning in the ultimate state of culture will amount to not less than 300,000 square miles with a tillage value for the area quite as great as that which may be had from the gains made on the sea-shores, or the possible subsistence of many million. If it should prove possible to till the middle and lower reaches of the great rivers which flow toward the Arctic Ocean, the Mackenzie in North America, and the several streams that traverse Siberia, the aggregate area of useful alluvial land may be much greater than is indicated by this reckoning.

The true morasses, those inundated fields lying outside the alluvial plains, are much more abundant than the winnable flooded ground beside the rivers. The most common of this group are the bogs formed in the lakes which gathered in the shallow pits that were shaped by the irregular disposition of the drift left on the surface of those areas occupied by the ice in the last glacial period. When that covering melted away these basins so placed as to hold water were almost incredibly numerous. Thus, in New England, when the earth was cleared of the glaciers, the number of them varying in size from areas of an acre to those one hundred square miles in extent were to be numbered by the tens of thousands. The writer has estimated that not less than ten per cent. of this district was thus covered with tarns or lakes. Taking the glaciated parts of the world as a whole, the disturbance of the drainage induced by the ice invasion probably brought about something like this proportion of inundated lands where in the earlier times the brooks and rivers had in their usual manner provided a complete drainage.

As soon as the glacial sheet had disappeared and the basins held in its débris were filled by water, a process of closing them began, a process which has been continued to our own day. Along the shores of each of those lakes where the waves did not have too much power to admit of such growth, a species of moss known as sphagnum, the form familiar in almost any swamp, found a foothold. The microscopic spores of this plant are readily borne by the wind for many miles from their parent stations, so that as fast as the pools were formed, the growth began, and as the ice sheet retreated the mosses were always ready to set about their peculiar work. Their task is, indeed, one of the most extensive and important of those performed by vegetable life. It is as follows:

Beginning with a delicate mat formed of the intermeshed fronds, the sphagnum mosses quickly form a shelf of their living and dead parts which extends outwardly from the shore and increases in depth until it may be some feet in thickness; next the shore it rests upon the bottom, but in deeper water it floats with its surface a foot or so above the water. From the lower margin of this raft of moss the dead parts of the plants fall upon the bottom and by their decay form the familiar black mud or soft peat which often gathers to the depth of twenty or thirty feet. Given time — and in a geological sense no long period is required — and a lake a mile or two in diameter will be closed over and solidly filled with the muck deposit. Only when the lake is of such area that heavy waves may form on it, which serve to break up the advancing mat of vegetation, is it preserved from this agent of obliteration. The result is that by far the greater number of the glacial lakes formed in New England when the ice of the last glacial period disappeared have been converted into peat bogs; probably more than nine-tenths of them have been thus closed. Further to the northward, where the ice went off in more recent times, than near its border, the process of occluding the glacial lakes is naturally less advanced than in New England. In these we more often find "quaking bogs," i. e., instances in which the sheet has closed over the lake, but where the deposit formed on the bottom has not been built up to where it supports the mat so that the peat-making process is complete.

The foregoing sketch of the history of peat morasses formed in lakes needs to be supplemented by an account of another method of their development, which in many parts of the world where the air is moist and cool gives rise to even more extensive deposits — those known as upland or climbing bogs. In this group the sphagnum begins its growth on the margin of any pool and extends its sheet away from the water so that it mounts slopes of considerable steepness, sometimes ascending to heights of a hundred feet or more in an advance of a mile. As it grows in thickness, the lower part of the mat dies and so forms an ever-increasing mass of soft peat on which the living tangle rests, holding, as in a sponge, the water needed for its growth. So effectively does it do this that in times of heavy rain the bog swells up and occasionally it bursts discharging a tide of black mud which flows like a lava stream, in many instances carrying widespread destruction to farms and villages in the valleys through which it flows.

In effect the fields covered by climbing bogs are limited to regions north and south of the parallels of 40° in either hemisphere, for there alone do we find the relatively low temperature and the high measure of humidity needed for their development. They originally mantled a considerable part of the land now tilled in the northern part of Great Britain, nearly all of the lower ground in Ireland, and much of the most fertile portion of Germany and Scandinavia, about the shores of the North Sea and the Baltic. They still exist in vast development in northern Russia and Siberia, in Patagonia, and in Canada. South of Canada, they are so scantily developed as to have no interest from our point of view. In Africa and Australia they find no place because of the high temperature or the dryness of the air, both of which conditions prevent the growth of the bog-making mosses.

It is not easy to estimate the amount of tillable soil which can be won from the fields now possessed by moss bogs; it may be taken as probable that the aggregate area exceeds 300,000 square miles, it being, perhaps, the largest part of the earth's surface which can be won from the covering of water. Should it prove possible to develop tillage in any considerable part of the tundra of Siberia the total may much exceed that amount; it may on those conditions rise to near half a million square miles.

As for the quality of the soil obtained from these peat-covered fields, experience shows that, though variable, it is good for a wide range of uses. The fields whence the climbing bogs have been stripped are of great and enduring fertility. The level bogs of the deposits which have filled lakes have a different character; they cannot so readily be brought to tillage. In fact, it is commonly necessary to strip the mat of living sphagnum off and then to cover the surface with sand or mix the upper part with ordinary earth. Thus treated the ground becomes well suited to a great range of important plants, especially those reared in market gardens. The interesting industry of cranberry growing is one of those forms of tillage in which the peat soil is turned to account. In fact this species of plant will not commercially develop in any other conditions save those of drained swamps.

One of the largest bodies of unwon yet winnable lands is that now covered by the waters of lakes. There drainable areas are very numerous, especially so in glaciated districts in the part of North America recently occupied by the ice-fields. There basins are to be reckoned by the tens of thousands, and their aggregate area is probably not less than fifteen per cent. of the field in which they lie. The greater number of them, though probably not half of the total surface, are to be, in whole or in part, drained and brought under tillage as soon as population begins to press upon means of subsistence. The ground thus made available for tillage is likely in North America to amount to not less than twenty thousand square miles.

The quality of the soil to be won by the drainage of lakes will in most instances be excellent. These areas of water, though in practically all instances of geologically recent origin, have been long enough in existence to have enriched their bottoms with deposits of lime phosphate and other materials favorable to the growth of plants. The soils drained from these accumulations will be prevailingly clayey and rather heavy, but very little enduring to tillage and of far more than average fertility. They may be reckoned on to afford fields as well suited to agriculture as the heavy land of northern Ohio, Indiana, and Illinois, where much of the surface took on its character below the former extension of the neighboring Great Lakes.

Although the greater number of drainable lakes and the largest aggregate area of them lie in the glaciated districts, there are many such in parts of the world where the ice-sheets have not shaped the surface. Other fresh water basins are among the results of mountain-building actions which have lowered considerable areas, forming such lakes as the Dead Sea of Judea, or the extensive lakes of the upper Nile. Many of these basins are so deep, their bottoms often lying below the sea level, that complete drainage is impossible in many, if not most instances. However, the conditions often make it possible to lower the surface of the water to such an extent that large fields of good land may be won.

As a whole, the lake beds may be reckoned on as likely to afford, in the ages when the earth is crowded with men, a resource in the way of tillable lands in area comparable to that which may be had from the deserts, the morasses, and the shallow fringes of the sea.

VI

THE PROBLEM OF THE NILE

GREAT rivers have always been rich in problems that concern mankind. Even in the savage state they set bounds to his movements as they do to the distribution of all creatures without wings. With the advance to the barbarian state, and thence to civilization, they constantly became of greater importance. On them the beginnings of navigation were made, and their mouths gave access to the oceans and created the temptation to seafaring. The alluvial plains of the rivers, their most characteristic feature, afforded the best sites for the development of agriculture; there the fields are invariably rich, generally continuous, and enduring to the rude tillage of primitive folk. The stream gives a path for commerce, and the escarpments of the table-lands on either side or the islands of its margins afford strongholds that are easily defensible against the marauding savages with whom the beginners of civilization had always to contend. It is clearly in the nature of things that the most of the first considerable upward steps in civilization should have been made beside the margins of the great rivers or on the borders of the greater seas where similar opportunities for economic development are found. We may note, in the development of the Jews, an apparent exception to this rule that men are dependent on natural ways for their advance. Their seat, though near the sea, was essentially inland, but we know that the important cradle-land of the people was the Nile valley, and that there and in Mesopotamia by large rivers they were to a great extent shaped for the part they were to play.

To the economic interest of rivers, which has been only lessened by the conditions of our modern civilization, we have to add that which has come from the development of geographic science. We now see that water channels of all sizes, but particularly the greater, are indices not only of the geologic structures they traverse, but of many other phenomena, such as the massive tiltings of the continents, the growth of mountain ranges, and the alterations in the level of the oceans. They tell us much concerning the ancient climates, of the humid and arid periods in former geological times. While every considerable river is thus rich in features of economic and scientific interest, the Nile and its valley are in these regards preëminent. It has contributed more to the development of civilization than any other, and what it has given and is to yield to engineering is of surpassing importance.

A glance at a world map will show the reader why the Nile valley held for several thousand years a peculiarly important place. The north African desert, save for occasional oases, limits the agriculture of that region to a strip of country near the Mediterranean.

This arid district extends to the eastward, including the Arabian peninsula and a large part of Asia Minor, as far as the valley of the Twin Rivers. Thus around the Mediterranean, from the Euxine Sea to the Pillars of Hercules, there is no navigable stream and none affording any considerable area of tillable land — except the Nile. These physical conditions for several millenniums protected the developing folk of the Nile valley from overwhelming invasion of less advanced peoples. Grace to this shelter of the deserts, the dwellers of the Nile were able to establish what seems to have been the first community that rose above barbarism. For about five thousand years, though subjected to repeated attacks, and several times conquered by foreign powers, their civilization seems never to have been broken up and the people to any great extent replaced by alien folk, as has been the case in other regions.

The exceptional continuance of the Egyptian people is to be accounted for by the singular, indeed, we may say the unexampled, conditions of the river which makes their land habitable. The Nile gathers all its water in the regions of eastern central Africa between the northern tropic and the equator. In that elevated district the rainfall is heavy and seasonal, the greater part of the precipitation occurring in the winter time. As the streams which collect it are long and pass through several lakes and great morasses, the passage of this annual tide to the sea is slow, and the discharge is continued for a period of some months, so that the alluvial plains on either side of the stream are subjected to long-continued and very regular inundations.

The passage of the Nile from the region of very heavy rainfall to that where the precipitation is so slight that there are no permanent streams is sudden, the change taking place in a distance of a few score miles. The result is that after passing the upper cataract the stream enters upon an arid district which rapidly becomes a desert as destitute of rain as any other equally extensive waste in the world. Thence to the sea, for a distance of about two thousand miles, it receives no contributions from the regions near its path, and but one tributary, the Atbara, a river which in the flood season brings a great tide from the mountains of Abyssinia. From the junction of that stream to the sea, the Nile has no tributaries save a few torrents, which are filled on those rare occasions, often at intervals of years, when a thunderstorm, such as is termed by our people a cloud-burst, occurs. In fact, from the mouth of the Atbara to the sea, the Nile steadily lessens in volume from evaporation.

The conditions above noted make the Nile in several regards the most peculiar river in the world. Other streams, such as the Rio Grande and the Colorado of North America, gathering the water in rainy districts, send their tide across deserts, but this work is not only done on a smaller scale, but these rivers occupy narrow valleys without extensive alluvial plains, or their flow is so slight as to be unimportant to tillage. In the

Nile, however, the conditions fit the needs of man as nowhere else. Owing to the fact that the land traversed by the river has in recent geological times been much higher above the sea level than at present, its stream originally formed a broad cañon-shaped gorge averaging about ten miles in width; when the land sunk or the sea rose to near its present level, the river deposits in large part filled in this depression, forming the existing alluvial plains and the delta. So that when men began their tillage they had at their service an area of some thousand square miles of exceedingly fertile land, which was covered in the springtime of each year by the extraordinarily regular and computable flood-waters.

Surrounded and protected by the desert which fended them from destructive invasions, the first dwellers by the Nile had an admirable opportunity to lay the foundations of a civilization. The sterile nature of the country on either side of the alluvial plain denied them all chance of subsistence by hunting or from flocks and herds, so they were compelled to give over those occupations which have so often held folk back on their way upward, and were forced to the better work of soil tillers. It seems likely that for a long period the agriculture of this field depended for its water supply on the annual inundations. The ground was delved before the flood came, and the sowing done upon the wet surface when it retired; hence the parable, "cast thy bread upon the waters and thou shalt find it after many days." Depending altogether upon the water contributed to the soil by the single annual flood, there could be but one crop reared in fields which were otherwise fitted to afford two or three in a year. So it naturally came about that a portion of the tilled ground near the main river was in time irrigated by means of various contrivances such as those now in use, the shedoofs and sakyais that border the river. Yet further betterment of tillage was accomplished by means of extensive irrigation canals and by storing water in reservoirs filled at the top of the flood to be used in the long dry season. With the needs of a population which appears to have been relatively exempted from the evils of war and famine, all the tillable land of the Nilotic plains was at an early time brought into cultivation much as we find it at the present day.

So far as I have been able to ascertain, the subjugation of the Nile valley was about as completely accomplished two or three thousand years before Christ as it is at the present day. There is probably no other equally extensive area in the world where the field of tillage has varied so little for a like period. In the time of Rameses the Great, the population-sustaining power of Egypt was probably about the same as it now is. There has been in recent times some increase of irrigation in certain districts, but these have in part, at least, been balanced by the abandonment of irrigation works in other parts of the country. As a whole, however, this land exhibits a singularly ancient adjustment of a people to their environment, one so early accomplished and so well maintained that there has been but little change in their customs or numbers for at least four millenniums.

Although in its long history Egypt has come under the control of many alien rulers, none of these masters down to the time of the last English conquest made any serious effort to better the conditions of its people by any considerable improvement in the irrigation system, or, indeed, in any other way that did not promise an immediate gain in their ability to endure further burthens of taxation. Upon the advent of the modern Englishman with the admirable training given him by his experience in India, where he had dealt with like problems, there came the beginning of a change in many ways the most remarkable that has ever happened to an unfortunate land. So much of this as relates to the administration of justice among people who had not known honest, foresightful ruling for nigh two hundred generations, does not concern us here. Nor can we attend to the very interesting political and military steps by which these the first merciful conquerors gained their hold upon the country. It is their task, in part already begun, in extending the tillage area of this field that concerns us.

So far the British rule in Egypt has been much hampered by the chronic dispute with other European powers, especially with France, as to the limit in time of this rule and the scope of the control of these new masters. Those grave questions have now been effectively disposed of, except that in respect to the claim of Turkey to suzerainty, and that is a mere political ghost. We may, therefore, assume that Egypt is henceforth to be even more completely in the hands of Great Britain than Hindostan, and this under conditions which permit a much freer exercise of power and a more complete execution of great plans for betterment than is possible in India. In the Indian possessions the work of improvement is hindered by the existence of many independent states, by great diversities of race and of religion, as well as by the number of the people, which amounts to near one-sixth of the world's population. In Egypt the folk to be dealt with, in all not more than ten million in number, are, as regards those features which have to be considered by the government, singularly uniform in quality, and in the region below Nubia a most obdurately contented and laborious folk. In the equatorial provinces, the district about the head-waters of the Nile between the northern tropic and the equator, where the people have not been subjugated after the manner of the fellaheen of Egypt proper, there is danger due to the curious recurrences of what may be termed the Mahdi madness, arising from the chronic expectation, among the Mahomedans, Arabs, and negroes alike, of a new prophet who is to lead all Islam to conquest. Since the battle of Omdurman there have been several pretenders to the title of Mahdi who have speedily won followers, but the ease with which their movements have been crushed shows pretty clearly that there is not much danger of trouble from that source. We may safely assume that with the economic development of the tropical section of the Nile valley the population will be completely at rest, and that the British government will find no hindrances in going forward rapidly in the organization of work for the development of the whole valley, except so much of its head-water districts as belong to Abyssinia.

On the basis of the foregoing all-too-brief account of the general conditions of the Nile valley, let us proceed to examine into the possibilities of its economic development by irrigation under British control. It should first be noted that the work already undertaken has wisely been directed mainly to extending the ancient system of irrigation in such a manner that a larger part of the area of Egypt proper, i. e., the region below the first cataract, should be watered from canals, and thus be able to give two or three crops a year in place of the lesser yield derived from the variable annual flood. The dam already established below Cairo has fairly well provided for the needs of the delta region. That at Asyut has been built in order to extend the range of the canal service and, incidentally, to better the navigation of the stream. That at the First Cataract has the same object, though it will store a large amount of water which will help to maintain the flow of the river in the season of low water, and slightly lessen the flood when it is dangerously great. It will also supply canals at a higher level than those now attainable. The benefits of these improvements will be great; when they are completely applied by means of the subsidiary ditches which are required, they will add perhaps one-tenth of the crop-producing efficiency of the region below Aswân. Other like works designed to accomplish the same ends are possible within the limits of Egypt proper, and may in the end increase the food-giving value of the part of the valley below the First Cataract to somewhere near twice its present amount, leading to something like a doubling of the population, and this within the lifetime of the present generation.

Great as has been the gain to the Nile valley from the work of the British engineers since the occupation in 1881, it is evidently but the beginning of the work they are to do, for when the river and the fields below the First Cataract are improved, so far as works below that point will better them, there will remain a serious imperfection in the system in that a great part of the alluvial plain will still be so long submerged that its yielding capacity will remain much below what it would be if the flood were prevented by a storage of its tide in the head-waters. It is evident that the larger future of Egypt, a future, indeed, larger than we can foresee for any other valley in the world, is to be found in the retention of the flood-water of the Nile in the region between the tropics, and in the fit distribution of it in the arid country along its banks for a distance of two thousand miles.

In some measure the problem of flood storage and the utilization of the store, primarily, for irrigation, but, incidentally, as a source of power, concerns the most of the great rivers of the world — those in the moderately humid as well as those in arid countries. But nowhere else is the matter so well presented or on such a scale as in the valley of the Nile. Here we find a seasonal and irregularly uniform flood, which begins to rise at somewhat various times in the different head-waters, according to the incidence of the rainy season. At Khartûm the rise of the Nile begins about May 20, and the characteristic green water of this section of the flood, derived from the extensive morasses further up the stream, arrives at the First Cataract about June 15, and at Cairo about ten days afterward. Upon this flood when it is near its height is poured the red muddy water of the Blue Nile, which begins to rise in the first week in July, and at about the same time the Atbara tide comes to top the inundation. The rise of the main river continues to about the middle of September. It is stationary for about a fortnight and then rises yet further, usually to the highest level of the year. Then, with fluctuations, it gradually sinks to the winter low level, the stream again returning within its banks in November.

The facts show that the continuous flow of the Nile is mainly from the branch known as the White Nile, which contributes only a small part, probably not one-fourth, of the flood-water. This tide comes from the Sobat, the Atbara, and the Blue Nile branches. The flow at the First Cataract is at the minimum only about 400 cubic metres per second, while at the maximum it amounts to 10,000 cubic metres per second, of which near one-fourth is lost by evaporation before it reaches Cairo. These main sources of the flood owe their rapid discharge of their contributions to the shortness of the rainy season in the basins they drain, to the steepness of their grades, and to the limited extent of the natural storage places, such as lakes and swamps. On the White or Main Nile there are extensive lakes and morasses which detain the flood-water and distribute the discharge over the greater part of the year, in place of concentrating it into a period of one or two months. We thus see that the problem, as briefly stated, which the engineers of Egypt's future have to face, is that of retaining the Nile flood in reservoirs and converting it to service in irrigation and as a source of mechanical power.

Before looking more nearly into the problem of storage of the Nile flood, let us consider what could be done in the way of extending the cultivable area of Egypt, provided the whole or even one-half the tide, which limits tillage and goes away directly to the sea, could be turned to account in watering what is now desert and in supplying energy for the arts. First let us note that all the arid district from the First Cataract to the sea, though it has a somewhat irregular surface, declines rather uniformly toward the shore, and is for the greater part in a position favorable for irrigation. Here and there it is intersected by valleys formed by rivers in a recent geologic time when the rainfall of this region was sufficient to maintain streams. These irregularities, though they would be somewhat inconvenient in the development of irrigation, would not prove a bar to such work. They would merely require either the lengthening of the waterways or the construction of aqueducts. We may assume that canals taken out at the site of the several cataracts could be made to deliver water to the most of the area lying within twenty miles of the river between Berber and the Mediterranean. In the section above the First Cataract the irrigable field would be narrow and of relatively little value, but below that point its average width would be much greater. It is impossible to estimate with any approach to accuracy the area of this potentially irrigable district, but it is several times as great as the existing fertile lands of Egypt. A very rude reckoning shows that it is from seven to twelve times as great, and for the irrigation of this desert realm there is abundant water in the Nile flood which now goes profitlessly to the sea.

As for the fitness of the arid soil of the arid country on either side of the Nile for the uses of tillage, there can be little or no doubt in the minds of those who have seen how, at the touch of water, it at once becomes fertile. The so-called sands of the desert, though here and there true sands, are very different from the similarly appearing material on the sea-shores, or in glacial accumulations. They are composed of bits of rock of varied mineral composition, which are usually much decayed and are extensively mingled with organic matter. Everywhere in the Sahara, as in other deserts, there is a slight amount of rainfall which induces some growth of plants and a limited development of animal life, with the result that the materials of the soil, even when blown about by the wind, are rich in the substances needed for crops and yield largely when supplied with water. We see in the oases how even a trifling supply may serve the needs of palms and corn and afford a rich yield.

Concerning the engineering work required to retain any considerable part of the Nile flood so as to limit its long occupation of the fields and to afford water for reclaiming desert lands, there lack as yet the surveys which will be necessary for any accurate or even approximate determinations; certain points are, however, clear. The White or Main Nile has, near its head-waters, a number of great lakes, the Victoria, the Albert, etc. There are also extensive swamps which appear to have been originally open basins which have been filled with sediments. As before noted, the effect of these natural reservoirs is to delay the discharge of the flood-water from the western side of the head-waters, and to distribute the flow more evenly throughout the year. It would be a matter of no great difficulty to extend this process so that nearly the whole of the tide from the White Nile could be held back until the main river was at its ebb. The Victoria Lake has, it is reported, an area of 28,000 square kilometres, and it discharges through a narrow gorge at a height of about 3,600 feet above the sea. It seems possible in this basin to hold the rainfall of all the area that drains toward it a quantity sufficient materially to reduce the height of the excessive floods of the stream, to reinforce those which promised to be insufficient, and in time to irrigate an area far greater than that of Egypt as it is now limited. In a less extensive way storage is possible in other natural basins of the White Nile, probably to an amount that may in the aggregate be equal to that of Victoria Lake. It is true, however, that the whole amount of the water thus impounded during the rainy season would probably not amount to more than one-third of that which passes to the sea in the time when the main river is in flood.

The opportunities for the storage of flood-water in the eastern tributaries of the Nile, the Sobat, the Blue, and the Atbara, are as yet unknown: they are certainly much less than in the path of the main stream; yet as lakes are delineated in some of the imperfect maps of that region there may be natural opportunities for impounding water that will prove of value in the development of the irrigation system. It is to be noted, however, that even if there be no possibility of retaining the flood of this section and distributing it throughout the year, the greater part of their value could still be utilized. The duration of the flow from these rivers is long enough to permit their streams to supply water certainly for one crop on the fields they are made to irrigate, while by holding back the tide of the main Nile until that of its eastern tributaries was exhausted, there would be a supply for a second crop in volume probably nearly equal to that afforded by the torrential rains of the Abyssinian highlands.

Besides the food-producing value that can be won from the deserts by the storage and distribution upon them of the Nile flood, this waste water has another economic feature of much importance. At the point where the several branches of the main stream enter the alluvial plains they have a great elevation above the sea. At Lake Victoria this height is about 3,700 feet; at Khartûm about 1,300 feet. In general, it may be assumed that, with an irrigation system such as will within a century or so be developed, the waters will pass into canals at such a height that a very large amount of power can be obtained from their waters before they are brought down to the level when they will be turned upon the fields. At the several cataracts of the main river, between Asswân and Khartûm, there is an aggregate fall of over 900 feet; and at the First Cataract a minimum flow of 400 cubic metres per second, which rises to about 10,000 cubic metres at the height of the flood. Even a slight regulation of the amount of water in the stream would afford in this section of the river a large amount of power. It is thus evident that in the systematic development of this valley a very great amount of energy available for industries can be brought into use.

Thus while the water of the Nile will have to be applied primarily to irrigation, there is reason to expect that it can be made in a considerable measure to serve the needs of power. These needs in the Egyptian district are already grave. There are no ascertained deposits of coal or oil in this part of the world, and there are good reasons for believing that resources of this nature are not likely to be found in any of the countries about the Mediterranean. At present all the fuel for producing power has to be brought from western Europe at a cost which prohibits its use except for transportation and in a small way for pumping water. It should be possible in time to win from the streams a most important contribution to this need. The greater part of this power will have to be generated above the First Cataract and in the present state of the art of electrical transmission would not be available in the lower reaches of the river. But with the advance in the systems of conveying this form of energy we may expect for it a much wider distribution.

The large political results which are to develop from the British occupation of Egypt become evident when they are considered with relation to the irrigation problem which the Nile affords. There are, of course, certain advantages of a strategic nature afforded by the control of a country which, together with the stronghold at Malta, gives the empire mastery of the Suez Canal, the main pathway of commerce between the Orient and the Occident, as well as of the most convenient path between Europe and central Africa. With the completion of the railway from Capetown to the Mediterranean, Great Britain will have its firm hand on those parts of the continent which promise to be of value to our race. But the most important results of this occupation will be found in the development of a larger Egypt, which can be made by the use of the Nile flood in the irrigation system which is to manifold the area it now waters. At the present time the population of Egypt amounts to about 10,000,000, supported almost altogether by the tillage of somewhat less than that number of acres of land. The improvements in the seasonal distribution of water, such as are now in course of development, are likely to increase the population by at least one-half of the present total. Although there is lack of data for anything like an accurate reckoning in this matter, it appears evident that with an adequate and possible storage of the flood-water of the Nile desert lands in Nubia and along the lower reaches of the river can be won to cultivation which will afford food for a population at least five times as numerous as that now dwelling between Khartûm and the sea.

Not the least important feature in this interesting situation is the quality of the people in this valley. The Fellaheen, who form the principal part of the inhabitants of the district from the First Cataract to the Mediterranean, are an admirable folk, laborious, enduring, fairly intelligent, and with an immemorial training in the art of adjusting themselves to their overlords. Moreover, they are singularly prolific and, with the betterment of sanitation now in rapid progress, they are certain to increase as rapidly as the means of subsistence are enlarged. Experience in the campaigns against the Mahdi showed that as soldiers the Fellaheen are, at least when led by European officers, well fitted for such military service as is required in Africa. The negro stocks of the upper valley, though perhaps less serviceable material for the uses of civilization, are in their way excellent and promise to afford a valuable element in the future of the country.

Thus with the development of the part of Africa which can be watered by the Nile valley, the British empire will come into possession of the power necessary to give it dominance in the African continent. The Egyptians appear to be the only folk in that land endowed with the qualities required for the task of civilizing the tropical parts of its area. At present they are debased by millenniums of subjugation, but they have retained through it all the qualities which under British leadership may solve the African problem.

VII

THE MAINTENANCE OF THE SOIL

FROM what has been said in the preceding chapters concerning the soil, it is evident that the critical point in man's relations to the earth is to be found in that coating of *detritus* on its way from the bed-rocks to the sea. That the relation is of the utmost moment is self-evident, for on it absolutely depends all chance of maintaining any considerable number of folk even in mere existence. For with the soil washed away, or reduced to sterility, the seas would be the only source of food, and men would become as the fabled icthyopophagi, a rare and scantily fed species, dwelling on the shores and subsisting on what the waters afforded.

At first sight, it seems preposterous to suppose that the soil beneath our feet is constantly slipping away into the sea, yet a very little observation, as before noted, shows us that this process is going on everywhere, in tilled and untilled fields alike, but far more rapidly in those that know the plough than in those which have their natural protective coating of vegetation. The rate of this motion mainly depends upon the inclination of the surface and the extent to which it is protected by vegetation; the amount of frost action, the rainfall, the occurrence of earthquakes, and other minor conditions somewhat affect the movement. In its natural state the average seaward movement of the particles composing a large area of soil may possibly be as small as a foot in a century. From something like that minimum it increases until it becomes so rapid that there is no soil coating retained on the surface, as is the condition on the areas where the bare rock is exposed.

In the naturally adjusted surface of the earth the decay of the rocks beneath the soil steadfastly and effectively provides for the renewal of the coating as it passes seaward. This process is going on in all regions except the relatively limited areas of the alluvial plains where the renewal is accomplished by the layer of silt laid down in times of flood. In this renewal of the upland soils the process is maintained and adjusted as to its rate by the vegetation living and dead. The plants act on the bed-rocks in ways that tend to disrupt them and to bring the materials into the finely divided forms in which they, along with decayed organic matter, form a life-sustaining earth. Until the soil attains a certain depth, the roots of even the lesser plants attain to the bed-rock, their slender fibrils enter into its crevices and, expanding there, seem to wedge the stone apart. As the coating becomes thicker, only the stronger trees reach down to their basement, and so this disruptive action becomes less. So, too, the decaying vegetation, by forming carbonic acid as well as other materials which promote rock decay and sending them in solution downward, serves to decompose the stony matter. The deeper this work goes, the less effective it becomes, so that it too is limited in its extension. The result of these checks on the process of soil formation is that the layer of broken-up rock which only needs to be mingled with the waste of plants to form a true soil is commonly of no great depth. In regions where the slopes of the surface are gentle, and there has been no glacial action in modern geological periods to sweep away the loose coating, it may amount to a score or so feet. Usually, however, it is not more than a yard in thickness.

Although the soil coating is a mere film on the surface of the rock sphere, it is the basis of all its higher life; that of the land absolutely depends upon it, for without the coating, however thin, there would be practically no living beings there. The life of the sea also, to a great extent, if not altogether, depends upon the materials which are taken into solution by the soil water, discharged thence in the springs, and sent by way of the river to the deep: there to pass, first, into the marine plants, and thence to animals that feed thereon. In fact, this layer of waste, which is ever slipping away in the streams to the sea, is a kind of *placenta* that enables living beings to feed on the earth. In it the substances utterly unfit to nourish plants in the state in which they exist in the rocks are brought to the soluble shape whence they may be lifted into life. All this process depends on the adjustment of the rate of rock decay to that of the movement of the renewing soil, from the point where it is formed to the ocean where it enters once again, as stratified deposits, into the crust of the sphere, in time, it may be, to tread again the round from rock to soil and thence back to sea.

At first sight it would seem that man's foremost duty by the soil was to stay this endless passing of *detritus* to the sea floors, and that the largest of the actions to come from his control of the earth would be accomplished by the arrest of this waste. A clearer sense of the process shows us that the movement must be allowed to continue, yet restrained within fit limits. It must go on for the reason that in any mass of broken-up rock, such as affords the foundation of the soil, more than half is of substances such as quartz that, save in small quantity, are useless to plants. Thus if the rock be granite the feldspar and mica and the small amount of lime phosphate are serviceable, while the quartz, which is apt to be in larger quantity, serves, as does the nitrogen of the air, as a mere vehicle for the really useful materials, the soda, lime, potash, etc. So it comes about that where the fields are so flat that the movement of the soil to the sea is too slow, the plant-feeding minerals may all be brought into solution and leached away to the streams, leaving the soil encumbered by the little-soluble, unprofitable, siliceous waste. The true aim, therefore, of a conservative agriculture, such as is to maintain the soil in shape to be useful to man for an indefinitely long future, is to bring about and keep the balance between the processes of rock decay and erosion in fitting adjustment.

Next after the problem of maintaining the soil as a structure with all the value it has by virtue of the chemical and mechanical conditions of the rocks whence it is derived is that of restoring to it the materials which are removed by cropping. In the state of nature these materials, such as the lime, phosphorus, soda, etc., which are taken into the plant when it is growing, are restored to the earth when it is dead, so that there is little waste of the precious store. But when in our agriculture the crops are taken away from the field and the soil elements they contain wasted, as in large measure they needs must be, the earth is deprived of its nutritive quality and inevitably becomes barren. The process of sterilizing may be slowed down by the use of barnyard manure, but it still goes on; only in very fortunate areas does the decay of the bed-rock keep up the supply at a sufficient rate to maintain fertility for centuries of tillage without resource to rock fertilizers imported to the soil. All the seats of ancient agriculture, except the alluvial plains where the annual floods bring their contributions of fertilizing silt, show this pauperizing effect of long-continued cropping with insufficient restoration of the waste it entails. In such areas we find that the used fields have shrunken from the hillsides to the lower slopes of the valleys, so that in a thousand years, as in many regions about the Mediterranean, it is evident that the acreage shared by the plough has been reduced, it may be, to half of its best estate by the combined pauperizing influences arising from the wasting away and the chemical exhaustion of the frail earth.

In considering what has to be done to keep this very sensitive vitalized coating of the soil in shape to do its fitting work for man, as well as for the other life of the world, it is well to begin with the matters relating to the over-rapid passage of the *detritus* to the sea when it is subjected to tillage. In its natural state the soil, except in the sterile deserts, is protected in large measure from the assault of the rain and winds by the coating of living and decayed vegetation which rests upon it and serves well as a defence. We readily note that on such a vegetated surface the winds, even the strongest, lift no dust into the air, while in the Sahara even a moderate gale whips up the finer particles of the *detritus* and bears them away, it may be for hundreds of miles, until they fall and are held down on a plant-covered area or are given to the sea. Thus from the north African deserts there is a constant and vast tide of soil material passing to the Atlantic, and from the arid region of central Asia the dust clouds pass to the humid region of China, there to be laid down in accumulations that have attained the thickness of thousands of feet and are constantly increasing in depth.

As regards the action of the rain on the surface of the soil, the normal coating of vegetation affords a shield quite as efficient as it is against the wind. Coming on such a surface, the water is held in the mat of living and decaying vegetation as in a sponge, and is only slowly yielded to the streams. The torrents that form in times of heavy rainfall usually come through and over the tangle for the distance of a mile or more. Even when the stream brushes aside the plant-covering and attacks the soil, it finds the material compact and interlaced with roots, so that the destructive work goes on slowly, and in the intervals between the flood seasons the wear is repaired by a new growth of vegetation. On the other hand, when the field is stripped of the native plant-covering and stirred by the plough, both wind and rain have open way to their destructive work. For a time, between the overturning of the soil and the growth of the planted seed the process of erosion is swift. A single gale may strip off from the dry surface and bear away more of the soil matter than would have been blown away in a geological period, and an hour's torrential rain may wash off to the sea more than would pass off in a thousand years in the slow process of erosion which the natural state of the earth permits.

Looking closely to this matter of soil wasting under the conditions of tillage, we note that the speed of it is determined by certain controllable conditions of the fields. The action of the wind, the least damaging of the two agents of destruction, depends on the dryness and roughness of the exposed surface. So long as that surface is moist, the air, however swift its motion, finds the particles firmly held together by capillary attraction; even if it be moderately dry, yet smoothed as by a roller, the wind does little effective work. The damage done by the rain upon tilled soils is in proportion to the steepness of their slope. When, as in the alluvial plains of the great rivers, their slope does not exceed two or three feet to the mile, on the alluvial plains it is much over-balanced by the contributions of sediment laid down by floods, but only a small part of the earth's surface, probably less than the fiftieth part of its cultivable area, consists of such flat ever-renewing soils. Nearly the whole lies on declivities having an inclination of from one to thirty degrees of slope. Probably near one-half of the soil areas that can be made to yield food for man has a slope exceeding one hundred feet to the mile.

The amount of rain erosion in tilled soils rapidly augments with the increase in the slope of the surface. While a field with less than 2° of declivity may retain its soil indefinitely, and many such have endured tillage for thousands of years without serious loss in the thickness of the coating, others of like composition lying at an angle of 20° will be effectively destroyed in a hundred ploughings. It is doubtful if there is such a field now fit for cropping which has been tilled for a century. It is clear on a mere inspection that in countries of considerable rainfall, especially where the precipitation is, from time to time, torrential, say to the amount of more than an inch in an hour, only those areas where the slope is at a less rate than 5° are fit for ordinary agriculture. As a whole, probably not more than one-half of the surface of the lands is in its natural slope and, without very special care, fit to be tilled.

With rare exceptions, the fields of all countries have been made to bear their crops without the least reference to the interests of future generations. Here and there in districts where the population has become crowded, we find that the steeper slopes have been terraced so that the tilled surfaces are made flat; this device, however, has been rarely resorted to except in the cultivation of the vine. The vineyard on the hillside is terraced, not that the soil may be spared for the men to be, but that the men who plant it may win better wine for themselves. We may search the world over in vain for a field which has been cared for with reference to the remoter needs of our kind.

Of all the sinful wastes of man's inheritance in the earth — and all are in this regard sinners — the very worst are the people of America. Coming from the British Isles, where the rains are rarely torrential and where the average declivity of the fields is not great, to a realm where land could be had for the asking, our folk developed an almost incredible carelessness in their tillage. In the New England district and westwardly the glaciated surface, generally covered by a thick and porous layer of *detritus,* was not commonly liable to rapid removal of its soils, so that in this region, with no thanks to the husbandmen, the damage as yet done is relatively small and rarely beyond remedy; but south of there, and westward to the arid country beyond the Mississippi, the destruction has been vast and, over large areas, irremediable. Nearly all the fields where the declivity exceeds 10° and that have been stripped of their natural vegetation are so far worn away by the rain that they cannot be restored to their pristine fertility. A large part of them has passed away from the service of man. In the State of Kentucky, which has been occupied by our people for less than a hundred and fifty years and has not been, to any considerable extent, tilled for more than a century, something like a tenth of its tillable area has passed through this process of soil destruction, and at least a thirtieth part of it cannot be brought back to its original fertility in any foreseeable time. It must return to the forested state and, in that condition, through the ages, slowly gather again its mantle of soil.

To prevent the eventual destruction of the upland soils and with it the eventual, though remote, reduction of mankind to something like a fourth of its present numbers, it will be necessary greatly to better our methods of tillage with reference to the risks arising from erosion. In a word, we shall have to bring the average rate of this wasting process down to the conditions of nature in all the areas which have been won to the plough, and to maintain it on that ratio in the lands hereafter subjugated. We may expect, indeed, to reduce it below the pristine rate in many regions of steep slopes — those at too high an inclination to amass soils except by some benching process. Much work has been done on a small scale, it is true, yet effectively, in all the vine-growing districts of Europe and elsewhere, where, on slopes so precipitous that even the wild plants could not arrest the washing away of the decayed rock, benches serve to retain a profitable soil.

The first step, leading from our present age of neglect to that in which the soil is to be adequately — we may say religiously — conserved, will be by a classification of fields into those in which the decay of the bed-rock or other agencies maintains the mass in its best estate, and those wherein the inevitable loss is not so made good. So far no such classification has been essayed. Accurately to make it would require very careful and extended observations, yet in a rough, but sufficiently complete, manner it can be done by mere eye inspection by any one who is familiar with the symptoms of erosion. Wherever a field shows a trace of rain-storm gullying by temporary streams we know that the process of destruction is very rapid. Even where this evidence is wanting, but the brooks have muddy water that makes a deposit in the places where it does not move swiftly, we may know that the rate of soil removal in the region it drains is injuriously high. When a great river, such as the Mississippi, bears a tide of exceedingly muddy water to the sea, we may be sure that a large part of its valley is subjected to destructive soil erosion. Thus, within a narrow margin of error, it will be an easy matter to group the fields into say three classes, i. e., those that need no care to prevent waste; those where precautions as to the methods of tillage may restrict waste within the limits of safety; and those where speedy destruction is inevitable without such precautions as benching where they are to be tilled, or the maintenance of grass or forest covering. On the basis of such a classification there needs to be a rigorous legal control of our exploitation of the soil. It is idle — nay it is criminal — to sacrifice the bread of man to notions of individual rights in the earth. Granting all the most extreme individualist can claim, the right of mankind to the conditions that make its life possible must brush aside the ignorances and negligences of the momentary tenant. Until this judgment is expressed in adequate action man will not begin to do his duty by his inheritance.

The fertility of the soil, because it is a matter of immediate profit or loss, has always been of much interest. Even our American Indians, rude as was their agriculture, are said to have known that by burying fish in their cornfields they could increase the yield of grain. Among all peoples who make much use of agriculture there appears to be some knowledge as to the value of barnyard manure. The use of this material may be taken as indicating the second stage in the art of soil tilling. The third stage of the art — that in which resort is had to the mineral stores of the earth for the maintenance of the fertility of the soil — appears to be essentially modern and to have originated in northern Europe, probably in England, the first step being taken in the process, some centuries old, of covering impoverished soils with burnt limestone. It is to the development to this last stage in the management of the soil that we have to look for the prevention of the exhaustion which cropping under any other conditions of management inevitably entails.

The principle on which rests the plan of refreshing the soil by the use of mineral fertilizers is simple. We see that all the earth matter removed by cropping has been derived from the decay of the rocks whence the body of the soil has been derived. Only the nitrogenous and carbonaceous materials have come from the air by the action of the plant and animal life it bears; these are to be had in any amount through the mediation of its living tenants. Therefore to replace the waste we have but to find those rocks which abound in the needed fertilizing materials, treat them in a way that will bring the useful elements they contain into a state where the roots can do their work, and apply the stuff to the fields. While all this is plain enough in the light of recent experience with commercial fertilizers, it escaped public attention until within the last half-century, when a curious series of commercial accidents and iniquities made the matter plain. The story of it need be briefly told, for it shows the way to the new agriculture — that which promises an indefinite duration of the service which soil-film renders to man.

Very long ago the Indians on the west coast of South America, a people who had attained to the first stages of civilization, learned to use what they termed *guano,* i. e., the organic waste from the nesting places of the sea-birds, for fertilizing their well-tilled fields. They knew the value of this substance when the country was conquered by the Spaniards nearly four hundred years ago. Toward the middle of the last century this guano began to be imported into Europe, where its value as a manure was quickly appreciated. In a short time the demand for the material outran the supply, so that what was imported was mixed with various substances, ground bones, waste fish, etc. At this stage the rapidly developing knowledge as to the chemical nature of rocks made it plain that the lime phosphate, the most important element in the guano, could be had as well from certain mineral deposits as from the waste of slaughter-houses and the burial-places of old battle-fields. So it came about that the rock phosphates were used in adulterating the guano brought from the bird rookeries, or complete imitations were made, still bearing the original name. This stage was quickly passed and the superphosphatics, i. e., crushed phosphatic rock treated with sulphuric acid to make it soluble, replaced guano in the market. In the form of "fertilizers" it usually contains ammonia, to furnish nitrogen, and potash as well as lime phosphate, but the latter is the most important constituent.

So rapidly has this use of artificial, essentially rock, manures advanced that it may fairly be reckoned as the most significant and important of the great winnings of the last half-century. All the other improvements in the arts but add to our range of action or increase the comfort of life; this insures the permanence of civilization when else its end was to be reckoned on in a historically brief time. To see the full possibilities that the use of geological fertilizers opens to us we need only note in a general way the manner in which these deposits have been produced, and the amount of their accessible stores. This may be briefly done as follows:

Every plant in growing takes from the water of the sea or the like water of the soil a share of the dissolved mineral substances, brings them into organic shape, and, at its death, leaves them thus fit for life in soil or sea. On the sea floor the strata are partly built of this organic waste, so when they are elevated into the emerged lands and brought to decay the soil becomes fertile in proportion to the remains of life that entered into it. Where the rock is a pure sandstone the resulting soil will contain an excess of quartz and possibly be unfit for tillage; when it is a limestone, made up as these rocks are of animal remains, it is certain to be fertile. Where it is derived from the so-called igneous or plutonic rocks, such as traps or granites, it is likely to be fairly rich in lime phosphate, soda, and potash, for the minerals of these rocks commonly yield a goodly store of these substances needed by the grain-bearing plants.

The animals most engaged in rock building differ much in the amount of plant food they contribute to the sediments they form. Thus the corals and mollusca deposit lime carbonate, and the rocks altogether composed of their remains are not rich in phosphorus;

but all the crustaceans and certain bivalve shells of the *lingula* kindred have their hard parts formed largely of lime phosphate and the soils composed of débris from them are always rich in this most important substance for the production of grains. Thus the silurian limestones in central Kentucky, which are so enduring to ill treatment that for a hundred years of misuse they have brought good crops of Indian corn and wheat, owe their continued fertility to the existence in the strata of layers containing often as much as twenty per cent. of lime phosphate, which is continually coming into soluble condition and so replaces the waste.

The extent of the deposits containing a sufficient share of lime phosphate to provide for the refreshment of our grain fields is not yet definitely computable. The demand for such materials is so recent, having been active for less than half a century, that only a small part of the world has, as yet, been searched for them. The subject is of such surprising interest that a brief summary as to the modes of occurrence of lime phosphate may well be given. The conditions are in general as follows:

First to be noted are the deposits of crystallized lime phosphate known as *apatite,* a hard, greenish mineral commonly found somewhat plentifully in veins occurring in granitic rocks. This is one of the richest forms of the substance, but, though at one time considerably used, has been replaced by the lower-grade but more cheaply won materials from the stratified rocks. These occur in a great variety of conditions in all of which the deposits have been concentrated from an originally more diffused state in the strata. Sometimes, and importantly, the accumulation is in the form of a bed just below the soil on top of the bed-rock, representing the waste left in the leaching away of the strata which have disappeared from the area. This accumulation has been brought about by the action of the downward percolating waters which, in passing through the soil, become charged with carbonic acid gas; thence, passing into beds containing lime phosphate, they take that substance into solution and bear it on downward until they come to a deposit of lime carbonate, then they lay down the phosphate, because the carbonate of lime is more soluble; the released lime phosphate gathers into a sheet or, more commonly, into nodules of the substance. There are other ways in which this concentration may be affected, but that just above set forth is the commonest in occurrence.

The amount of these concentrated phosphates formed in the manner above noted is great; those of South Carolina, Georgia, and Florida have come into very extensive use in this country, vastly bettering the production of cotton and other crops. Like deposits are constantly being discovered in other lands. It is probable, however, that these concentrations will be effectively exhausted in a few centuries to come, so that resort will necessarily be had to the beds of rock much less rich in the precious material of these accumulations. The quantity of these is so great that they may be judged adequate for all the demand that we can conjecture for all the ages that we can conceive of man's tenancy of the planet.

As regards the other needs for the refreshment of the soil, especially the potash and soda, the sources of supply seem fairly adequate for an indefinite future. They are contained in various, but often large, quantities in the feldspars, the micas, in salt, and other common minerals. From these substances they can be won, though it may be in the case of potash at more expense than is now required for their production. There seems, however, no reason to apprehend that if we keep our soils from an over-hasty going to the sea, the generations to come will ever have occasion to blame us for the lack of their stores we have wasted in our careless neglect of their rights. Therefore we return, for a final word, to the danger arising from excessive erosion as the principal menace to the value of the earth as the dwelling-place of the higher life — that of man.

In the manner that soil-tilling men have ever dealt with the earth — as we for all our enlightenment are now dealing with it — the processes of tillage everywhere and in terms of centuries mean a progressive pauperizing of its vitalized part, the soil. So far as this degradation is due to a lessening of the chemical stores needed by plants, rehabilitation is possible, though at much cost, by resort to the mineral manures. So far as it brings about a lessening of the mass of the soil, except where the underlying rock is breakable by the plough — a seldom condition — the damage cannot be remedied save at the impossible cost of importing soil from other fields. Recognizing then that the main aim of those who would save for the earth should be the preservation of the film that maintains the higher life, the question comes as to how this task can be effected.

This question as to the method of controlling the administration of the soil and other earthly resources is to be considered in the last chapter of this book, but in order to avoid leaving in the air the matter we are considering, it may be said that the only way in which the need can be met is by enforcing through laws the principle, clearly enough recognized in our codes, that the wealth a man controls is his to use but not his to waste. A man may not burn down his house or play the spendthrift with his fortune, because the state or his natural heirs will suffer from his folly or his malevolence. On the same ground the commonwealth-law should arrest his action if it wastes the substance of the unborn. It is an old and well-affirmed concept, though too little worked out, that our governments exist in part that they may guard and preserve the societies that build them. If such is their purpose, their first duty should be to see that the material foundations of mankind are not idly wrecked.

VIII

THE RESOURCES OF THE SEA

SO far in our consideration of the resources of the earth that have value to man, we have reckoned on those stores alone which the land affords. We have regarded the oceanic field as having no great value as a source of the materials needed for his subsistence. Judged by the conditions of to-day, we might well dismiss the resources in the way of food afforded by the wildernesses of the sea as we have those from the wild places of the land. They are interesting, but worth no more than a passing remark. But while the waters of the sea contribute at present probably not more than two or three per cent. of the food of man and but little else of prime importance to his immediate needs, there is reason to expect that in the future they may yield largely to his necessities through arts as yet in their beginning, but capable of indefinite extension.

To forecast the food-giving value of the sea in the time when the earth has been brought under the effective control of man, we have to note certain of its general conditions which bear upon the problem. First of these is the fact that the sea-waters are the great repository of the mineral materials which have been leached out of the rocks and soil to find their way to the deep through the streams. To this store is added the commonly very soluble rocks thrown from volcanoes in the form of ash and pumice and falling directly upon the waters. From these sources of supply the oceans receive each year several cubic miles of varied substances which are, or quickly become, dissolved in its waters. We know them in a gross way in the bitter saline taste — the saltness of the sea. Analysis tells us that in each cubic millimetre of the fluid there is probably a share of all the elements that enter into the earth and very many of their compounds.

Owing to the ample variety of materials in the sea-water and to the considerable amount of these solids which it contains, it serves the plants it feeds as the soil-water serves those of the land. These marine plants draw their nourishment from it just as the land plants do, only they take it not through roots but through the general surface of their bodies. Some of the multitudinous species of marine vegetation are fastened to the bottom, others, in great variety, float in the water, drifting in its currents. In amount this vegetable matter of the seas is probably equal to the plant growth of the land, though it is less varied in species and nowhere accumulated in forest-like masses. It is true that one of the sea-weeds of the northern Pacific Ocean is said to have a stem much longer than any tree is high, but for all that the marine plants are characteristically of lowly growth, as they are lowly in structure. Their real importance comes from the fact that they serve, as all plants do, as a medium of communication between the mineral realm and the animal. As is well known, animals cannot go directly to inorganic substances for their supply of food, but have to take it by the intermediation of plants which alone have the power of appropriating from the mineral kingdom.

Although the rate of growth of marine plants is probably slower than that of land species, yet because of the fact that the seas have about thrice the area of the lands and a large part of their life floats in the water, the aggregate production of vegetable matter is probably greater than that formed in the air. Moreover, practically all of this marine vegetation is at the service of animal life, while only a relatively small part of that developed above the sea level is accessible to animals. The result is that seas provide through these plants a store of nutriment such as the radiates, molluscs, articulates, and vertebrates require in quantity very much greater than that accessible to the animals of the land. The effect of this is seen in the vast amount of this life that feeds on marine vegetation or on the creatures that subsist thereon. Though there is no basis for computations, there is little doubt that in total bulk the oceanic animals very much exceed those of the continents, even in their primal wilderness state.

The foregoing considerations which, though very limited, may suffice to give the reader some notion of the body of marine life, at once suggest to him that there are vast potentialities in the way of food to be derived from the oceans, provided it ever becomes possible to turn the store to the uses of man. The range of these possibilities cannot as yet clearly be foretold, but that they are very large will be evident on a nearer view of the conditions which we will now seek.

At present, men the world about look to the life of the marine realm for a limited part of their food and a yet more limited share of materials useful in the arts — whalebone, oil, and the ivory from whales' teeth, shells for carving, pearls for ornament, fishes and sea-weed for manure, etc. It is evident that it is the fishes and molluscs and crustaceans that are in the future, as at present, to have noteworthy value. The sea-weeds may come to importance as a source of potash, soda, etc., provided resort is had to the floating sargassum or gulf-weed that so abounds in certain parts of the oceans. It may be found possible to gather this material by vessels constructed for the purpose, squeeze the water from it, and bring it ashore for the value there is in the ash of the plants. So too in time it may be found advantageous to collect the mud from certain parts of the shallows, using the material as manure. Still, the only large opportunity the seas afford is in the way of food.

It is to be noted that we now win from the sea, as primitive hunters won from the wildernesses, only a very small part of the food supply which those fields yield. As regards our access to the food nurtured in these wilds, we are worse off than the lowest savage in the woods with his spear or throwing stick. In that stage of human advance the most productive forest supplied so little that several square miles of it were needed to support a man. Brought to high tillage the area might be able to feed him from the products of an acre of its ground. The question therefore arises as to how far it is possible for the process of subjugation, such as man subjects the dry land to, to be extended over the watery realm. The answer is evident — not very far. We cannot till the sea floor; we cannot hope to replace the marine vegetation with plants more serviceable to man. The gain that may be won will have to be made on other lines of advance, so far as we can see, in the ways set forth below.

The most evident way to increase the amount of food derivable from the sea is that already entered on by the experiments in propagating marine fishes, which are conducted by our federal government. These experiments rest for their chance of success on the well-known fact that by far the greater part of the young produced by any of our food fishes perish before they attain maturity. Thus in the case of our common mackerel, the female lays some fifty thousand eggs, and of these, on the average, not more than two come in turn to reproduce. Moreover, the greater part of the loss occurs while the young are so small as to be sluggish and unable to escape their enemies. By hatching the eggs of this and other species artificially and maintaining the creatures until they can shift for themselves, it is fairly expected that, in place of one in twenty-five thousand, one in a dozen may live to be adult. So far, the trials of this project have been made mainly with the *anadromous* fishes, i. e., those like the shad and the salmon that run up the fresh-water streams to lay their eggs. The results have been amply successful, showing that the theory of fish growth and the accidents to which the young are liable is true. It has not been commercially successful with the other groups, such as the cod, haddock, etc., probably for the reason that these purely marine species are more given to wandering far from their birth-place, so that they are not so much exposed to capture by fishermen. There is no evident reason why we should question its success with them provided the breeding were extensive enough to stock the seas with the young which had been protected — not the wide oceans but the rather limited fields which a particular species is wont to inhabit. While the matter must be regarded as one for the future rather than for the present, there is no reason why man's care of the sea fishes that suit his needs should not become as effective as that of an English gamekeeper who cares for his stock of pheasants.

With the molluscs and crustaceans the hand of man finds much easier subjects for partial domestication than the true fishes. These creatures are less migratory, and lend themselves to processes of rearing and feeding. This art, already well developed in the oyster industry, can be extended to many species of molluscs fit for food and, probably, to lobsters and their kindred as well. By artificial hatching and the proper use of enclosed embayments of the sea, there is no doubt that the amount of food derived from its waters could be greatly extended.

There is a field of experiment not yet essayed, in the matter of marine animals, which deserves consideration. This is as to the possibility of developing varieties and even species specially fitted for the needs of man. Among the fishes, at least, we know that we have forms that can be readily changed by the breeder's art. It seems altogether likely that, in the time to come, we shall have many products of this art introduced into our fresh waters and into the sea under conditions which will give them dominance over the existing forms. This is evidently possible with those species which include the greater number of the so-called food fishes that have the habit of dwelling in the shallow waters near the shores, and when they make seasonal journeys usually seek to return to the fields they have temporarily left.

It is probably not yet the time to undertake any extensive experiments in hybridizing or otherwise improving our marine food-giving species of animals. Such undertakings probably better await the further development of our knowledge of heredity — of that vast complex of actions which modern science is exploring. Moreover, the need of sources of food is not yet what it is to be in the time to come. Here and there, as yet but locally, population is pressing on the means of subsistence, but until the tillable lands are subjugated, it will not be worth while to undertake those vast essays necessary to develop the latent resources of the oceans. There is, however, evident use for an international work in the study of marine life from the point of view of its general economic importance. We have already excellent government commissions for the study of local fishery problems, but, so far as the matter relates to marine animals and plants, there is need of a board which shall deal with the matter in a far wider manner than any bureau can. At a trifling international cost, say that required for the maintenance of a small squadron of modern warships, we could have a study made of all the food animals of the oceans as well as extended experiments in naturalizing useful species on shores where they do not now exist. There are good reasons for believing that in this manner a large and immediate profit would be won. At the same time the way would be prepared for the greater task of domesticating so much of marine life as would lend itself to the service of man.

There is yet another interesting field for experiment with marine life which, if properly essayed, may possibly lead to the development of an important addition to the resources afforded by the sea. This consists in the domestication of certain species of seals. As is well known, among the many forms of these carnivora there are a few which readily lend themselves to domestication. The common seal, the *Phoca vitulina,* of the north Atlantic coasts, is perhaps the most tamable of any of the wild carnivora. Made captive when young and reared by hand, it accepts man as a master quite as does the dog. It seems not unlikely that, if protected from hunters, certain species of these seals, including those whose skins are valuable, could be bred in captivity and by selection and colonizing not only made to yield more valuable pelts, but brought to inhabit the shores of many districts where they are now unknown.

The fact that the seals are prevailingly wide-ranging in their habits, journeying for great distances in search of their food, which consists mainly, if not altogether, of fishes, need be no hindrance to their partial domestication, for they have the habit of returning to their wonted breeding-places at a certain time of the year.

It is probable that the seals are the only marine mammals which are likely to be available for experiments in domestication, for they alone have the habit of resorting to the shore. The other marine mammals, the manitee, porpoises, whales, etc., seem to be quite beyond the possibilities of human control; but in this group of the seals there is evidently an admirable field of experiment, one that deserves immediate attention, for the reason that the most interesting and promising species are approaching extinction from the murder that is done upon them.

The sea-birds offer an interesting field for experiment in domestication and improvement. The flesh and eggs of many species have value as food and the feathers of certain of the ducks, as the eiders, are serviceable. In a condition of affairs when the hunter has ceased to be, it should be easy to develop rookeries on many a hundred miles of shore where desolation now abides. The birds of these marine species, such as the sea-pigeons and the eider ducks, gather their food over wide ranges and find it in marine species which are of no service to man. They do not interfere with the fishes that serve for his sustenance, so that any increase in their species would in no wise lessen the value of the existing fisheries. Nearly all the rock shores of high latitudes about the North Atlantic appear to be here and there well suited to the needs of these sea-fowl. Wherever there are cliffs and isles so isolated that the foxes and other predatory mammals cannot have access to the nests of these birds, one or another species will flourish. In the primitive conditions of this region, these shores were amazingly rich in avian life, but man, like his kindred the monkeys, is by nature a nest robber, and the devastation he has wrought is nearly complete.

It is not yet known how far the marine birds are improvable by the processes of breeding. It is, however, to be noted that every one of the social species which man has adopted have proved to be readily domesticable and lend themselves to the breeder's art. In fact, the class of birds, as a whole, is by far the most pliable of any in the animal kingdom. In size, quality of flesh, plumage, and the features of mind that make domestication practicable, the birds are singularly well fitted to be the servants of man. There is no reason to believe that, among the numerous species which have the habit of feeding at sea, there will not be found certain kinds which, with our ever-advancing knowledge of heredity, can be brought to lend us profit from their lives.

Thus while the oceanic realm is, and is likely ever to remain, an unsubjugable wilderness, there is fair basis for hope that, in time, its life may be made to contribute far more than it now does to the needs of man. In its depths the absence of light, and the consequent scantiness of life, make it essentially a desert. So, too, in the regions far from the shores, the life is commonly small in amount and consists mostly of the lower forms. But in the shallower water, near the shores, are the fields to which we may look for help in the ages when the world is to be taxed to meet the needs of our kind.

IX

THE CHANGES TO COME IN THE HUMAN PERIOD

IN looking forward to a geologically long sojourn of man upon this planet, the question arises as to the changes beyond his control that may affect his station for better or for worse. What are we to expect from within and from without; what alterations in his body and mind or in the conditions in the realm in which he dwells? The field is large as the seas and lands, and in exploring it we have little guidance, yet there are certain leading facts which make the effort worth our while.

It may at the outset be said that the span of human records, of any clear nature, taken at its greatest computable length of say eight or ten thousand years, is too brief to serve us as a scale. Looking forward for a like period we may be sure that no considerable change in man or in his environment is likely to come about; ten millenniums, measured in terms of human life, is a great time, but in those of the organic or physical history of the earth it is but a day. It is only as we look forward to man's fate, in some such period as half a million years in the future, that we may begin to reckon on alterations in himself and his surroundings that may radically affect his life on this earth. Taking this far view, what, then, does our knowledge afford us for guidance in our conjectures?

Knowing as we do that it is the nature of organic forms to undergo changes in the geologic ages, the most immediate question is as to the permanence of the human body; we would like to know whether our successors who are to inherit this realm are to be shaped like ourselves, or, if their form is to alter, in what directions the modifications are to trend. On this matter there is much light to be had from what we know as to the history of our kind in its long, slow passage from its station in the lower mammals to its present estate. This is no place for a discussion of the large mass of evidence that needs be adduced in a scientific presentation of the problem; we must limit ourselves to a few simple statements setting forth facts so well known to biologists that they may be deemed unquestionable, and to the legitimate inferences to be made from them.

An inspection of the facts gathered from the geological record and from the living species of mammalia shows us that the body we inherit was, so far as its most essential features are concerned, determined on at the beginning of the mammalian series. The limbs, muscles, organs, character of skin, and the relations of the several parts were in existence in the first of the suck-giving vertebrates, certainly as far back as the Triassic, and, probably, in the Carboniferous period. No computations of geologic time make this beginning less than ten million years ago: it is probably more than ten times as remote from the present day. So far as we can see, there has been but one physiological change marked by the development of a new structure in this series leading to man. This consisted in the invention of the *placenta,* a functionally important modification which has not changed the general shape or quality of the body.

Beginning with all its structural elements determined, the placental mammal has effected its advance without any innovations in the way of bodily parts, and altogether by minor alterations in the number, shape, and proportions of the apparently unchangeable plan to which it has adhered. In the lower part of the human genealogical tree among the mammals in general, up to the time when our ape-like ancestors were shaped, the body was more plastic than in its upper portion when it began to take on the man-like aspect. Since the beginning of the anthropoids, or human-like forms not yet of man's estate, the changes have been but slight and altogether in the proportionate length of limbs, size of brain, etc. It is evident that, due to some cause that we have not as yet ascertained, the series of animals that led from the marsupials to men is the most unchangeable of any known to us in the type of vertebrates, but that this rigidity of the body has been progressive is shown by the fact that the *genus homo,* though the most widely distributed over the lands of any vertebrate, and meeting a singularly varied environment, has its several speçies very closely related to one another, the differences being far slighter than we are accustomed to find them among forms having such a wide range.

There are a number of organic series which have attained something like the fixity of structure which we find in man. Certain groups of fishes, reptiles, and batrachians among the lower vertebrates show the same feature of stability. This quality is found also among the molluscs and articulates; it would not be difficult to gather a list of half a hundred instances of persistency in anatomical structure essentially like that of man. Whenever once fixed the form does not again become variable; it abides in its rigidity until it ceases to be. Furthermore, the fact that a group has become invariable appears in some ways to insure it great longevity. This is in certain instances perhaps because the particular adjustment is well contrived to meet the ills that come from within and from without, and so the shape endures; but more commonly it appears to depend upon a certain fixity in the form itself which prevents it from altering, however great the need of change, in order to adapt the structure to the conditions of environment even though they be greatly changed. A good example of this is found in the crayfishes that have retained essentially unaltered the lobster shape since when, in the Carboniferous period, they separated from that marine group to become the tenants of the fresh-water streams. In their new station their habits of life are utterly different from that of their ancestors in the sea. They have been forced to make very radical changes in the stages of metamorphoses through which their young pass on the way from the egg to the full-grown form. They have been led to construct extensive and complicated systems of subterranean ways, totally unlike anything done by marine crustaceans, yet the adult form has undergone no important alteration since it dwelt in the sea mayhap fifty million years ago.

In man we evidently have a genus that is in some way, so far as the body is concerned, essentially immobile. This incapacity for adjusting itself to changes of environment is not a novel feature in the genus: it is characteristic of the series to which it belongs, and has been more and more affirmed with the advances toward the human station. Therefore, unless man should in some as yet inconceivable way gain control of those conditions of inheritance which determine the shape of his body, he will bide substantially as he is to the end of his history. It is in the highest degree improbable that the advancement of learning will ever give him mastery over the shape of his kind. So far as we can see, the conditions determining that shape are as inevitable as those ruling the order of the solar system, and as little within our control.

Though, so far as we can fairly conjecture, mankind of the last generation on earth are to be structurally the same as those of the first, there is good reason to believe that important changes of proportion are likely, we may say certainly, to occur. We base this opinion on the fact that they have recently come about among men. The several species and varieties of men which have developed are the product of conditions peculiar to particular fields, probably within less than one hundred thousand years. The difference between these stocks is not great, yet they are sufficiently clear to show that the human frame within a rather narrow range of alterations is capable of change. So far as we can clearly discover, there is no one evident tendency in these movements unless it is to produce individuals of larger size, and particularly of larger brain capacity, than the first of the genus, and to clear the body of the hair. The present writer is of the opinion that there is a prevailing tendency to certain slight modifications as, for instance, the enlargement of the great toe, and probably to a lessening in the size of the external ear. These changes, if they be real, show some fluctuation in the proportions of the human frame in the later-formed varieties of the kind; but they are far from indicating any tendency to depart widely from the primitive type by introducing new features, or by great modifications of those now in existence.

It has frequently been suggested that the body of man might be indefinitely altered by a process of selective breeding — stirpiculture — as it has been termed, so that even the organic type could be changed. As evidence of this it has been urged that the individual variations in the several human species are noteworthy, perhaps greater than in any other known species of mammal; by accumulating these diversities through systematic mating, it has seemed to some selectionists possible to vary the form without limit. Leaving aside the moral objections to this scheme, we note the fact that the weight of evidence concerning the process of originating new species and genera is now to the effect that the innovations do not arise by the accumulation of slight *variations*, but through the occurrence of sudden and great alterations, *mutations* as they are termed, which alterations have the value of new species. When the mutations occur, they are subjected to the selective process; if they are suited to the environment they abide; if they are unsuited thereto they disappear. Be it said that this view does not overthrow the hypothesis of natural selection. It merely transfers its effective action from slight variations, where it has always seemed to many able biologists of doubtful efficiency, to larger and therefore more easily selected and accumulated features.

It is in his intelligence that we are to look for the important changes in the nature of man. In that part of his being we find a measure of variability the like of which exists nowhere else in the organic realm. Between the lowliest and the highest varieties of living men the difference in mental power is so great that if like variations existed in their bodily parts, they would be assigned to different orders or perhaps even diverse classes in the type of vertebrates. From the most inferior normally developed human intelligence and the noblest the interval, measured in like manner, would be vastly greater than between races or tribes of men. It is not excessive to say that it exceeds the anatomical range from the fishes to the highest mammalia. Were it not for the fact that these differences are hidden under the unforming mask of our human shape, they would be overwhelming in their effect, such indeed, as to take away all sense of kinship with our fellows. Thus, while measured by physical standards, we must assume that the earth is not likely to come by a new anatomical genus of man, and may never attain even so far as a new species differing from those now existing as much as the Hottentot from the Aryan, it may come to know intellectual species, genera, and families of which we can form no conception. In the mind of man we have entered upon a new realm of life, one where development appears to have no such limitations as control the lower stage of anatomical history.

While it must be reckoned an essentially vain endeavor to forecast the psychic future of man in its fulness, there are certain trends which are evident and which concern our general problem as to the future of the earth. We see clearly enough that the best indicated of these trends is toward a more intimate association of the individual units of our societies. The primitive close-knit clan, with its family traditions as the basis of union, is now expanded into vast commonwealths where millions are united in social endeavors. This advance at every stage means the growing power of mankind as a geologic or change-bringing agent. We may expect to see this coöperative work, now but at its beginning, extended and affirmed until the folk of the time to come will be so united that their action will be as by one vast creature, controlled by a sympathetic understanding which will make it effectively an individual in its deeds. This with the control of energy and means of application of forces will make man a geological agent of singular capacity; under his command a large share of the energy available on the surface of the earth is to be applied to psychic ends. There are many ways in which the individual man is to become quite other than the man we know, but his world-might is to come from the economic sympathetic union of his endeavors.

Perhaps the greatest organic advantage that the future man is to win will arise from his avoidance of the tax that disease puts upon him individually and upon his societies. In the infra-human life this tax is so slight as to be of small consequence, at least among the vertebrates; it is not great among the lowlier tribes for the reason that the habits of brutes and brutal men do not lend themselves to disease, and even more for the reason that maladies mean the speedy removal of the sufferers from the association, and, as the result of the selective process, the protection of the stock from contaminating inheritances. It is when the weak come to be protected that the malady tax on the society in which they belong effectively begins. Thus the first result of sympathetic care for the invalid, that care which marks the first stage of the truly human society as distinguished from the mere herd, is to lower its capacity for action, so that in the existing conditions of our commonwealths the care devoted to the inactive absorbs probably near to one-half of their resources. There is reason to believe that we are now coming to a stage where the disease tax, which has hitherto mounted with the advances of culture, is to be diminished by the extirpation of maladies. This is evidently not to be accomplished by any hideous Spartan plan of destroying weak infants, but by a fitting care that such come rarely to life and that they do not send their weakness on to mar the race. We are rapidly coming to a sense that while the individual life has an absolute right to a seemly place in the world it has absolutely no inborn right to send its infirmities onward through the generations: that this question as to the fitness of the men to be belongs to the commonwealth and is to be determined by reason. It is also to be accomplished by the development of sanitation — in the larger sense of that large word — through which our kind is to effect the most important part of its difficult task of reconciliation with the environment.

The phrase "reconciliation with the environment" has a much larger meaning in the case of man than in that of any other creature. With the lower forms it represents, it is true, a great complex of actions from within and without which have to be brought into a profitable equation. The adjustment is not only with climatal conditions, but with the doings of a myriad other claimants for a place in the world; but the demands of these lowlier individuals are relatively simple — they include no ideals beyond that of sufficient existence. With man, however, because of his ever-expanding ideals and the desires they breed, the reconciliation is almost infinitely more difficult to effect. It is, indeed, unaccomplishable. Our kind may fairly be distinguished as a new type of being, one in which the movement toward adjustment with the surroundings is on an asymptote, i. e., a curve which constantly approaches the straight line, but can never attain it. With each advance in this process new desires originate, so that the finish to the process is infinitely remote, to be won only when he has in the largest sense of the word comprehended the realm.

Turning to the matter of the permanence of the earth's conditions during the sojourn of man upon it, let us consider how far we can reckon on these external elements in the equation of the creature with the environment. It needs no other than familiar evidence to show that this sphere is very much alive — the geological record attests incessant change so far as we can see, never more active than in the time since man, at least in his bodily shape, came to be. The earth is still in its physical youth; none of its original functions show any sign of exhaustion. The senility which appears to have come to the planet Mars, and the death of physical and organic life which has evidently overtaken the inner planets Venus and Mercury — if indeed they have ever been the scene of life — is remote by millions of years from our sphere. Assuming that the whole of the planetary machinery, earth's depths, air and sun, are combining still to keep the structure living, what then are the results to be expected in the foreseeable human time from the operation of these engines?

As to the climate of the earth, all the evidence points to rapid changes within narrow, yet functionally very important limits, within a few hundred thousand years. That these limits are firmly set is shown by the fact that for a hundred million years or more the continuance of life on the earth has not been interrupted by any general excess of heat or cold. When we remember that the temperature of space is about five hundred degrees below zero of Fahrenheit, that of the inner earth some ten thousand degrees, and of the sun perhaps ten times as much, and further that the limits of organic life are between 32° and 150° on that scale, we see how nicely the adjustment has been preserved. We see that we have reason to believe the workshop of the world is well enough ordered to admit the continued existence of man.

The climatal changes we have to apprehend are those which will from time to time and from place to place bring about those extremes which are marked by the cold of the Arctic regions and the glaciated conditions of Greenland or that of the waterless deserts. The geological record shows that practically every part of the earth's surface has known the vicissitudes of humidity and aridity in recent geologic periods, say since the beginning of the Tertiary period, and that the greater part of the areas poleward from the parallels of 40° have ranged in temperature from climates which permitted our lower Mississippi valley plants to grow in Greenland, to enwrapping glaciers as far down as the Ohio and within sight of the Mediterranean. These changes have been frequent and, in a geological sense, sudden. They are least extensive in the tropical belt being, perhaps, lacking save in rare instances in all the lands where the sun comes to the zenith; they are most to be reckoned on in the regions beyond latitudes 30° in both hemispheres.

So far as we can determine, the life of man took its human shape in the latter part of the Tertiary time, probably before the Pliocene period. At that time the climate, in the northern hemisphere at least, was much more even than at present when indeed the lands nearest the pole could have been tilled. In his beginning man was without doubt a tropical creature, but he probably pushed beyond that realm before the last great climatal change began, introducing one of the many glacial periods the earth has known. During that period, at least in its closing stages, we know him in Europe as a hunter of the mammoth — the long-haired elephant, a species which ranged up to the borders of the ice-fields. The evidence is fairly to the effect that our rude forefathers underwent the trials of the climate of the last glacial epochs, and as hunters, following the "biggest game," our kind has ever chased over ground where the glaciers in their successive advances and retreats brought an essentially Arctic climate.

We are living in the declining stage of the last or pleistocene glacial period: just what is before us in the way of immediate climatal change is not yet clear. So far as the evidence goes, it is to the general effect that the change in this regard within the historic period is slight, but in the direction of greater cold and lessened rainfall throughout the northern hemisphere, especially in the region beyond the tropics. All the desert countries which have been carefully examined afford evidence to the effect that during the last glacial period they were the seats of abundant rainfall which has rapidly lessened in amount during the present epoch and seems to be still diminishing. We therefore may expect that the climatal cycle will be likely to carry the earth, or at least the northern hemisphere, into somewhat drier and possibly colder conditions than now exist.

We know, as yet, too little concerning the causes of glacial periods to essay any prediction as to the times of their occurrence. It is most likely that they are not due to any one cause but to the conjunction of two groups of causations, those due to variations in the amount of the sun's heat that falls on the earth or upon either of its hemispheres, and those that control the distribution of that heat through variations in the shape of the lands and the consequent variations in the course and volume of the ocean currents, such as the Gulf Stream and its mate that sweeps northwardly by Japan. It is beyond the limits of this writing to consider the exceedingly complicated problem arising from the interaction of these diverse causes of climatal change; for our purpose we need only note that the result of the complex is an incessant, and, in terms of earth durations, swift alteration within the above-mentioned narrow limits of the heat and moisture of the earth's surface. In this process of change the glacial periods represent the times when the amount of snowfall in the cool season is greater than can be melted in the warmer part of the year. This condition occurs, at the present time, here and there on all the great lands except Australia. Relatively slight changes in the equation of the weather would sweep these ice-fields away, or extend them to a range so wide that we would have again the vast sheets of the glacial period.

In the last ice age there were sundry epochs when the glaciers ranged far, separated by times of considerable duration when they shrunk back to the highlands and poleward on the low ground. It may be that we are now in one of those intervals of retreat, and that within a hundred thousand years we may find life dispossessed from the greater part of the regions beyond the parallels of 40° in one or both hemispheres. So far as we can discover the change when it comes, as it pretty surely will come again, and probably often during the sojourn of man on the planet, the advent will be in the human sense slow, several thousand years elapsing before the desolating process goes so far as to interfere in a serious manner with the possessions of man. When it comes he will have to join the vast procession of life on its way to lower latitudes in a march such as the hosts of plants and animals have again and again made before this shape of death. In this movement there is no reason to expect that mankind will do more than suffer: we may fairly expect that the march toward the equator will be made in fit order, and the return in due time by this the highest as it has been by hosts of the lower life.

The amount of injury that may be done to the interests of man in the far future from excessive dryness is fitly a subject of more anxiety than that due to recurrent glaciation. The ice times clearly are periods of more than normal humidity, so that while quite one-third of a continent, as in the case of North America, was during the last of them sterilized by the glacial sheet, the remainder was so much better watered that the field as a whole was probably as good a source of food as it is at present. We cannot safely reckon as to how far the present advancing desiccation may go, or how much it may diminish the life-sustaining capacity of the lands. We see some limit in the fact that the tropical belt, as a whole, shows little sign of ever having had much variation in its rainfall. We may therefore reckon that here will always be a safe refuge from the trials of high latitudes in the region about the equator: a realm which from the early geologic ages has been a kind of almshouse whereto the organic groups, beaten out in their struggle with the hard stresses in the regions near the poles, might retreat. These fields of the vertical sun have always been the place of refuge of creatures driven from those of varying and often destructive climates, such as we find near the poles. Thereto have shrunk the remaining species of elephants, rhinoceroses, and many other groups which once ranged as far as any of the mammalian series.

The geographic changes which can be foreseen in the computable future of the earth are not such as can menace the success of man. His life, in common with that of all the higher plants and animals, depends upon the maintenance of those wrinkles of the earth's hard surface which bring portions of it above the level of the sea in the form of continents. For the stage to serve the needs of the play it is necessary that these wrinkles shall grow up as fast as they are worn down by the winds, the rains, the glaciers, and the waves — else the actors will soon disappear with the stage. This balance between sea and land is of ancient institution and has been singularly well maintained. The continents were in existence at least as far back as the Cambrian period, and probably since the beginnings of life on this sphere. When man departs pretty surely it will not be for a lack of dry land whereon to stay.

The changes which are to be anticipated in the future geological periods will bring about many and considerable alterations in the outlines of the existing great lands, but not their destruction. We know that the continental masses sway up in one part and down in another in curious alterations, but so far as we know, none of them, once established, has ever been destroyed.

There is some reason to believe that there may have been a way by which the land life of South America came into intimate relations with that of South Africa and Australia about the Jurassic period, and some naturalists have conjectured that this shows that there was a continental land connection between these areas across the southern oceans. There is no evidence of such a vanished land having existed except the kinship of a limited number of species of animals, and this evidence can, from the point of view of dynamic geology, be better explained by the former existence of many volcanic islands now destroyed, or by the migration of the creatures from some common point of origin to those widely separated areas than by the destruction of such a vast and abnormally shaped land as has been conjectured. We may accept the continents as very ancient establishments and believe that they will outendure this abiding creature man.

The changes that may be looked forward to in the continents during the probable human occupancy of their fields, are mainly in the gradual extension of their areas. So far as we can see, this process of enlargement has steadfastly been in progress since these structures began to take shape in the early geologic time. They most likely occupy more of the earth's surface at present than in any earlier period. There is reason to believe that the additions will be in the immediate future at least due not to the development of any new continental area, but to the general uplifting of those that exist, and to the baring of the shallower sea bottoms near the existing shores. These shallows appear as a very generally developed continental shelf, fringing the shores in a general way, the shelf apparently having been formed of the waste borne from the land and heaped high on the sea floor along with the débris of organic life. This continental shelf or fringe of shallows is more or less extensive along all the shores of the great lands. It is particularly well developed about the North Atlantic, where it has an average width of about one hundred miles and a depth on its outer edge of some five hundred feet; from that margin the sea bottom descends with a tolerably steep slope to the abyssal depths of the sea. As the continents, gradually, irregularly, but on the whole, steadfastly rise, this ever-growing shelf is brought into the state of dry land.

The process of elevating the continental shelf above the sea is complicated by the continual swaying up and down of the sea bottom which now lifts and now lowers the oceanic plane. Since the ice-sheets passed from this continent and Europe, there has been one of these upward movements of the water level to the extent of two to five hundred feet affecting, of course, all the shores of the connected seas. The movement appears to have taken place with such rapidity that the waves did not have time to break up the forest beds as they passed over them; this is shown by the fact that all about the world we find these submerged forests along with river valleys which have been flooded in their lower reaches by the invading sea.

This last upward movement of the ocean level, due to an uplifting of some part of its bottom, probably in the Pacific Ocean, somewhat diminished the area of the continents. Supposing that it amounted to as much as 500 feet of elevation, the lessening of the dry land area may be safely reckoned as, at least, one-twentieth of the whole as it stood before the movement began. The existence of sea-beaches, at heights much above the present shore lines in most parts of the world, shows that in recent geological periods the sea has been on the average much higher than it now is; so that we cannot say whether its next movements will be upward or downward. The only safe presage is that the present situation is impermanent and is shortly to be followed by other changes in the relative height of sea and land. But, as before suggested, these alterations in no wise menace the perpetuity of land life: that life on any continent has continued without interruption for many geological periods and is doubtless to be further continued for all the time that we can in any clear way foresee.

Next in importance in the field of geological change come the mountainous breaks of the earth's crust. These are to grow upward and to be worn downward in the time to come or in the time before; but there is no reason to believe that the result will be any serious disturbance in the conditions of land life. There is reason to believe that all of our higher mountains are at this day growing at quite as rapid a rate on the average as they have ever grown. Yet we see that the process goes on with such steadfastness that, save for an occasional quake of the earth, there is nothing to indicate the action of the vast forces which bring the slow movements about. These earthquakes are formidable enough, yet we see that in Japan, a field where, on the whole, they are the most violent and frequent of those in any part of the earth, they are not inconsistent with a high civilization and the utmost profit from the earth. Therefore we may safely reckon that this part of the earth's mechanism will in no considerable measure interfere with the use of the earth by man.

As for volcanic action, all the evidence goes to show that it is a fairly constant element in the earth's processes. Within the historic period it has been continuously at about the same rate. Now and then an eruption, such as that of Krakatoa in 1883, or the more recent outbreaks in the Antilles, because of its violence or its effects on mankind, suggests that there is grave danger from this might of the under-earth. In fact, however, the loss of life from this action is far less than that from any of the common diseases of our kind — vastly less than from war or famine. Nor is it at all likely that the world will ever know a time when the outbursts of volcanoes will be more serious than they now are. This action appears to be due to the inclosure of water in the stratified rocks at the time when they are laid down on the sea floor; this crevice water becomes heated as the rocks become deeply buried, and, by the central heat, is brought to an exploding strain. The process is constant and its manifestations appear to be uniform and little disturbing to the life the earth bears.

The foregoing sketch suggests some of the reasons why we may look forward with an assured mind to the future of man on this planet. He is young, and the sphere for all its age still young. We may well rejoice in our anticipation of the great and long-continued work they are to do together before their great task is done.

X

THE BEAUTY OF THE EARTH

NOT the least important question as to the future of the earth when it has become completely domesticated concerns its expression to the eyes and mind of man, the beauty that it may then convey to beholders as it does to us in our time. There are those who feel that an intensely humanized earth, so arranged as to afford a living to the largest possible number of men, will lack much of the charm that it has now; that it will become so far artificial that its primitive nature will be utterly lost. A careful examination of the conditions will show us that while the order of beauty is doubtless to be greatly changed by the hand of man, there is reason to believe that the alterations will enhance its æsthetic value, making its features far more contributive to spiritual enlargement than they were in their primal wilderness state. To discuss the reasons for this belief it will be necessary to set forth in brief the naturalist's view as to the place of the æsthetic motive in organic life, so that we may see how safely we may reckon on its development and control of man's conduct in the future.

It needs but a glance at the realm of animals and plants to make it plain that their qualities are largely shaped by influences that make for beauty. Their forms, colors, even their features of association that enter into landscape effects, are so ordered that they afford delight. In larger part these elements of beauty are due to natural actions, to the operation of forces that are absolutely beyond the control of the individual, and are hardly more to be termed organic than those that give rise to the shapeliness of crystals, to mountain outlines, or the order of the celestial spheres. In part, however, and this is a most important fact, this beauty is due to the deliberate intellectual choice of some one of the many animals that are engaged, even as we are, in an effort, however unconscious, to embody their conceptions of beauty in the objects they shape.

Although the extent to which the lower animals have by choice contributed to the beauty of the world is, as yet, but little known, for the reason that the subject has only come into the field of enquiry within the last half-century, it is already clear that what they have effected is, in quantity, great, and in quality, of a very high order, measured in terms of our best human art. Thus the beauty of the flowers of all those plants which have colored and shapely corollas is unquestionably due to the choice of insects who are attracted to them by those features which attract us. These blossoms are, in effect, like tavern signs set up to tempt the moth or bee to visit the plant, there to be regaled with the nectar or pollen, and by its visit to effect the process of fertilization in the desired way. In this manner, by this or that device of beauty in form, hue, or scent, the plant appeals to the insect's mind, to its sense of the æsthetic, and by the result gives us proof that even in this lowly state of mental development the desire for the beautiful is kindred to our own.

In a very great number of insects, including representatives of nearly all the main groups of that class, as well as of the spiders and their kindred, the æsthetic motive of the creatures is well shown in the results of sexual selection, which leads to the evolution of such beauty as we find in the wings of the butterflies and moths, the coloring of spiders, and a host of other ornamental features. Although this result arising from the selection of males on the basis of their beauty is much commingled with others due to protective mimicry, it remains clear enough to warrant us in believing that in many species of this class the sense of beauty, though of course quite unconscious to the possessor, is far stronger and more dominant than in mankind.

When we come to the vertebrates, we find in all the classes evidence that the motive of beauty is quite as manifest as in the lower realms of life. In them we find it shown, as in the lower life, both in the organic control that shapes the creatures to harmony, and in the individual choice of mates that leads to the selection of the most charming and, through that action, to the accumulation of beautiful features. Both these methods of attaining the common end are well exhibited in the fishes and the reptiles and, less distinctly, in the amphibians. When we come to the birds, the lineal successors of the reptilia, we find the quality of beauty more predominant and nearer to our own kindred emotions than in any other class of animals, even that in which we belong. Moreover, in the birds the beauty is to a greater extent the result of the selection which the female makes of its mate at the time of pairing. The result is that these creatures are, to us, the most beautiful of all organic shapes.

That the sense of beauty in the birds is not altogether limited to their sexual habits is fairly well shown by the fact that their nests often have a grace that seems to be attributable to a wider-ranging æsthetic motive, a measure of care beyond what is required for mere utility, or often given to them apparently to satisfy a desire for shapeliness. In one species, at least — the "bower bird" — the pair, or the members of a covey, decorate an assembly place with bits of bright-colored objects which apparently serve for ornament, for they cannot be for any other service. Add to these visible indications going to show a sense of beauty that derived from their songs, which, though perhaps not in a strict sense musical, are unquestionably charming, and we have a combination that clearly indicates a high development of the æsthetic sense.

It is an interesting fact that, as a group, the mammalia below man, and particularly in the series that leads toward him, manifest much less of the æsthetic motive than in any other great division of animals. In the sub-class of marsupials, the kindred of the opossum and the kangaroo, there is but little trace of sexual ornament, and that of insignificant æsthetic value. In the higher sub-class, that of the placentalia, to which we belong, we find that some of the diversions from the main stem, such as the deer, antelopes, and the kindred of the cats, have by sexual selection acquired a certain measure of ornament in color and structure, such as antlers and banded or mottled hides, in no instance, however, comparable to the attainment of the birds. In the central part of the class, that which led toward man, sexual selection, as far as it has acted at all, has given shapes and colorings that are not beautiful, and in the apes may often fairly be classed as obscene. Of all the varied aspects of this group not one can be termed charming; they may, as a whole, be reckoned as the most hideous of animals. Moreover, in all the nearer brute kindred of man we find no collateral indications of an æsthetic sense, no shapely structure, no sexual calls having any quality of song, unless possibly in the howling monkeys wherein, according to some observers, the notes of the cry run through an octave.

With an essentially unæsthetic ancestry, extending through thousands of species from the level of the amphibia, man comes to his life as man, as it would seem from the point of view of the æsthetic, the most hopeless creature on the planet. But here we find a marvel, perhaps the most wonderful of all that beset our passage from brute to man. As for all his other powers, his rationality, his sympathies, all else that goes to make his mind, we find that humanizing means no more than a swift and vast enlargement of the qualities that existed in the lower stages of his development. In the history of the æsthetic motive in man we come upon a sudden change in quality. The very lowest of his kind, the Andaman Islander and the lower African tribes, exhibit little, if any more sense of beauty than we find in the anthropoid apes. The evidence from these and other primitive tribes is to the effect that our genus did not begin with men who showed any kind of æsthetic spirit. On the contrary, their first steps in constructive work, their huts, weapons, clothing, and utensils are lacking in grace; they show that the sense of beauty had not yet awakened. As soon, however, as some skill in fashioning objects was attained, we note at once that the art motive is aroused. The original rude flint, no further shaped than would serve its clumsy purpose, is now fashioned with grace and with laborious patience dressed to graceful form: at once in a great diversity of races and tribes this motive of beauty swiftly enlarges until the men can do no manner of work that does not embody it.

This is not the place to consider the combination of impulses which inevitably lead all kinds of men, though in varying measure, to an awakening of the æsthetic sense — for it is a large and obscure problem. For our purpose, we need do no more than recognize the fact that the search for the beautiful is due to an instinct which naturally awakens in man as soon as he obtains command of the skill of hand sufficient to express his state of mind in fashioning things. We should also see that the results of this motive are in æsthetic quality essentially like those which owe their character to the minds of insects, as expressed in the beauty of flowers or the sexually selected ornament of the birds. In a word, the facts indicate that the sense and love of the beautiful is an essential quality of mind; that while it may long lie dormant, as it was in the mammalian ancestry of man, it remains unimpaired in its possibilities, ready to enter controllingly into action as soon as the chance is afforded. The main fact is to see how the world over, apparently among hundreds of tribal associations, this motive sprang up and at once took its place as the equal of any of those primal impulses which were inherited from the infra-human series all the way back to the beginnings of intellectual life.

Although the æsthetic motive in mankind when aroused was at once strong, it lacked the coherence and the certainty in its actions which we find in the lower life. Thus our art work is not so surely beautiful as that of the birds or the insects. Whole groups of men have for a time lapsed into mere fashion, or have lost their once well-developed æsthetic sense. Nevertheless the onward march of this impulse has been, on the whole, more continuous than is the case with any other of those developed within mankind. The alterations of the interest never seem to occur save where there is a breach in the conditions of its development, such as has taken place in the passage from household technics to systematic modern factory work. So long as it is a question of the solitary mind and the separate complete work the motive remains true. On the other hand, the extension of the impulse with the advance in human associations is remarkably great: beginning with the savage and his arms or his clay vessels, we find at each upward step in culture a widening of the field of art interest. At first it relates to personal affairs; it extends thence to the decoration of temples and of palaces, then to detached art in sculpture and painting. Finally, in the later stages of civilization, it begins to occupy the field of the landscape, first in forms of gardening closely united with architecture and sculpture, and finally with the landscape apart from all the accessories derived from other arts.

It needs but little enquiry into the history of the æsthetic perception of the landscape to show that while the motive was felt by many rather primitive peoples, it is the last of the fields of beauty to be widely opened to the appreciation of men. Among the Greeks there was a certain measure of sensitiveness to the charm of color and movement in the landscape, but little of that of form. A curious instance of this is to be found in the topography of Athens. On the north of the town, and fairly within it, there is the most interesting and beautiful hill in the Attic plain. This hill, Lycabetus, rises to about double the height of the acropolis, and is a far more picturesque object. It is, indeed, the leading feature in the scenery of the field, in a way controlling the whole view, yet it appears to have been quite unappreciated by the people who dwelt beside it, though their æsthetic perceptions in all save matters of the landscape were more highly developed than they have ever been in any land or time. So far as I can learn, there is but one mention of this mount in classic times, which if near any of our modern centres of culture would have found a large place in literature. There is no allusion to the surpassing beauty of the landscape visible from its summit, yet it must have been known to every one who dwelt in Athens.

The interest of the Romans in the beauty of nature was even as slight as that of the Greeks. We find with Virgil a sense of the charm in the humanized landscape, and now and then, though seldom, a note of a wider appreciation that extends to some of the primitive aspects of the world; yet it is still with reference to men that it interests him and not for the pure nature of it. In the last of the poets of the classic period, in Rutilius Naumatianus, we find a touch of the spirit which is truly modern when the scene is valued for itself. After Rutilius there is a break of some eight centuries, when we come to the modern awakening, the so-called period of the new birth. From that time the growth in the appreciation of the landscape has been steadfast, though in greater part since the seventeenth century. It has mainly affected the peoples of western Europe, though it is exhibited as well in the art of Japan.

The whole history of the landscape appreciation clearly shows that this extension of the æsthetic sense is the result of a natural process of development in which the spirit of man, at first intent on those things alone which immediately and personally concerned him, has, with the widening of his understanding, gone ever further afield until now it compasses the visible realm. We see that the sense of beauty is the companion of knowledge and that it is certain to keep its place in all the interests of man. We see, too, that it is naturally keenest in those fields where the will of man affects the expression. The absolute wilderness, however noble in its aspect, has æsthetic interest for relatively few persons. Even to them it lacks the charm of the fields that bear the impress of the hand of man. They need to be peopled in our sight or in our imagination, so that by sympathy we feel that we ourselves are commingled with it. Hence it is that only the more expanded souls can rejoice in the untrodden deserts, the pathless woods, or the mountains that have no trace of culture. Such people these places with their fancy — at least they feel the Lord is there: and so they have their bond with what else would be utterly strange to them.

The main point of this rather far-going yet insufficient account of the perception of landscape values is that the motive may safely be reckoned on in estimating the future of the care that is to be devoted to insuring the beauty of the earth. We see that the work of the landscape architect, effectively begun less than a century ago, is now advancing more rapidly than that of any other profession. At first it concerned gardens alone, the aim being to supplement the accomplishments of the architect by uniting his structures with the surrounding nature, so that there might be no jarring to the eye in the sudden passage from the artificial to the natural. Thence the duty of these artists has been extended to the care of parks and public reservations which, beginning with the commons of England, the play-grounds of rulers, and the spaces kept open for the defence of strongholds, have extended until every city has come to regard such holdings for the use of its people as necessary even as the streets and schools.

A concomitant of this development of the landscape architect's profession is the growth among all classes of men above the lowest of a sense of the beautiful in nature. A century ago travel, except for trade purposes, was limited to the very few — not one in a hundred journeyed to look upon the world. Now it is safe to say that practically all the folk who control our states regard their contemplation of natural beauty as one of the rewards of life. It does not matter that they, as yet, do not see with the trained eyes and mind attuned to the best; the vital point is that they have the hunger. As regards this art of the wide nature, they are in the state of the primitive man when he began to make his stone implements shapely: the work was, for a time, ill done, but it held the sure promise of noble growth.

We may now clearly discern that the landscape architect is no longer mainly to be concerned with beautifying patches of the earth with his clever contrivances of open spaces and vistas. His real part is hereafter to care for the beauty of wide realms. The principle is well accepted that all the larger interests of man, those where the direction of affairs cannot safely be intrusted to individuals or corporations, shall be in the control of the commonwealth. Such matters as public health and education, navigable streams, roads, and bridges, are now recognized as in the hands of the state. We are quite ready for the extension of this concept of duty to the field of æsthetic values, and we may confidently reckon that in the immediate future we shall have at least the beginnings of an effective care for those aspects of the earth which are of value to the spirit of man.

In forecasting the future of æsthetic values of the earth, we should take account of the fact that the oceans are unchangeable by the hand of man: they may lose their majestic loneliness as they become more peopled by ships, but here the wilderness quality will ever remain. So too with the strip of shoreland which they desolate. Save for the results of brutal misuse, which may readily be avoided, this debatable fringe of the land may retain its pristine quality. Of the continental expanses quite one-fourth of the area, so long as the earth's climate remains as it now is, will be unfit for tillage and only contributive to man's needs by its forests or its mines. Thus the arctic sixth part of North America, being fairly beyond the reach of agriculture, must remain a wilderness save for the scanty population that its mineral wealth may support. The same is the case with its arid deserts of the Cordilleran field. For all that may be won from them by irrigation, they are to stay in their barrenness even as the seas. Add to such natural reservations the higher mountains, and we have even on this rather happy continent quite one-third of its area which is to retain its natural aspect, so that all men may for all time have a chance to behold the primal realm in its nobler shape.

On the other continents, the fields reserved by nature from the occupation of man are, on the average, quite as extensive as in North America. In Eurasia they form an even larger part of the land area, as is the case also in Australia, where probably not one-half of the surface will ever know any kind of tillage. In Africa not over two-thirds can be reckoned as of economic value. In South America alone is the proportion greater. In that continent the man-sustaining soils may be found to occupy four-fifths of the surface. It is thus evident that the first question in the future of the earth's natural beauty concerns the care that should be given to these inevitable wildernesses. On this point it is to be noted that the American government has, without formal design, made an extended experiment in this class of undertakings, an experiment which gives promise of being the type of such work. Beginning with the Yellowstone Park, the American government has in succession set aside a considerable part of the national domain to be preserved in its natural state, kept free from the depredations of hunters or the defacements of business. These holdings in the interest of mankind now include the most important part of the scenery of the Cordilleras, between Canada and Mexico, and we may be reasonably sure that these areas are effectively preserved for all foreseeable time.

It is interesting to note that the principle of keeping untouched the choicest parts of the American landscape has not only met the unquestioning approval of all of its people, but the system has fairly been adopted into the life of the folk. The inhabitants of the far West are not only eager to have new reservations made, and those already established well cared for, but those of the East are willing to tax themselves heavily to redeem from private ownership the more important parts of their landscape that are in danger of defacement. We may fairly reckon that this motive, though as yet mainly limited to the United States, will become awakened in all civilized countries, in such measure that care will be taken to preserve the most valuable elements of the earth's natural beauty.

In estimating the needs of care for the safety of the beauty of the earth it is evident that there are two important groups of these features which are in imminent danger of irretrievable damage: these are the primeval forests and the streams with their waterfalls.

As for the forests, the reservations such as have been made in the Cordilleras abundantly provide for the preservation of sufficient samples. Though they will have to serve as sources of timber, and must thereby lose some of their pristine quality, they will retain their essential beauty as landscape features unharmed.

While the western protected areas are sufficient to ensure for the future samples of all the best of its woods, the Appalachian section of the continent is not thus guarded. The broad-leaved woods of the Ohio valley, those of the southern pine, the noblest of its group, and the northern species of white pine, which is at its best in New England, need immediate care lest they be utterly destroyed. There is no land in the East in government control, so that this warding will have to be done by purchase. It can effectively be brought about by two commonwealth parks of relatively small extent, one including the higher mountain district of North Carolina, with a small share of the lower valleys, in all about half a million acres, the other including the White Mountains of New Hampshire of about like area. These two reservations will cost about as much as two battleships, a trifle in the reckonings of the nation, but unlike the warships they will abide forever.

There is in this country yet another most desirable reservation — that of the Everglades of Florida, where there is a bit of nature the like of which is not found elsewhere, a field of unique beauty, that has not, as yet, and may never have, any value for the uses of civilized man. Not the least of its interest consists in the fact that it is the dwelling-place of the Seminole Indians, who escaped deportation beyond the Mississippi at the end of the wars in the first half of the nineteenth century. These people having been exempt from the control of the government, and practically so from contact with the whites, are the least changed of any aborigines in this country. A reservation here would not deprive our race of any notable economic values and would be a refuge for the most interesting remnant of the eastern tribes of American aborigines.

To do for the world at large what has so far been done in this country that we may assume its completion, will require a like system of deliberately chosen reservations on all the continents. These cannot be at once reckoned either as to their fit place or their extent. It is, however, evident that they will have to be in something like the proportion that they are clearly to have in America, including in general between a fiftieth and a hundredth part of the surface, yet not sacrificing any noteworthy part of the economic values of the earth. It may well be that from the timber they will afford they will, in an economic sense, justify their establishment.

Speculating on the possible position and extent of these reservations we see that they may well serve as harborages for many of the mammals and birds which else are sure of being swept away. Thus in Africa, in the region about the head-waters of the Nile, a reservation might well be established where a large part of the important mammalian species now near extinction could be preserved. There also, if the destructive process of civilizing the lower tribes of men could be avoided, we might hope to maintain sundry interesting varieties of our kind, now as certain to be destroyed as the giraffe or the African elephant. It may seem unreasonable to abandon an area of fifty thousand square miles, say as large as New York, to savagery, but if we consider the matter we will see that the primitive life of the world has its claim to existence quite as well as that of our civilizations.

Turning again to the question of preserving the beautiful aspects of the earth, we note that the streams and lakes are the most likely of all natural features to suffer from the action of man. In some ways this damage is unavoidable. The need of power, the most immediate and far-reaching of all man's necessities, is certain to destroy our waterfalls and rapids and to reduce all our rivers to a series of lake-like pools. This is their certain fate in a few generations from the present time, save when they enter the reservations where they are to be kept as samples of what they were when the earth was free. On the other hand, the lesser lakes are likely to retain much of their pristine beauty. Here and there they will be drained away that their bottoms may be tilled. In many instances they will be so controlled by dams as to retain the flood water of the rainy season to supply wheels in the dry season. This, by making a variable level, is somewhat harmful to the beauty of the shores, yet it will not be generally so.

If we would forecast the aspect of the lands when the earth is completely domesticated, we can do so in a fairly accurate way by visiting some of the centres of the highest culture, such as are to be found in England, Holland, Egypt, or wherever men and wealth are most crowded: there we find beauty of a high order. It lacks, it is true, that quality of the primal which the wilderness alone can give, but in place of that single note of the deeps we have the great harmony of man's life. In the time to come this beauty of culture will be ordered as it is not now, so that the use of the earth may give harmonies with no discords. The nobility of the primitive fitly recognized may have its due place, even in an earth subjugated to the uses of man.

XI

THE FUTURE OF NATURE UPON THE EARTH

THAT the title of this chapter may not be enigmatical, let us understand that by nature is meant the primitive species of animals and plants and their associations, the physical conditions which give the earth its expression; in fine, the assemblage of objects and actions that make up the wilderness when it is untouched by the hand of man. It is evident that all this is to undergo a great change by that same masterful hand of the supremely wilful creature whose progressive desires are likely to leave little, save with deliberate purpose, of the shapes that the ancient order established. We see, already, vast alterations since those desires began to expand. Half the land has lost its pristine aspect; many of the greater woods are gone to their remnants; hosts of animals have been destroyed, and other species once wide-ranging and dominant are reduced to scattered bands and are on the verge of extinction. The life of the world has learned of its new master in wide-spread slaying and subjugation. The question is as to the measure of it that the awakening reason of the tyrant may leave.

First let us note that the organic species of the earth — animals and plants together, including the invisibly small as well as the visible — probably number between two and three million. We know as yet little concerning the microscopic forms, such as the bacteria, save when they are forced on our prying attention by their interference with our affairs. For all we know or are likely soon to learn, the number of these kinds may be as great as those of the other visible forms of life. It is by no means likely that our means of exploring the world of the small are or can be made sufficiently effective to reveal the least of these creatures.

Organic life does not consist, as some think, in a mere huddle of living objects contending with each other for a place in the world. It is rather a group of vast associations in which the species, each representing certain capacities and powers, are united as in a commonwealth. It is true that some prey upon others and most are competing with rivals for a chance to live, as is the case in our human societies; but for all the contention these great combined faunas and floras, these organic hosts of the earth, are effectively balanced organizations, the order of their relations having been determined by endless trials through the geological ages in which they have been developed.

We may see a little of this adjustment of species to species in an organic host when we consider the history of what we may term weeds, be they plant or animal. It is characteristic of all these excessively successful species that they are new-comers in the fields they infest, brought in from some other province where they are so adjusted to the species with which they have long been in contact that there they have no more than a fair chance to develop. In the region where they are weeds or pests they are not checked by their ancient rivals and enemies, species educated to contend with them, and so they run riot in their new-found freedom. This is the case not only with a host of plants, but many animals as well. The hares brought to Australia from Europe were in their native country kept in check by several carnivorous animals, foxes, weasels, etc., but the immigrants, not finding any effective enemies in their new country, became weeds — species with a measure of freedom none have in an adjusted assemblage of life. These weeds usually have their success in the tilled fields and not in the wildernesses; there they are apt to be beaten off by the well-organized forces of the natural life.

Now and then, in the natural order, there enters into these temporarily balanced organic hosts some species developed in its midst or introduced from some other field, a species which disturbs the original order. Usually, however, as above noted, the original occupants of the fauna and flora hold their ground so well that the solitary invaders have no chance to establish themselves: the changes are likely to occur not by haphazard immigration of species, but by the movement of the organic host as a whole under conditions of climatal or geographic change, which permit or compel assemblages to move this way or that over the surface of the land or the floor of the seas. The one exception to this general truth is in the case of man. He alone by his militant and progressive desires has become the successful invader of all the organic provinces — the supremely successful weed.

In his primitive state before he became in any considerable extent a tool-maker, man appears to have been limited in his distribution, much as are the lower animals; but in proportion as he became endowed with fire, clothing, weapons, and other tools, his capacity to invade increased and his efficiency in destroying the inherited order of organic life rapidly augmented. We see the stage to which this has attained; we clearly foresee that it is as yet in its mere beginning, and that the original complexion of life is to remain only so far as man desires to leave it as nature made it. On the supposition that man is soon to begin to manage the life of the planet, not, as at present, in an accidental and generally destructive manner, but rationally and with a view to keeping and leaving it in a shape to be good for his successors, let us see what we can forecast as to the direction and results of his endeavors.

We may assume that the progress of man in the subjugation of the planet will eventually lead to the further disturbance of the ancient organic order. In fact these overturnings will be inevitable, as was the destruction of the North American bison, because most wild species of large size cannot maintain themselves save in large numbers and with a measure of freedom not possible where the land is to serve the needs of man. In part the destruction will be due to the fact that the creatures are on the natural way to extermination, as was the case with the dodo and the great auk, the hand of man giving no more than the last touch in the series of actions that brought the end. In some part the elimination of species will be due to the fact that the creatures are directly harmful to man. The tiger and its kindred among the mammals, sundry venomous serpents, and, perhaps, a few other vertebrates, will on this account have to be eliminated. Yet in this great group of back-boned animals there is certainly not one per cent. of the forms that by their habits warrant extermination.

In the life below the vertebrates we find the groups of animals and plants where the interests of mankind demand extensive destruction; yet there are only three of the many classes where such work is seriously called for. These are the bacteria, certain plasmodiums, and certain limited families of insects. The bacteria have a bad name, but of the vast host of their species there may be no more than a few score, possibly less, that harm man or his domesticated animals and plants. The greater number do work which from our point of view is beneficent, in some cases absolutely necessary for the maintenance of organic life. Of the plasmodiums we know that some forms are harmful, as they are the source of fevers. As a whole, these lowly organisms are to man by far the most inimical of all organisms: certainly more than half, probably more than three-fourths of the deaths in his species are due to their action; all the other agents of death save old age are of relatively trifling importance. His largest and most difficult task is to eradicate these mighty, though invisible, enemies.

From the Protozoa to the insects it is interesting to note that there is not a species which can be regarded as a serious enemy of man or of his domesticated animals. Some few, as the slugs, prey upon his gardens, the sea-nettles may sting him or, in the tropics, the land-crabs may become a nuisance, and certain worms are the source of serious diseases, but from this great field of life he experiences at most but limited ills. When we come to the group of insects we find quite other conditions: there is a host of species which directly or indirectly bring us calamities. As is now well known, in the mosquitoes and the flies they transmit the bacteria and plasmodiums which produce malarial, typhoid, and yellow fever, and probably other maladies. The servants of man, the domesticated animals and plants, suffer even as much as their master from insect scourges; in fact, agriculture and herding have from the beginning had to war with these creatures which, by their adaptability to the conditions of other life, their marvellous energy and swift increase, are able to assail as no other creatures can.

The history of the ravages of the locusts in North Africa and elsewhere shows that it is possible for an insect profoundly to affect or even to exterminate a civilization. We are just now on the way of a momentous experiment of this nature in America. A species known as the Gypsy Moth, long and unhappily known as a pest in Europe, has recently been introduced in eastern Massachusetts. In its new environment, where the few enemies that in the old world contend against it are lacking, the species is spreading steadfastly and certainly. Where it is allowed freely to increase for a few years, it develops in such multitudes that it devours all kinds of vegetation, that of the forests as well as of the tilled ground. So far, in its spread it has come to occupy only a few hundred square miles of territory, and the efforts to supress it, though miserably irresolute, have served to restrain its depredations. There seems, however, to be a certain and very grave danger that when it becomes firmly implanted in the forests its assaults will be practicably irresistible. It is in the power of this creature, that a touch will slay, by its numbers to endanger our culture. This it will certainly do if its increase is not in some way arrested.

In general, we may trust to the arrest of the multiplication of any species of insect developing in its ancient associations with other life to the development of some inimical insect or some of the mould-breeding forms of life competent to destroy it. For a few years these plagues may increase after the manner of the army worm until their devastations are startling, then some ichneumon fly, which has the habit of laying its eggs in their grubs, avails itself of the extended opportunity and becomes in turn so plentiful that it destroys the host. But when, as in the case of the Gypsy Moth, the pest is an invader from another host and does not have to meet enemies trained for combat with it, the danger of its ravages is vastly enhanced. It is likely to be long before species competent to restrain them are brought to efficiency, and in the meantime the destruction goes on.

As before noted, the organic hosts are generally so well organized that their closed ranks usually defy the efforts of would-be invaders of their realm. It commonly requires the assistance of man, intentionally or unintentionally given, to effect the naturalization of a foreign form. Thus none of our weeds from the old world would have had a chance to obtain a foothold in this country, save for the fact that they have entered by the ways of commerce and have been first implanted on our cultivated fields. From that lodgment and nursery they can have a chance to spread to the less hospitable wildernesses. A good example of how this works in insects is again well illustrated by the history of the Gypsy Moth in America. This insect has the habit of laying its eggs whenever it finds a chance to deposit them; where the creatures abound they are very often found on timber, furniture, casks, etc., so that it may be assumed as certain that for centuries they have been plentifully imported into this country. We have to believe that in thousands of instances these pests have hatched and the young had the chance to develop, but in no case did the species establish itself until in the latter part of the last century, when some of the kind were brought to eastern Massachusetts for purposes of experiment and reared in cages: by accident a considerable number of them in the grown state were released, and thereby the implantation was effected.

We see by the facts above noted that man's relation to the organic life about him will in part consist in two series of actions: in the suppression of the creatures noxious to him because of their assault on his health or comfort, and in the restriction of the wanderings of species which are kept in control in their native realms but become weeds when they are implanted elsewhere. Another part of his endeavors should go to the limitation of his destructive work within the narrowest possible bounds, so that the body of life of which he is to be the master shall suffer as little as may be from his control. That it is inevitably to suffer much from his innovations has to be accepted as the price to be paid for the humanization of the earth, a process which is but at its beginning and is to go on until the quality of the sphere is to be vastly changed. But the measure of the alteration and its essential results are for his determination, and their effect will be in large measure to determine his station.

It is evident that so far as the land-life is concerned the increase of numbers of mankind will inevitably break up many of the ancient organic hosts. The creatures of the sea, except those that afford food, are not likely to be disturbed, but with all the serviceable land occupied by the few plants and animals that are of use to civilization, and with the forests that remain after this selection devoted to the growth of those trees only that have value as timber, there will remain but the deserts and the untillable fields of high latitude where there will be a chance for nature to be maintained. Europe is already near to this state of complete subjugation: it seems pretty certain that in another century its wildernesses will all have disappeared. Not long after, the same conditions of utter domestication will come upon the fields of our own continent, and soon thereafter, even in the sense of human time, all the lands will be brought to the same state. It is, therefore, not too early to consider what losses this change will entail and what we of our time should do to minimize them.

First, we shall note that, manage the situation as best we may, this humanizing of the earth will necessarily entail a great loss of its organic species, for while only a few hundred, or at most a few thousand, kinds, need be sacrificed for the betterment of man's estate, a host will pass away because of the general disturbance which his civilized life brings about. It may be said that in the history of the earth the passing away of species is as common an event as the death of their individuals in our own times, and that human interference will but add a few score thousand to the hundreds of millions that have departed in their time. Yet we have to remember that this life of the earth is the record of the greatest work of the world and that, precious as it is to the science of to-day, it is to be vastly more so to the science of the time to come. Each of these kinds we destroy is absolutely irreplaceable; no record we can make of it will be satisfactory to the learning of a thousand years hence. When a species dies it goes forever; for its like will never come into existence again. Moreover, we have to consider that, in the lame and impotent fragments of Nature that man is to leave, the processes that make new forms of wild land-life are in general to lapse, so that the places of those to be swept away are not likely to be filled. The question to which we are led by the points above noted is as to the groups of wild animals and plants which should be especially cared for, and the means by which they may most effectively be preserved.

While we cannot clearly foresee what animals will be most important to the science of future centuries, certain points of their interest we may fairly conjecture. We may presume that they will need to have types or examples of each group retained and, above all, those animals which belong to the more intelligent species: for the questions of mind in the lower creatures, interesting as they are to us, are to be far more so to our successors, who will be better able to approach the problems of psychology. We can see clearly enough that they have a right to demand from us the utmost care in preserving those forms that, even with our limited view, are clearly enough seen to be of singular psychologic value.

Leaving out of view the marine species where the advance of man is not likely to have much disturbing effect, and those in which we discern nothing of extraordinary importance, we still find very many groups that demand protection. Among the invertebrates there are no species below the grade of the insects that are in danger of passing away because of man's action, but in that class there are sundry forms of remarkable mental quality that are likely to be exterminated before they have told their story to the students of the future. These are limited to those groups in which there are few kinds that need to be extirpated because of the damage they do. These groups are the ants, the bees, and the termites. In them we find the highest development of that form of mental action we term instinct. In the ants there are probably some hundreds of social species that show in a great variety of peculiar accomplishments the development of instincts. The same is the case in the groups of bees and wasps where the species, if less limited, are even richer in variety of mental actions. In these series of the hymenoptera there are few species in any measure harmful to man, while on the whole they afford the richest and most varied conditions of mentality existing in the invertebrates. The termites, commonly reckoned with the ants, but belonging to a very different order of insects, are a small and peculiarly interesting group: though occasionally harmful to man, they are not likely to be exterminated by him. As a whole, the insects most important to the psychologist are not likely to be exterminated or, if in danger of passing away, the passage will not come about for many centuries.

It is in the invertebrates above the level of the fishes that all the great losses arising from the domestication of the earth are to be expected. In the reptiles and batrachians, the lower classes of the type, the groups are already far advanced in their decline from the richness of their development in the middle age of organic history: there is little among them to preserve that seems specially important from the point of view of psychology. They may well be left to their chance of survival, good for a long time to come, except in the case of the larger saurians, the kindred of the crocodiles, and the more venomous serpents. The humbler and harmless forms are pretty sure to keep their place beside man.

It is otherwise with the superior classes of the vertebrates, the mammals and the birds. In these groups the species are generally so active in their habits and so entangled in their environment that any considerable change in the conditions of their life is likely to lead, as it has in many instances led, to their speedy destruction. Among the birds it is probable that a dozen species have been extirpated by man within a thousand years, and many others are on the verge of extinction. Some of these were recently most abundant. Thus the passenger pigeon, which the present writer remembers only about half a century ago as the most numerous land-vertebrate of this or perhaps any other continent, is now a rare bird not readily to be found in any part of the field where it then superabounded. Another instance from the same field is afforded by a species of parrot of the kind known as paroquets, which when Kentucky was first settled ranged as far north as the Ohio river. This interesting form has now been driven to the far South: the species is perhaps lost. In every part of the world the bird life appears to be far more disturbed by the advance of civilization than that of any other class. There are scores if not hundreds of species which are on the verge of extinction. It is indeed probable that, except for peculiar care, the most of those forms, which do not in a way adopt man and his works in the manner of the British sparrow, will be swept from the earth. This fate is particularly likely to overtake the migratory species, for in their wanderings they are exposed to a great variety of environing conditions, all of which are likely to be changed by the alterations that man is to make. It behooves us to take especial care of these creatures, for they are in many ways the noblest products of life.

It is in the mammalia that we find the species which the students of the future will most desire to explore, for they are our nearest kindred and from them we learn the most as to the history of our own minds. Of the several thousand kinds of wild, suck-giving animals, none but a few score of the smaller sort, and some of the marine species which do not resort to the shores, will be safely housed when the earth is completely subjugated, save they be kept in selected wildernesses protected from the depredations of the monumental slayer. It is not too much to say that nearly all the larger forms already have been brought to the danger line, and that the greater number of them will, in one or two hundred years if they be not well cared for, utterly disappear. Within fifty years, several of the large mammals of Africa and America have been exterminated or brought so near to extinction that their end is certain.

It is not likely that any practicable measure of care will serve to protect the whole of our kindred mammalian species from death. The larger carnivora, the lion, tiger, etc., are too inconvenient to be spared. Certain of the herbivora, such as the African buffalo, are too ineradicably fierce to submit to the domestication of preserves. Of these unsavable forms there are not many; perhaps not more than a twentieth part of the whole number are beyond salvation. The remainder can be preserved, provided their master is willing to be a providence to them. Some of these, perhaps thirty species, need speedy care; the most can wait for a century or so before they are in imminent danger of extinction. On the whole the herbivorous mammals of Africa are the most endangered of all their kindred. That continent, by far the richest in large species of the class, remained until the last century practically untrodden by the sportsman. The human assault on the life of this land was made for food, or, in the case of the elephant and the hippopotamus, for ivory, and with ineffective arms; now the land is the favorite range of that mighty beast, the big-game hunter, who, with tools vastly more effective than the native's spear or the flint-lock gun, kills not for profit but as a dog in a sheepfold for the mere love of killing. The African elephant, several of the antelopes of that country, and other very interesting species have been brought to the verge of extinction. In the opinion of those competent to judge, certain forms plentiful a hundred years ago have already passed away. The Indian elephant, because of his large place as a domesticated beast, although he does not breed freely in captivity, is apparently safe from extinction until supplanted by some kind of engine, but his African kinsman being much less domesticable, hardly fit, indeed, for the service of man, is doomed to certain and speedy extinction unless sedulously guarded from the sportsman; like most other large herbivora, it cannot maintain itself as a solitary paired form: it needs the conditions of the herd for its survival. As soon as it becomes rare it will speedily pass away.

On many accounts the elephants are likely to prove the most interesting of the lower mammalia to the psychologists of the centuries to come. They belong to a branch from the stem whence man came, that separated from that main stem at an early stage of its history and has departed further than almost any other of the herbivora. The most of these aberrant groups, such as the whales, the bats, the armadillos, etc., have low-grade mental powers, but the elephants, for reasons which cannot here be discussed, reasons still doubtful, are mentally the ablest and most human-like of all the brutes, with the possible exception of the anthropoid apes. Those apes have indeed the brutal qualities of man in startling perfection, but the elephants, at least those of the Asiatic group, share with us many of the better human attributes as do no other of the lower mammalian species. It is a most interesting question in the history of mind how these creatures came by their intellectual, and we may fairly add their moral, capacities. As the nearest of our spiritual kinsmen except the domesticated dogs, they demand our care; they should have it also for their scientific value. From this point of view the African species is needed for comparison with its diverse Asiatic kinsman.

From the point of view of the natural history of man, of which we yet know very little, it is particularly important that all those species which lie near the path through which he came from the lower life should be preserved for future enquiry. It is unhappily certain that there is no infra-human species or genus now existing through which we can trace our descent. Yet the gorilla is a near collateral, so near, indeed, that it may fairly be claimed that he is in the same family as man, or even that as animals are usually classified in the same sub-family or tribe. It is likely enough that he is as near to us in the genealogical tree as is the sheep to the goat, the lion to the tiger, or the bison to the buffalo. So, too, with all the creatures commonly termed apes; they lie about the place of the parent stem of our life, representing in a hundred or so living examples the marvellous history of that age-long up-climbing that brought, in the end, our kind. The greatest of all science problems is this of the coming of man; so far as we shall solve it the work will have to be done from the study of the life nearest to the path on which he won his way. If these monuments be destroyed before they are surely interpreted the riddle may never be read.

It is always difficult to foresee the needs of the generations to come, and nowhere more so than in the field — we may indeed say the wide realm — of enquiry; yet it is safe to anticipate the needs of handing on to our successors all we can of our and their heritage of the earth as little impaired as we can contrive it to be. We may be sure that they will more readily pardon the waste we may make of its physical resources, its coal and ores, or even of the precious soil, than any unnecessary or avoidable destruction of its organic species. They will require these creatures not only for the advance of knowledge in general, but for much they have to learn concerning the safety and development of the mind and body of mankind. It is, for instance, evident that, in studies yet to be made as to the nature and modes of prevention of human diseases, many species of animals are to contribute largely to knowledge as to their nature as well as to the means of prevention. Two out of the limited number of our domesticated animals, by their physiological characteristics, now preserve us from two of the most fatal maladies. The cow has by the method of vaccination effectively relieved us of small-pox, and the horse is the only available creature for producing the antitoxin of diphtheria. Thus we see that, with the next beast swept away, there may go the possibilities of help to life as well as to learning.

In another chapter some of the ways in which we and our heritors may best deal with this difficult problem of making over the surface of the earth with the least possible destruction of its indigenous life will be noted. The arrangements to attain this end cannot be made at once, they must be gradually developed, as required by the advancing needs. What is, however, needed at once is a sense of the situation, a clearing away of the primitive childish notion that the marvellous life of this world is fitly to be taken as a toy for man, to be carelessly rent away with his plough, or slain for his diversion. The establishment of a truly civilized state of mind, as regards man's duty by those creatures of all degree who share life with him, is the necessary foundation for such conduct as will keep our race and time from shame in the age to come.

XII

THE LAST OF EARTH AND MAN

IN the previous chapters it has been more than once remarked that the earth is still in its youth and that the ages that it is to endure are likely to be as long as those which it has passed through since it came to bear its precious burthen of life. The evidence of this essential vigor is to be found in the fact that the two sources of energy, the sun and the underground depths, whence are derived all the processes of the sphere, are yet in the full tide of action and show no signs of exhaustion. Certain physicists, reckoning the sun's heat as due altogether to the falling in of its elements toward its gravitative centre and the consequent expulsion of its heat, have reckoned that the supply would be exhausted in from four to twenty million years. In this computation they have neglected to take into account the fact that as the sun grows smaller it grows hotter, which would greatly prolong the heat out-giving process. Moreover the discovery that some elements are radio-active, giving out vast stores of energy acquired, we know not how, has made an end of all reckonings as to the origin or the endurance of the heat in the celestial spheres. If the sun has only a ten-thousandth part of its mass of radium, there is no limit to be assigned to its endurance as a vivifying centre of heat, by any computation we yet can make.

While the trifling part of the heat lost by the sun that falls upon the earth is the source of all its atmospheric movements and of organic life, that from its depths is necessary to keep the surface in the condition of mingled land and sea. The reason for this is simple, at least in its general nature. By losing heat the earth shrinks; as the loss of heat is from the depths, where a high temperature still exists, the shrinkage mainly takes place there and not to any considerable extent in the relatively cool outer parts of the sphere; hence this outer part of the sphere has to wrinkle in order to fit the lessened centre. This, though too briefly stated, is the cause of the upward wrinklings of the crust which form the continents, and of the downward that hold the seas. There are sundry other actions that come in to determine the mode in which this work is done, but the main point is that these movements are necessary in order to keep the dry land from being reduced to the level of the ocean. Should the earth's interior cease to lose heat, this uplifting process would come to an end, and the lands be worn down to the level of the waves. This would take time, for the average rate of the downwearing is somewhere about a foot in four thousand years; but it would be a matter of only a few geological periods before the continental areas would be brought to the condition of low, ill-drained plain lands, and a large part of their area would disappear beneath the sea.

What we know of the internal heat of the earth leads by lines of fact and argument, too long to be discussed in this writing, to the conclusion that the store of it is great enough by its loss to keep up the continent-building process for a vast period, probably for far longer than all the time which has elapsed since life came upon the earth. The amount of the loss is not great, being no more than would bring about a shortening of the earth's diameter by a foot or two in a thousand years. Yet this is enough to continue the upgrowth of the great lands at a rate sufficient to compensate for the down-wearing, as well as to maintain, in a way about to be described, the revolution of the earth on its axis, despite the fact that the tides produced by the moon and sun are ever and vigorously at work to arrest this movement. This curious tidal action has so large a place in the history of the celestial spheres, and so important a bearing on the future of the earth as a theatre of life, that we should see it, so far as concerns our enquiry, as clearly as we can.

The general nature of tides, so far as those of the ocean go, is a matter of popular knowledge. We all know that the gravitative pull of the moon or sun on the earth is in accordance with Newton's law directly as the square of the distance of the matter that does the pulling; hence the water on the face toward the attracting body is lifted higher than that on the sides of the earth, and that on the face opposite the attraction is less lifted than the mass of the sphere. So that there are two tides formed, one because the ocean is pulled away from the planet, and the other because the earth, as a whole, is drawn away from the remoter waters. This is an over-simple explanation, but it is all that needed brevity will allow.

It has long been recognized that the earth in its daily rotation is ever swinging against the tidal waves, pushing them aside with its lands much as a ship breaks the wind-made waves. The result is necessarily somewhat to slow the turning movement of the sphere. The action is like that of a brake on a fly-wheel which continually diminishes the power that keeps it in motion. There is no means by which this energy of turning can effectively be replaced. It is a part of the original movement impressed on the earth at the time when the nebulous mass became separated from the other parts of the solar system: any subtraction, however small, necessarily slows and presently prevents the movement. When a man climbs a westward-sloping hill, he applies an infinitesimal amount of energy to accelerating the earth's movement; as he descends the eastern slope he does like immeasurably small work in speeding the machine. The tides are giants in this treadmill, and computation shows that in the course of a few thousand years they should mark their action by the shortening of the day by a second or two. But now come the astronomers, with fair proof drawn from evidence as to the time of occurrence of ancient eclipses, showing that the day cannot have shortened by as much as a second for all that tidal friction should have brought a vastly greater result about. The only discernible way out of this tangle is through the following considerations:

When a sphere is whirling with a certain fixed momentum, as in the case of the earth, as we lessen its diameter we increase the speed of the rotation. A familiar and fairly good instance of this may be had by swinging a weight attached by a string so that the cord winds around the finger; as the line shortens the turns are made in less and less time. Effectively the same principle is applied to the steam governor. We thus see that if the oceanic tides tend to diminish the rotation of the earth, as they surely do, then there is reason to believe that this action is neutralized by the shrinking of the sphere. This action of the oceanic tides is only a small part of the tidal work which has profoundly affected the celestial spheres and is continually acting, so long as they are not rigid to the gravitative pulls of other bodies. The wide-ranging effect of this action has recently been made known to us by George Darwin, and has, as yet, not entered into the field of popular science. It may, therefore, be worth while briefly to set it forth.

The effect of the tidal action of two spheres, while they are in the fluid or plastic state in which the tides can by their attraction cause the shapes of their masses to alter, is to send them further apart. Thus when the moon was set off from the earth, both spheres were, doubtless, much nearer to each other than they are at present. They may have been almost in contact, but at that time both of them had such a mobility of their particles that each produced great tides in the other. The effect of the interaction of these tidal protuberances was to push the bodies apart. The way in which the process is effected cannot be set forth, save in rather recondite mathematical form, or by complicated diagrams. Hence it may better go as a bald statement, with the assurance that the result is unquestionable.

So long as the earth and moon remained sufficiently fluid to allow their whole spheres to be tidalized, the constant, slight, but efficient strain, due to the action, pulled them away from one another. When they become so far solidified that the tides ceased to deform their spheres, they ceased to work apart. The relatively slight uplifts of the oceans still have effect in this way, but it is so small that we cannot expect to trace it. In the case of nebulous masses which are passing into the state of solar systems where there are for a time fluid spheres, this sundering action of the tides has much to do with their shaping. This is particularly the case with those most puzzling wonders of the spaces, the double stars of the type when two neighboring suns revolve about their common centre of gravity. Because of the heat which their shining indicates, we have to believe that they are fluid enough to have vast tides which, in the manner above suggested, are driving them apart until they become separated, it may be, further than the most remote planet from the sun.

Coming back to the matter of the continuance of the earth in something like its present condition, we see that all the discernible facts point to the conclusion that, so far as the conditions of the ancient relations between the heat of the sun and of the earth's interior, the important elements in the mechanism, are concerned, there is no reason why a hundred million fair years of life may not be before this planet. As for the tidal effect, the earth has passed the time when the solar tides can push it further into space, for it is, as we know, too rigid to yield to that action except in the slight movement of the oceans. The question arises: Are there any other foreseeable accidents that may mar this fair prospect? There are certain of these which some pessimistic naturalists have looked forward to as possible and even probable sources of calamity. These we will now consider.

First of all, there are suggestions that the earth's atmosphere is in process of being deprived of the most important of its constituents, oxygen and carbon dioxide (CO^2), by the daily routine of its organic life. This is undoubtedly true as regards both of these substances. They are rapidly passing into the solid crust; each thousand years takes of them a notable amount from the air. In the case of the carbon, the vast withdrawal in forming limestones, coals, and coral beds is probably compensated in part by the emanations of its gas from volcanoes, and in part by the entrance of carbon meteorites into the atmosphere from the celestial spaces, where they are burned or oxidized because of the high temperature the friction against the air brings about. In the case of the oxygen, the problem is not yet clear. We see no source whence the vast withdrawal due to the geologic processes can be made good. That it is in some way fed into the air, perhaps in the atomic state from the spaces, is made effectively certain by the following evidence:

We know that the atmosphere has not changed much in mass during the geologic periods from the Silurian to the present day, for since that time there has been no great alteration in the general character of the earth's climate. If the atmosphere were greatly increased in quantity, the effect would be proportionately to augment the temperature of the surface. A gain of one-tenth in the mass of the atmosphere so caused would probably change the heat at the sea level by not less than 50° Fahrenheit. Such an increase would, it is true, be resisted by the evaporation due to the gain in temperature, and the consequent development of a permanent cloud-wrap, impenetrable to the direct rays of the sun — a veil something like that which shrouds the planet Jupiter — but the effect would be to disturb the admirable balance to which we owe the fitness of sea and land to nurture life. The fact that, since the Cambrian period, we have had the normal succession of glacial periods and those of no glaciation down to about the same parallels of latitude is fair proof that the mass of air has not been greater than it is at present. A like train of reasoning leads us to believe that the mass of air has not been very much less than it now is since early geologic times. For if that mass had ever been reduced by as much as one-fourth, the result would have been a devastating cold, such as we encounter at the height of say twenty-five thousand feet above the sea level, where no living forms whatever can abide. In a word, the persistence of the air in vitalizing quantity seems to be well proved by the past of a hundred million years or more, so that we may reasonably assume that it is not likely to be disturbed for an indefinite time in the future.

As for the chemical constitution of the atmosphere, the evidence goes to show that it has been as constant as this mass. Experiments on a variety of animals and plants show that they do not tolerate any considerable variation in the quantity of the carbon dioxide or the oxygen it contains. A slight increase in the proportion of either of these substances held in the air is at once destructive to animals or plants alike. Nor can we fairly assume that in other ages these forms were more tolerant to the increase of these necessary materials. The fact seems clear that organic life began with an adjustment to the atmosphere substantially as it now exists, and throughout its history has found these conditions unchanged. Thus, so far as the mechanism of the earth itself is concerned, we may confidently reckon that the machinery is marvellously well fitted to keep on as it is for a vast time to come.

Turning now to the external dangers of the earth, let us see what chance there is of catastrophes due to events in the stiller spaces that might make an end of the ancient terrestrial order, or so far damage it as to make an end of its rational period — the reign of man. There is an interesting group of conjectures as to variations in the temperature of space which deserves brief mention. These are, in effect, that the stars in the heavens, the heat-radiating suns, are variously grouped so that there are realms of warmth where they abound, and others of cold where they are remote from each other. Now as our solar system is journeying at a speed of something like twenty miles a second toward the constellation of Hercules, may it not be that the earth will come to be in hotter and colder places during its voyage? The answer to this once much-discussed suggestion is that the share of heat given by the stars is presumably equal to the light they send, so that it would require that these radiant orbs should be very numerous and inconceivably near before they would materially affect the temperature of space. Moreover, though we are flying at stellar speed, it will require tens of millions of years to bring about any considerable change in our relation to the positions of other suns. Therefore, though this may be in a slight way a true cause of climatal change, it is too remote for us to reckon upon. It is safe to say that for the duration of man he will know skies like those of this time.

There is the old popular notion that a comet would in the end bring the finish to the earth; but now we know these bodies as trifling affairs: so far as danger is concerned not worth taking into account. It is doubtful if any of them are much more than clouds of scattered particles, shreds, it may be, of the ancient nebulous matter, from which solar systems are made, which did not get embodied in the process of aggregation. Should one come in contact with the earth, an accident almost infinitely improbable, the effect would probably be a startling meteoric display and nothing more. There is, however, another group of bodies: the meteoric bodies composed in part of iron and in part of stony materials which give enough token of danger to warrant scrutiny. The facts about these materials are as follows:

Each year there are likely to be a number of meteoric falls, the masses varying in size from the smallest bits that can be identified to those weighing a ton or more. None of the greater masses have been seen on their way to the earth, but as these largest are of the iron group and, in most instances, easily discriminated from any earth materials by very evident features, there is no doubt that they are of celestial origin. So far as these bits that are known to have fallen on the earth are concerned, they are of no importance in its economy. Up to this day there is no well-attested instance in which they have in any way interfered with man. If we knew that we had learned the whole of the story we might well turn over the meteoric problem to those who are trying to solve the scientific aspects of it. There is, however, the chance that it may have import in relation to the future of the earth for the reason that, while as yet we have found none of these visitants of more than a few tons' weight, it is at first sight not inconceivable that one should collide with us of vastly greater size, say a mile in diameter. What will be the effect of such a contact?

We readily see that a meteoric mass weighing as much as a ton coming upon the earth at a speed of about twenty miles a second — perhaps twice that speed if the earth is swinging toward it — applies a vast amount of energy to the planet before it comes to rest. But by far the greater part of this is spent in rending its way through the thirty miles or so of air it traverses, so that when it strikes the ground it seems never to have the velocity of a modern cannon shot, as is shown by their slight penetration of the earth. If, on the other hand, the body was a mile or more in diameter the consequences would be very serious. Only a small part of the energy would be spent in the air, and the heat engendered in air and on earth as well as the shock would be sufficient to bring about the destruction of life over a wide area. The damage would increase with the diameter of the body in a high ratio, so that such a collision with a mass twenty miles in diameter would pretty surely be fatal to all the land-life of the earth.

Fortunately for our peace of mind, there seems good reason for believing that bodies of the group to which meteorites belong are not likely very much to exceed in size those we have found on the earth, and this for the reason that these bits have not been formed in the celestial spaces, but are evidently fragments cast forth from a sphere in the volcanic manner. This is proved by the fact that they are perfectly crystallized in a way that shows them to have been parts of a large mass. Their shapes indicate that the mass to which they belonged was subjected to strains that developed joints and faults. Their rent faces tell that they have passed from the parent body by explosive action. All these facts justify the hypothesis that they have been thrown out from volcanoes. Now all that we know of such explosions indicates that masses more than one or two thousand cubic feet in volume are not cast forth, the reason for this being that the violent action of the ejective process causes the rock to be broken into bits along its joint faces, or through the mass if joints be lacking. We may, therefore, presume that so far as these falls of meteoric stones is concerned, there is little risk that we shall encounter any large enough to bring any damage to the earth.

Besides the meteorites, there is another group of bodies in our solar system from which there may be danger of collisions. These are the bodies, such as the asteroids, which inhabit the space between Mars and Jupiter, masses of relatively small size, apparently varying from a hundred to a thousand miles in diameter, and somewhat plentifully sown through a wide field. It is likely that they exist there by the thousand, and it is not improbable that very many of them are much smaller than those that have been detected. One body of this class, known as Vulcan, lies between our earth and Mars. It seems to be of rather irregular shape, and, what is more important, to be treading a very irregular orbit. As to the origin of these odd bits of matter, we are as yet in the darkness. They are too large to have been ejected by volcanic action, and seemingly too small to have run the normal course of a sphere from the primitive nebulous matter. It has been conjectured that they are the result of an explosion of a planet which hurled the mass into fragments, but their distribution in the field they occupy is against this view. Moreover, we cannot as yet conceive the action of any force that would so rend a sphere to bits. While the theory of the formation of these singular bodies is interesting enough, we are at the moment concerned with the question whether there may not be many of the same group too small to have been detected by the telescope which may, in course of time, collide with the earth.

As for likelihood of danger from stony planetoids or bolids colliding with the earth, we have two sets of evidence drawn from the physical history of the moon and the earth. In the case of the moon, we have a sphere the surface of which is very ancient. There is reason to believe that it antedates the solidification of the earth's crust, and so, most likely, is some hundreds of millions years old. As the present writer has elsewhere noted, the visible part of the moon shows in the so-called seas what appears to be proof that there have been collisions with falling bodies large enough to melt the lunar rocks over areas some tens of thousands of miles in diameter. These collisions took place at a very ancient time after the greater part, but not all, of the heat of that sphere had passed from it. There is no basis for a reckoning as to the time of occurrence of these accidents, but for the reason that the moon, through a relatively small sphere, still retained, at the time of these accidents, a share of its heat, it is reasonable to suppose that the earth had not yet cooled down to the point when organic life was established upon it. This would establish the time of the lunar falls as at least a hundred million years ago, perhaps very much more remote.

The fall of large bodies on the moon, if it occurred, and the facts well warrant the supposition that it did, appears to have come about at or near the same time and, as we have noted, at a very remote period. If such then took place on the earth as a part of the same accident, it probably happened before our sphere had passed out of the universally molten state. Nothing that can be regarded as evidence of such a catastrophe has been found by geologists. If a record of it had been written on the solid globe, it would probably be evident to this day in a vast area of igneous rocks of a uniform nature such as apparently exist in the so-called lunar seas. Moreover, the demonstrated continuity of life on all the continents from an early stage of the earth's development is proof that the delicate adjustment of its temperature has not been disturbed. The fall of a celestial mass sufficient to have formed the lava of the smallest "sea" on the moon would inevitably have disturbed the organic order in a way that would appear in the geological record.

Looking upon the problem of the earth's organic future in the light of its past, a method of enquiry by far the safest, for it involves no hypotheses whatever, we find great evidence that the conditions are such as to make a very long survival of the present conditions as certain as anything in this varied universe can be. We may assume that for a future, probably as long as the geologically recorded past, the sphere will go onward through time and space, free to work out its problems of life, with no break in the succession due to accidents coming from within or without. Here is a free field for much in the way of deeds. Whereto are they to lead and what is to be the end of it all? It is a great field of action and a fair one for speculations, though as yet but little explored.

The most important element in the future of man is the extent to which he may be able to obtain control of the processes of his own body, those which determine health, longevity, and, above all, his inheritances. In the chapter on the rational control of the earth the probabilities of such accomplishment are considered and the conclusion reached that there are large possibilities of gain in all these regards. The question arises as to the directions in which the quality of life may be advanced through these accessions of capacity to shape it. In this field there is room for unlimited conjecture, but little to guide the process.

There are, however, certain features of this future which appear to be fairly determinable, and, though they are shadowy, not without interest to those who would forecast the future of mankind.

It is with a pleasure not without an alloy of regret that we may confidently look forward to men who are to look back on ourselves, as we to our ancestors of the bone and cave age — not despisingly, as we look upon those troglodytes, for the man to come will have too large a sense of relations for that — yet with a judgment that we were far back in the night when we thought we dwelt in the day. We may be sure that they will take us largely and tenderly, these folk of mayhap a million years hence, for they will feel the unity of life, while we merely discern it and that only in part. It is in this sense of the common bond of all life that those who are to look upon us from afar will have their greatest enlargement. Knowledge they will have beyond the conception of our time, as ours is beyond that of the lowest of our kind; but it is in the extension of the sympathies that our kind is to make its largest gains. By this our successors are at once to go far from us and to come nearer. In that field the gain may well be such as to make a new species, a new order of man, parted from us as we from the lower brutes, yet including our little lives in its vast extension.

There are many signs that show us the present wonderful expansion of the economic part of civilization which, by its magnitude of material achievements, hides from us the more important changes and gains that are taking place in the higher realm of the sympathies. The first effect of this great modern movement was, in a measure, destructive to the emotional side of man that related to the so-called fine arts; we lost in part the ancient mode of expression of it through literature, sculpture, and painting. This loss seems to have been no more than the diversion of an ever-gathering stream into ways that led to an immediate rational sympathy with the fellow-man and the fellow-nature. In this field of action the only monuments are institutions and the states of mind they indicate These show clearly that within the last four centuries, since we began to emerge from mediævalism, the gain in sympathy has, in the Aryan race, been greater than in all the previous stages of its advance. Other races, for obvious reasons, show less of this movement, but it is evidently a part of a series in which all the civilizable groups of men are to share, leading in the end to the completion of the evolution which began with the earliest organic form.

We may fairly expect this sympathetic development of men along with the rational within a brief geologic time to bring our genus to an intellectual and spiritual control of life such as we can but faintly divine with our imagination. There is no reason to forecast the end of this new order until the sun goes out, or the under-earth ceases to renew the theatre of life. That, so far as we can reckon, may well be as remote in the future as the dawn of life is in the past. We seem to be in the middle of the term with the most of the great doing, and with that in the spiritual realm yet to be done. When the end comes we may be sure that it will not be in the vile Schopenhauer way — by the voluntary abandonment by man of his life as a thing of evil — but by a cheerful surrender of it in the conviction that a great work is done, and that it is a fit part in an infinite accomplishment.

We may ask ourselves as to the last steps in the time when the earth and sun begin to wane in their activities and to verge slowly to the end. Will those far-off men elect to keep up the battle to the imperative finish, contending with the degradation that comes from shrunken lands or scant heat, or will they in their wisdom choose to pass out in their nobler state? To this we can give no other answer save that those enlarged semblances of ourselves will make their judgment from a high station and dutifully, as we should in our happier estate.

XIII

THE ATTITUDE OF MAN TO THE EARTH — SUMMARY AND CONCLUSIONS

THOSE who have read the preceding pages of this book must have perceived that so far as the matter they contain has other purpose than to be interesting, that purpose is meant to awaken a sense of the nobility and dignity of the relation man bears to this wonderful planet and the duty that comes therefrom. In this closing chapter I propose to assemble certain of these considerations in an effort to show the need of another than the old way of looking at the world about us as a mere toy or, at most, a useful mechanism, and to consider the obligations which it lays upon us.

There is a school of philosophers, like the most of such schools ancient and rather out of date, whose followers hold to the interesting notion that the universe is but an extension of the individual man: that all in the realm is but an enlargement of him who cognizes it — having its existence altogether from his appreciation. Like many another philosophy, this of the solipsists (i. e., *only himself-ists*), it is good to entertain its views at least for a time, because they serve, even if not strictly true, to enlarge our conceptions. As the naturalist sees it, this paradoxical statement of man's relation to the universe needs but a change of form to fit the facts better than any other theoretical interpretation. If we say that the universe is an extension of man because he has come forth from it and embodies in a way all in himself, we have a form of solipsism that suits the student of nature — apparently the new mode of phrasing reverses the tenet — but it retains the essential point of the ingenious philosophy, for it acknowledges the identity of man and the realm in which he dwells.

There is good reason to believe that the main idea embodied in the philosophy which regards the world as essentially kin to ourselves is to be that held by the men of the hereafter. The whole trend of the understanding as to the relation of man to the realm leads to the conclusion that whatever else he may be, he is the sum of a series of actions linked with all that has gone on upon this earth. Already the more discerning see that our kind have come to the beginning of their mastery of this world by penetrating into its meanings, and further knowledge can only increase the clearness and sufficiency of this vision. We may assume that our successors will, generation by generation, be more and more inspired by this understanding: that they will come to see the world as a wider aspect of themselves.

If the above suggested view as to the trend of thought of men as to their relations with nature be true, then we have not long to wait until the care for the economical resources of the earth which has been advocated in the first chapters of this book, and for which people are already prepared, will be merged in a larger care for the sphere as a part of man from which he has been alienated by ignorance, but with which he is to be reconciled by knowledge. Seeing, as he must, for it is written on earth and sky, the oneness of Nature and intelligence as its master, man is sure to go forward unto the higher life of understanding out of which will come a sense, of which we see barely the traces in our time, of his duty by the earth. At present, the conception as to our place in the realm is so new, so confused with the ancient misunderstandings, that it is difficult to see how we can do the first part of our task by co-operating with the conditions which have made for the advance which has brought us to the gates of the new life. Certain directions for our endeavors are, however, plain.

To bring men to an appreciation of their station as masters of the earth it is necessary that they be effectively taught the nature of that relation. This is, indeed, the part of modern science, but we are as yet far from its accomplishment. So far as science is now passing to the body of the people, it is in the form of special, though elementary, knowledge of this or that group of the facts. Of such, men may have an endless amount and yet not be nearer to the understanding of the important truth; the need is to have this truth taught as a gospel. It has to go to men with the quality of religion, by the way of imagination and the emotions with which it is conjoined. There is reason to hope that we are at the beginning of the process which is surely to require generations for its accomplishment. At best this enlargement will be slowly brought about and it cannot be expected immediately to affect the common folk. Unless the world of men should become philosophers, we must look in the future as in the past for the leading spirits, the rare men, to be guides to the new dispensation, the masses following in the ancient dumb way — taking their light not directly from nature, but in the good old way, mediately through their prophets.

Something may be done to hasten the growth of a better state of mind as to man's relation to nature by a much-needed change in our methods of teaching science. We now present the realm to beginners as a group of fragments labelled astronomy, geology, chemistry, physics, and biology, each, as set forth, appearing to him as a little world in itself, with its own separate life, having little to do with its neighbors. It is rare, indeed, in a very considerable experience with youths to find one who has gained any inkling as to the complete unity of nature. Seldom it is, even with those who attain mastery in some one of these learnings, that we find a true sense as to the absolute oneness of the realm, or the place of man as the highest product of its work. This is the inevitable position of those whose task it is to advance the frontiers of knowledge. The mass of their knowledge required to make way in any field is so great that little can be known of any other domain. But this situation of the investigator needs not be that of the ordinary man. Save for the merest trifle of knowledge which he gains by the simplest individual enquiries, he must take this nature on faith in his teachers. So far from trying to compass the learning of the smallest bit of the realm, he needs be limited to the little of it that will best serve to enlarge his understandings of the world as a part of himself.

In the revision of our project concerning the share of natural science in our scheme of popular education — a revision long overdue and now sorely requiring action — we need begin by determining, first of all, what of its truths have cardinal value from the point of view of conduct; what of them, in a word, help to dutifulness by ennobling the conception of man's place in nature. Other matters may be taught for other purposes, for their purely intellectual values, or for their economic uses; but the great gain we are to have from the modern knowledge of the world is in the change of attitude it is to bring about: in the sense of kinship with the anciently alien realm and of duty by the great inheritance of life. To the making of this new spirit no great body of learning needs go; it will depend for its development far more on the way of approach than on the mass of the knowledge that is gained. So soon as men come to feel themselves as really the children of the world, the tides of affection that instinctively tend toward it, but have been sorely hindered by ancient misunderstandings, will help in the good work, and give us souls reconciled to their great house and eager to help its order.

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