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THE PHILOSOPHY OF GEOLOGY AND THE ORDER OF THE STATE[1]

ONCE each year we come together to renew our strength, like Antæus, by touching the earth.

I am conscious of taking some degree of liberty in departing from the usual form of this established function—the annual address. It would gratify me and might in some measure have diverted or persuaded you, if this occasion were given to the illumination of some specific technical theme. But the spirit of the hour seems to impel me rather to read from out my experience and observation, or at least to portray, as I see it, some part of the obligation of the state to our science and the responsibility of this science to the state.

The occasion is perhaps opportune, not so much in this place of meeting which happens to be the seat of government of but one of the many states here represented, and in the presence of members from two great federated governments; but essentially because, for the sake of all parties of interest, we must recognize more clearly the civic element in geological science and insist more pertinaciously on the immediate as well as the ultimate dependence of a state, if organized to endure, upon the demonstrated laws of this science.

I wish I might extend to my colleagues among the official geologists of many states an assurance that this address is to be devoted to some added demonstration of the obligation of the state to exploit to the utmost its geological resources, for the sake

[1] President's address before the Geological Society of America, Albany, December 28, 1916.

of the commercial interests of its community, but such public arguments are now superfluous. It is a primary impulse and an almost elemental instinct in the state to develop the commercial assets of its rocks. The appeal is so direct, so simple, so imperative that no state can afford to ignore a well-directed official effort to increase thus the general well-being and comfort of the commonwealth. The broad proposition is not debatable; the proposition in detail has always been debatable and debated. Too often and too much in representative public opinion is the existence of the official geological organization justified by certain perfectly obvious considerations which subtend a large angle in the public consciousness. Gold and silver, iron and coal, petroleum and natural gas, and terms like these are made too often to set forth a reasonable vindication of official geology. But you and I may well insist that such factors as these reckoned in terms of the wealth of the state are not the justification of official geological research. We may as well draw back the veil—private enterprise will pretty effectively take care of such things as these without much help from us. Against such factors which we may term the obvious sources of wealth must be weighed the more recondite products which have seldom entered into the estimate of the lawmaking body or the public knowledge.

It is in these that many of our states are richest, not in those obvious factors. In a state like this, which I cite not for comparison, but for illustration, the unexploited iron ore would seem to be well over a billion tons, while the actual value of the annual product of iron is not more than one tenth that of the annual output from thirty or more different mineral products. And we can not even begin to estimate for our state the vast reserves in products undeveloped or conceive the now unknown applications to industry and the arts which our commonest geological compounds are competent to supply in response to the demands of the state.

I can see in such a state or in a union of states and governments such as ours, the demand for every human need, to-day actual and to-morrow possible, which is in any way dependent on the rocks of the earth, fully met here without reliance on any outside source. And it is of eminent importance that the state take counsel with itself to magnify such independence, at the sacrifice of its commercial ease, for dependence in commerce means no less than does dependence in the scheme of nature, that is, degeneration of stagnation.

I counsel, therefore, you who are official servants of the state, to urge, within your power, upon the state this primary obligation; to take from no other what it can itself as well produce from its own stores. Insist, as the right is in you, that the state shall take account of the knowledge you possess for the full but conservative development of its own resources, and neglect no occasion to enforce the claims of the man who knows best, to precedence in these councils of the states.

I would not seem to profane my high office by stating in this presence the elemental conceptions of the science, but it is most imperative that I here, and you elsewhere, shall be lucid, exact and comprehensive in setting forth its claims, namely and briefly: that there is no substantial conception of property apart from the products of the rocks, the soils, the mines, the water, the air—and these in all their functions are geological factors; that there is no correct understanding of the meaning of human life, individually or in its complex community relations, if we stand with our back to the great panorama of events

which have builded the earth and the trains of life which have moved over it from the dawn of its history. It is most essential that every state should above all things comprehend these facts.

The current of my thoughts is toward the well-established principles of geology which have constituted the state; not the state as a geographical section of the earth, and not just now those principles which have laid its material foundations, builded its rocks, formed its veins and beds of ore, made its soil, established the sources of wealth as expressed in terms of human market; but unavoidably I turn to those principles which illumine the trail of humanity and have given it direction. My time has been long enough to ripen some of the green fruit of experience and enforce some deep-seated lessons. In the light of this experience and these associations there is no escape from the earnest conviction that the things of supremest value to mankind, the refined essences of the earth, lie in its records of the life which has gone before us. As the emergence of what we call the living, quoting Professor Chamberlin, is the transcendent event in the history of the earth, there is certainly no other fact in the presence of humanity so vital as that and the vast procession of the ages with the key it holds to our present state and future hopes. Need I say to this audience what I would wish to say to a wider: We are passing, we have stopped only to see the march of life and play our small part in the tremendous and endless pageant, happy indeed if, endowed with powers of divination, the rays of truth have dawned upon us from out of the past, to light the imagination on toward better things.

To what extent, then, are we fortified by the evidence of the past career of life in reading its oracle for our present guidance? This inquiry sets plainly before us, first, the paramount question as to the oft-alleged and too often magnified imperfections of the record of life upon the earth.

In many, probably in most, expositions of the science of geology and paleontology, prepared for the use of students and general readers, the so-called imperfections in the record of past life are brought out with a vivid intensity. These expositions are, I think, in large part due to a more or less unconsciously apologetic attitude on the part of the authors, as though they were in some way, being apostles of the science, likely to be held to account for any overstatement of its claims; and these attorneys in bankruptcy are not inaptly, to my mind, comparable to buyers of ancient but damaged rugs, torn, raveled, worn bare of their patterns: ostentatiously declaring their defects while overlooking the beauty, the symbolism, the perfection of the design seen clear through all the ravages made by the wear of time.

I find myself out of sympathy with such deprecating portraitures. Neither my experience nor my philosophy finds support for pessimistic conceptions of the ultimate hope of completing our tapestries from the patterns we know and the threads we are yet to pick up. For a few years, as we reckon human history, we have scratched with our hammers some surface exposures of the tablets of the law in parts of the earth most easily accessible to us, and the occasional explorer into remoter parts has gathered the life records in haphazard way, here a few pounds' weight, there a few tons'. Not one fiftieth part of the exposed rocks of the earth has yet been closely scrutinized for these life records, and of the unexposed but known strata, practically none at all in the great total. This State of New York covers 47,000 square miles, two thirds of which are underlaid by life records of the earth. This fossiliferous area is one eight-

een-hundredth part of the land area of this globe, about one eleven-hundredth part of the exposed fossiliferous rocks. In this state the work of assembling the evidences of the life record has proceeded continuously in organized attack for eighty years. An eminent French geologist has intimated that there are few places of equal area in the world where the life record is so completely assembled—and yet every year brings new and necessary additions to our quiver. What shall we say of the other 1,099 equal areas of fossiliferous rocks on the earth? Many of them have indeed been studied with precision, but there remains and must remain for long years yet an overwhelming balance of the unknown. In the abundance and perfection of the life that is preserved in these rocks only the living seas themselves are comparable. I have estimated the number of individuals of a few of the species occurring in one insulated mass of marine Devonian strata known as the Percé rock, a section which above the waterline represents a sea deposit 300 feet thick, 1,300 feet long and about 250 feet wide; and the figures for these few species run into the hundreds of millions of individuals —yet the rock is not richly fossiliferous, in the customary use of that expression.

It seems to be my experience, too, that the most closely studied formations have already yielded up a large percentage of their actual fauna. For some well-studied formations in limited areas the known fauna is, approximately speaking, a true and fairly full expression of the actual fauna. I can not of course pursue this matter here into its further details with its brilliant vistas already before us of learning the inchoate life of the primitive soils and first impounded waters, but I think I shall venture to enter the lists on call, to contend that for plant and animal life alike the records of the rocks, where unaltered, are unimpeachable for adequate suggestiveness of the designs which the threads of life have woven. And when the imputation is too often made of imperfection through loss of anatomical detail, or the destruction of essential structures, compare by way of simple illustration compressed into the emergencies of this occasion the growth of knowledge of fossil anatomy within the fragment of the lifetime of one man. Fifty years ago all that was known of the ventral organization of the trilobite was a mere suggestion embedded in a nest of speculations; of its ontogeny a few discrete facts. So far has knowledge advanced that to-day we seem to know these animals in all their essential details and development; and if aught is left to become known of internal anatomy or ecology, the lessons of the past are the promise of the future. What was known of the Eurypterida fifty years ago was little but their outline and their grosser form. To-day their ontogeny is understood almost from birth onward, their anatomy almost to ultimate details, their habits at least as well as those of vast numbers of living animals, their phylogeny as well as or better than the phylogeny of any living race subjected to this speculative treatment. Supplement these illustrations, which are nearest to me, with the scores of others known to you and with the tremendous strides made in this same period of time among the extinct vertebrates, and within the realm of lost floras where sheaves of knowledge have piled higher with every year.

These are the theses I should wish to nail on the doors of our temple:

Nature makes for the individual. This truth is registered on the tablets of the earth; it lies also in human observation and in human experience. Its recognition is of paramount importance; its acceptance sweeps away cobwebs of vagrant hypoth-

eses which befog the pages of writers on political and social economics.

In the progressive line of development which in the present terminates in us, the procedure of nature has been one of only limited concern for the family and of tried out and abandoned experiment for social partnerships and the division of labor. To perfect the individual inconceivable safeguards have been thrown about him. The individual is creation's unit in terms of which all progress in life is to be reckoned. With unsparing hand she makes and wastes these units, both for her greater purposes and those which we may call her lesser ones. Units of purpose are wiped away to make place for units of other purpose. Yet the unit type remains; remains with its full seeding of possibilities, armored for its fight with double portions of food supply, of sense organs, of locomotive means, with an inexpressible superfluity of reproductive supply. Whether a given unit survive till its work be done or perish in the doing, it is the individual type that is at stake, it is against this individual type that all the powers outside it are imposing their obstacles.

This the geologist knows: There has been no cooperation in the historic development of the life in which we are directly concerned. We may not yet know the trend of many life lines for far in their history, but wherever such lines are best known, within the limitations of large natural divisions, those that run through from limit to limit and point the way both backward and ahead, and those other lines collateral to ours which have ended and determined fruitlessly—these all can be conceived in no other way than variant expressions of the individual. And in the history of human life is it aught else than the individual that has stood for the progress of mankind? Was it the barons at Runnymede, was it some bill of rights, some declaration of independence, some joint action of human agencies that have been the crowns of our achievements? Or was it the Aristotle, the Plato, the Socrates, the Christ, a solitary Shakespeare, an incomparable Franklin, a rebellious Darwin, or the historic twenty individuals, who have stood for the progress of the race?

I say this only for the purpose of saying *per contra,* that the history of the excellent life (and by that I mean the line of life that is best perfecting its psychology), has shown the futility of attempts at progress through any other agency than the independent individual. This is so important a conclusion to every state taking cognizance of its dependence on natural laws that it is highly essential to consider nature's own alternatives to such individualistic effort, her own experiments in trying out other modes of ascending heavenward. For "individual liberty," said President Butler speaking before the constitutional convention of this state, "is the cornerstone of the free state." That is the decree which is written in burning letters on every milepost of the course of life. "The perfection of the individual is the perfection of the race" says Professor Hoffman, "but," he adds, writing on the organization of the state, "the individual can have no rights or duties that conflict with the good of the whole"—a supplement for which it is exceedingly doubtful that any substantiation can be found in nature.

(*a*) It has been my environmental control to study and, I hope, to learn some of the lessons of life from their simplest and most legible expressions—a result that has come from living and laboring in a state built from the early waters with their undifferentiated expressions of life. The panorama of successive early worlds of life glows with the simple expressions of law

which become more involved, supplemented and beclouded as the passing of the ages complicates the process of higher evolution, and produces expressions which, in terms of existing life alone, would be difficultly intelligible. The study of the meaning of existing life without the light of its vast history leads nowhere.

It is safe to say, I think, that living beings at the start, animated nature whatever its composition, had an equal chance for progress and improvement. How soon that chance became forfeit we can not say, but it is obvious that life was not long begun and its greater stocks established when their courses throughout existence were set and determined. Nothing is more obvious in chronology than nature's deliberate failures, nothing more clear in paleontology than her set purposes.

The vast subkingdom of the Mollusca started well with bodily independence, fully equipped with locomotive powers, an excellent innervation, but they sold their birthright for ease and content. They soon became dependent upon the movements of the waters and waited for the waves to bring them food. Compact in their protection and adaptation, these types of life have come crowding down through the ages in inexpressible variety. They and their allied phyla in the great subkingdom to which they belong have, it would seem, struggled now and again to regain their primitive independence and maintain it, but the early condemnation of the law has overawed them and out of them all has come, and can come nothing better. They had their chance. That chance was missed; for untold millions of years they have failed to improve. They still cumber the earth and teach the lesson of an incurable heritage. You who are students of ancient life know how great is the multitude of lessons like this.

None of the observations of the competent have afforded any evidence that the lines of development through such groups of lowly animals have led to anything of promise or of excellence. The ages have rolled away and left them still with us, progressed, arrested or degenerate within their own narrow limitations, as the case may be. There is no evidence to indicate that these great groups from which nothing can be expected were deprived of their equality of opportunity as contrasted with the other great subkingdoms of the annelids and the articulates from one or the other of which, or from one and the other in succession, our own line has been derived.

The lesson then is this, that dependent conditions of life, however we may see them, throughout untamed nature or in our own communities, are not primitive, are not in the essence of things, but they are set back so far in the history of life that they are now or seem to be unavoidable and unconquerable.

These evidences I have discussed before this society on previous occasions. The field of observation and of inference as well, is greatly to be enlarged and well justifies the appeals that have been made on its behalf, but so much at least is indicated: that here and in analogous cases parasitic existence in whatever group in nature, and with whatever expression in the natural assemblage or the community group, involves the essential abandonment of normal direct upright living and the benefactors thereby are types of life which nature has cast out and aside as hopeless.

It is probably yet to be determined, at least there is no record I can find, that even in the passing of the ages nature has ever set up again upon its feet an organism or group of organisms once fallen into this dejected mode of life.

It is well the state should recognize this

harsh truth which is a law. With a police power guided by intelligence and sympathy, some of the harshness in this inevitable human condition may be ameliorated, but the paleontologist looking at the record of life on the earth says to this state: Be intelligently guided in the treatment of hereditary community parasites, defectives, congenital or confirmed misdemeanants, whatever the form of degeneration may be, by recognition of the presumption that in so far as they can not be physiologically corrected, they are abandoned types in which there lies little hope of repair. I can state this conclusion only thus succinctly without here attempting to present or argue its many ramifications.

(*b*) Soon after the great outburst of articulate life in the Cambrian, wherein, so far as our present knowledge permits, we find the lines along which have come the complicated expressions of to-day; somewhere in there, we may not say securely now, branched out the great phylum which led into the world of insects. We are wont to say that the first whirr of insect wings was made by the dragon flies and great cockroaches of the Devonian forests—an admission which of course implies that long earlier ages saw the differentiation of this type of life. At all events the six-legged type of articulates adapted to life in the water and air, full of vivacity and agility, with full independence, equipped with all potentialities that come from abundant innervation—this type, this six-legged articulate expression of existence, the insecta, started reasonably early on its career. It is my desire to note only in passing that, however close and direct may be the derivation of the vertebrate type from the primitive articulate stock, we have no inheritance from and hence only a collateral interest in this six-legged type of articulate life. Yet the outcome of development along this line has led to most extraordinary displays of morphological and psychic differentiation. A distinguished naturalist has said that the brain of an ant is the most marvelous speck of matter in existence. I hardly need, before this audience, to recall the exquisite and minute specialization in morphology, physiological function, performance and, I should say, conscious or at least psychic behavior among the most advanced attainments of development in the six-legged articulates, the social insects. The ant colony is the ideal of differentiation of function. Its members are by birth and inheritance, food and training, destined to certain specific duties in the colony. Armies are marshalled, wars are waged, the wounded nursed, the captives are trained for their duties, gardens are planted and crops are harvested; the stock is fed and food is stored, and a score of marvelous concerted doings which amaze us by the perfection of their totality, which is—the welfare of the community. Here the individual is actually constructed nervously and physically, anatomically and physiologically, for the niche in the community which he is destined to fill. No human community where cooperative efficiency has submerged the individual and has been the objective and the attainment, no such human community has ever yet reached such an ideal of joint effectiveness as has a colony of ants. The ants are nature's great triumph, her highest performance in communistic effort and in cooperative achievement. And what has come or can come of development along this line?

Let us look back a little into the antecedents of the ants. Says Professor Wheeler:

> So many genera and species of these insects appear full fledged in the early Tertiary we are compelled to believe that they must have existed in

the Trias or even in the Lias, but belonged to so few genera and species, or lived in such small communities that they left no remains.

This distinguished student cites 276 Tertiary species as indicative of their sudden outburst, or perhaps it would be safer to say the development of better modes for their preservation, and he has further stated that there is no reliable observation to prove that polymorphism was existent among the earliest ants of this long period. This differentiation does, however, show itself in the fossil ants of the Quaternary.

This paramount attainment of intellectual activity in the line of insect development, in the line of the six-legged type, would seem thus to have been accomplished largely through the same period of time when the human line was perfecting its mentality. The psychology of the two ultimate results is separated by processes and directions of development as wide apart as the poles. Neither is to be expressed, perhaps, in terms of the other. The results too are wide asunder—one a deadly communism, a moribund partition of labor, a lethal socialism; the other an active, progressive and fertile individualism. For the former the student of nature's history sees no outcome. These too are nature's experiments. The six-legged type with all its purposes, in its highest expression lies prostrate on the ground at our feet, it and its achievements have risen to nothing higher than an ant hill, its communistic relations and subservience are entirely apart from the true genius of humanity. Socialism and communism have been tried out and found wanting, and nature holds conspicuously before the eye of the state the warning that they have nothing either for the growth of the spirit or the progress of the intellect.

(*c*) I regard as peculiarly a doctrine of paleontology, one whose demonstration or confutation would be hopeless in the hands of the biologist, that of palingenesis, or recapitulation, or in other words the broad and familiar statement of the fact that each individual carries in himself and his development history, the history of the race to which he belongs, however accelerated or however retarded it may be. I am trenching familiar ground, but it is because I would remind this audience that not the mere existence, but the panorama of life, is essential to this conception and that the law remains only an assumption of probability as long as its manifestations are pursued only among creatures of high specialization. In our bodies politic the more complicated our existence becomes the more like a tangled web of ordinances become our statutes. Forty-five thousand new statutes it is said have been enacted in the last five years in these states for some of us to trip and fall over, and just as it is difficult to pick our way through this tangle of expediential legislation, so it is likewise difficult to read in highly specialized organisms the leading of this great governing principle of biogenesis. If we do trip and fall among the entanglements of the statutes, the difficult mechanism of our present community life, let us remember that also back even of the bewildering, confusing, interlocking webs of the physiological mechanism of evolution lies, outspoken and luminant, the simpler expressions of the basic law on which rests the whole superstructure of evolution whether of the individual or of the state.

(*d*) It is well for us, well for the state, that we read aright the teaching of the greater past upon the doctrine of majority control, for whatever enduring virtue it has takes its roots in these past procedures of life when laying the foundations of its phyla. Over and over again the dominant race has started on its career as an insig-

nificant minority struggling for its existence against an overburden of mechanical and vital obstacles, armed only with specific virtues which have little by little fought their way into the foreground, and by so doing consummated their upward purpose. If I refer to the geological history of the phylum to which we belong, the Mammalia, it may stand for the oft-repeated procedure which has in various forms come under the notice of every paleontologist. The Prototheria, or the first of all mammals, appeared upon the scene in the Jurassic, diminutive, mouselike creatures even yet retaining from reptilian ancestors the function of ovulation, possibly having already developed a marsupial pouch for their nurslings, insectivorous in dentition, creeping inconspicuously through sheltered places of the forests or among the crevices of the earth, their minute but agile brains, by which they were steering their course, tremendously exceeding in proportion the brains of the giant reptiles whose variant forms constituted the majority and made them masters of earth and air and sea—whose gigantic physique and fleshly lusts had outstripped the early promise of their cephalic ganglia and left them hopelessly decephalized. Insignificant in size and number, but equipped with the vigor of phyletic youth, agile adaptability, locomotive independence left unimpaired through excessive food supply, with such equipment, good balance between cephalic and motor nerve centers, these inconspicuous and feeble folk started on their career of triumph over an overwhelming majority. Time passed and the deed was done. The agile-witted founders of the race had spread abroad through the earth. They grew vast in number and variety, adapted to all media of earth and air and sea. To them at last came the temptations of the flesh pots; they grew great in bulk, slow in body, weaker in locomotion and feebler in proportion. They too had met their impasse and there was nothing beyond. The majority had arrived, but the majority had fed itself fat on the spoils of the conquest and was moribund. Once more out of this majority arose the protest of the minority and again the keener witted, better cephalized, unimpaired, but obscure and diminutive minority, strong always at the head, emerged from the welter of self-indulgence to save the race. Robbed of luxuriant food supply by a mantle of ice, its vitality quickened and stimulated by the invigorating cold, imperiously compelled by a world chill which hung upon the earth unknown years to purge itself of indirection and seek the straightest way to physical salvation through the practise of simple virtues; from out of such conditions came the human stock.

If we do not recognize fully the fact that a majority control in our governments is purely a matter of expediency in the handling of civic affairs, let us remind ourselves of it on this occasion. We need only the reminder, for however often the man in the ward and the voter at the polls conceives that a majority is the paramount issue at stake, it is too often forgotten that the majority is purely numerical while wisdom and truth may rest with the minority. Amidst the inevitable expediencies of government this is its salvation—that the minority, if clear and strong at the head, like an antecedent river, will cut down mountains of opposition.

Said Lord Acton:

> The triumphs of liberty have been due to minorities. The rule of the tyrant is tyranny whether he have one head or many. The principle of absolute majority rule is as profoundly immoral and as profoundly undemocratic as is the principle of the divine right of kings. Majority rule is a practical device for the working of free institutions and not

a principle without limits or bounds upon which free institutions may be based.

This is the teaching of our science; the ephemeral worth of majority control is always obvious; the voice of the people is not the voice of God.

(*e*) We have come to a point in our researches where observation and inference teach us that life originated in unicellular microbic forms under conditions which have been indirectly indicated by the Chamberlins, father and son, as governed by and intimately associated with a conjunction of soil and moisture, with obstructed air, and probably without direct exposure to the actinic action of the sunlight. There has already been interesting and substantial confirmation of the presence of actual bacteria in the most ancient rocks of continental origin antedating the Cambrian, and many well-demonstrated expressions. The discovery of fossil bacteria is to be accredited to several students, Van Ingen among others, but their existence in this age preceding the primordial outburst of life, in times when by every line of sequential reasoning they should exist, this important determination is among the brilliant results of Walcott's researches.

So now every legitimate evidence of fact and deduction points to the origin of microbic unicellular life in the moist, subaerated soil away from the direct sun; and the soils of to-day are alive—a mighty host —with such microbic creations existing under paranaerobic conditions. This army, we are coming to understand, is endowed with specialized functions; and if this statement is, and is to remain, approximately correct, then the acquisition of such special functions speaks of a long past with its gradual and cumulative inheritance. It still remains to be demonstrated that the cycle of life is renewing itself from day to day by the continued transmutation of the inorganic to the organic, however such a possibility may lie in the lap of logic. But it is well for us to realize that this microbic life which in the passage of time has become adapted to such special functions that we recognize among them germs of disease as well as of benignancy, has the historic impress of hostility to the direct rays of the sun. Microbic disease is disease only from the human standpoint, from the point of view of the host of the disease-causing parasite. For the germ—the microbic parasite itself—it is normal living. I think we may well urge upon the attention of pathogenists the importance of estimating the historic impress which is, in all disease-making bacteria, the natural primitive and inherited hostility to the sunlight. In the adjustments and readjustments of these parasites to special hosts and specific toxic processes some may have overcome in a measure this natural antagonism, but for the most their work is in the dark. The marvelous results which have been attained in the treatment of tetanus during the present war, by simple and constant exposure to the sunlight, encourages us to believe that in similar pathology a like treatment would be historically and logically correct.

Fifty years ago, when President Andrew D. White published his "Warfare of Science and Religion," he said:

A truth written upon the human heart to-day in its full play of emotions or passions can not be at any real variance with the truth written upon a fossil whose poor life ebbed forth millions of years ago.

These fifty years since have enabled us to say with equal security that the record written on the fossil is the candle by which we must read the fate of the community, the passions and emotions of the human heart.

We have been shocked into a consciousness that not all the virtues abide in us.

You may recall the ancient days of Rome when the people annually gathered to pay an offering of oil and wine, of milk and violets to the spirits of their ancestors, from the study of whose examples they gained for themselves and inculcated in others a respect for the virtuous past. So we say our *aves* to the great past out of which we and all our guiding principles in individual life, in the community, in the state, have come.

Our broader vision which must be the bloom of our intense specialization is like the dream of the patriarch who, resting his head on a pillow of stone, saw a ladder reaching from this earth to heaven and beheld the angels of God ascending and descending on it.

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THE COMMITTEE OF ONE HUNDRED ON SCIENTIFIC RESEARCH OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

REPORT OF THE SUBCOMMITTEE ON ASTRONOMY

THE science of astronomy differs in a marked manner from many other departments of human knowledge. Owing to the large sums of money which have been given to it, extensive organizations have been effected, thus enabling astronomers to undertake the great routine investigations which at present are regarded as the most important objects of astronomical research. No one will doubt that in this, as in every other science, the advance depends largely on individual genius and initiative. The invention of new methods has, however, now been so far accomplished that many astronomers are able to devote their time to applying these methods to large numbers of individual stars. Investigations which require years of continuous effort, and an expenditure of many thousands of dollars may thus be undertaken and successfully completed. The application of the methods of scientific management has effected the same saving as in industrial processes. An excellent example of this is the determination of the accurate positions of one hundred thousand northern stars. This work, begun half a century ago, was divided among a dozen observatories, and was probably the most important astronomical research undertaken up to that time. One zone occupied an observer and corps of assistants for twenty years. The salaries alone exceeded one hundred thousand dollars. By the aid of photography this work is now being repeated with double the accuracy, and at less than a tenth of the cost. In another investigation, a saving of one minute in the reduction of an observation will reduce the time of its preparation by two years of the work of one assistant.

The greatest need of astronomy appears to be a large fund whose income could be used in the following ways:

1. Reestablishing the friendly international relations of astronomers of three years ago by assisting large astronomical projects directly or indirectly. Such projects can often be carried out far better and more economically by dividing the work between two or more observatories. The Cape Photographic Durchmusterung is a striking example of the excellent results of such cooperation.

2. Furnishing assistants to astronomers who would thus be relieved of laborious routine observations and computations. An excellent illustration of this was the article in SCIENCE, Vol. 41, 82, giving the replies of twelve leading astronomers regarding their greatest need. In almost every case it was one or more assistants.

3. Aiding observatories south of the equator in such a way as to render our knowledge of the southern stars more nearly equal to that of the northern stars. At present, many times as many observations are made of northern, as of southern, stars.

4. Providing means whereby preliminary investigations, sufficient to decide upon the best and most efficient methods of carrying on large projects, can in all cases be undertaken before these projects themselves are entered upon.