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THE UNITY OF PHYSICAL SCIENCE.*

THERE is a tradition, still tacitly sanctioned even by men of science, that there have been epochs when the more eminent minds were able to compass the entire range of knowledge. Amongst the vanishing heroic figures of the past it seems possible, indeed, to discern, here and there, a Galileo, a Huygens, a Descartes, a Leibnitz, a Newton, a Laplace or a Humbolt, each capable, at least, of summing up with great completeness the state of contemporary knowledge. Traditions, however, are generally more or less mythical, and the myth in this case seems to be in flat contradiction with the fact that there never was such an epoch, that the great masters of our distinguished predecessors were, after all, much like the masters of to-day, simply the leading specialists of their times. But however this may be, if we grant the possibility of the requisite attainments, even in a few individuals at any epoch, we shall speedily conclude that there never was an epoch so much in need of them as the immediate present, when the divisional speakers of this congress are called upon to explain the unities which pervade the ever-widening and largely diverse fields of their several domains.

The domain of physical science, concerning which I have the honor to address you to-day, presents peculiar and peculiarly formidable difficulties in the way of a summary review. While we may not be dis-

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posed to limit the wide range of inclusion specified by our program, we must at once disclaim any attempt to speak authoritatively with respect to most of its details. There is, in fact, such a vast array of knowledge now comprehended under any one of the six departments of our division, that the boldest author must hesitate to enter on a limited discussion with respect to any of them. But if it is thus difficult to consider any department of physical science, it appears incomparably more difficult to contemplate all of them in the bewildering complexity of their interrelations and in the bewildering diversity of their subject-matter. What, for example, could seem more appalling to the average man of science than the duty of explaining the connections of archeology and astrophysics or those of ecology and electrons?

Happily, however, the managers of the congress have provided an adequate division of labor, whereby the technical details of the various departments are allotted to experts, giving thus to a divisional speaker a degree of freedom with respect to depth in some way commensurate with the breadth of his task. Presuming, therefore, that I may deal only with the broader outlines and salient features of the subject, I invite your attention to a summary view of the present status and the apparent trend of physical science.

Whatever may be affirmed with respect to science in general, there appears to be no doubt that all of the physical sciences are characterized by three remarkable unities—a unity of origin, a unity of growth and a unity of purpose. Physical science originates in observation and experiment; it rises from the fact-gathering stage of unrelated qualities to the higher plane of related quantities, and passes thence on to the realm of correlation, computation and prediction under theory; and its purpose is to interpret in consistent and verifiable terms the universe, of which we form a part. The recognition of these unities is of prime importance; for it helps us to understand and to anticipate a great diversity of perfection amongst the different branches of science, and hence leads us to appreciate the desirability of hearty cooperation on the part of scientific workers in order that progress may be ever positive towards the common goal.

Glancing rapidly seriatim at the different departments of physical science as specified by our program, we come first to a consideration of formal physics, and we may most quickly orient ourselves aright in this department by trying to state in what respects the physics of to-day differs from the physics of a hundred years ago.

In spite of the extraordinary perfection of the work of Lagrange, Laplace, Fourier, Young, Fresnel, Poisson, Green, Gauss and others of the early part of the nineteenth century, it will be at once admitted that great progress has been made. In addition to noteworthy advances and improvements along the lines laid down by these masters, there have been developed the relatively new fields of elasticity, electromagnetics, thermodynamics and astrophysics; and there has been discovered the widest of all generalizations in physical science—the law of conservation of energy. Whereas it was easy a century ago to conceive, as in gravitational astronomy, of action at a distance across empty space, the universe in the meantime has come to appear more and more plethoric not only with 'gross matter,' but with that most wonderful entity we call the ether. The astronomers have shown us, in fact, that the number of molar systems in the universe is enormously greater than was supposed possible a century ago; while the physicists have revealed to us molecular systems rivaling our solar system and its Jovian and Saturnian subsystems, and they have loaded down the ether with a burden of properties and relationships which its usual tenuity seems scarcely fitted to bear. Whereas, also, a century ago the tendency of thought, under the stimulus of the remarkable developments of the elastic solid theory of light and the fluid theories of electricity, was chiefly towards an ether whose continuity would have pleased Anaxagoras, the tendency to-day is chiefly towards an ether whose atomicity would have pleased Democritus.

On the whole, it must be said that the advances of the past century, and especially those of the past half century, have been mainly along the lines of molecular physics. The epoch of Laplace was distinctly an epoch of molar physics; the epoch of to-day is distinctly an epoch of molecular physics. Light, heat, electricity and magnetism have been definitely correlated as molecular and ethereal phenomena; while the recently discovered X-rays and the wonders of radioactivity, along with the 'electrons,' the 'corpuscles' and the 'electrions' of current investigations, all point towards a molecular constitution of the ether. Thermodynamics, likewise, large as it has grown in recent decades, is essentially a development of the molecular theory of gases. It would be too bold, perhaps, to assert that the trend of accumulating knowledge is towards an atomic unity of matter, but the day seems not far distant when there will be room for 'a new Principia' and for a treatise which will accomplish for molecular systems what the 'Mécanique Céleste' accomplished for the solar system.

One of the most important advances of recent decades is found in the fixation of ideas with respect to the units of physical science and in the great improvements which have been wrought in metrology by the 'International Bureau of Weights and Measures.' Our standards of length, mass and time are now fixed with a degree of precision which leaves little to be desired for the present, and the capital resources of measurement and calculation are now available to an extent never hitherto approached.

It should be noted, however, that confidence in the stability of our standards is by no means comparable with the perfection of their current applications. Indeed, we may raise with respect to them the question so long mooted with regard to the motions of the members of the solar system, namely, are they stable? Notwithstanding the admirable precision of the intercomparisons of the prototype meters and prototype kilograms and the equally admirable precision of Professor Michelson's determination of the length of the meter in terms of wave lengths of cadmium light, we can not affirm that these observed relations will hold indefinitely. Our inherited notions of mass have been rather rudely shaken, also, by the penetrating criticisms of Mach, and it appears possible even that the law of conservation of mass may need modification in the light of pending researches. But worst of all, our time unit, the sidereal day, is so far from possessing the element of constancy that we may affirm with practical certainty that it is secularly variable. Having realized, through Professor Michelson's superb determination just referred to, the cosmic standard of length suggested by Maxwell thirty years ago, we are now much more in need of an equally trustworthy cosmic standard of time.

If the progress of physics during the past century has been chiefly in the direction of atomic theory, the progress of chemistry has been still more so. Chemistry is, in fact, the science of atoms and molecules par excellence, a distinction it has maintained for well nigh a full century under the dominance of the fruitful atomic and molecular hypotheses of Dalton and of

Avogadro and Ampère, and under the similarly fruitful laws of gases established by Dalton and Gay-Lussac. Perhaps the most striking feature of this progress, in a general way, is the gradual disappearance it has entailed of the imaginary lines which have been long thought to separate the fields of chemistry and physics. Through the remarkable discoveries of Faraday the two fields have been found to overlap in actual electrical contact. Through the wonderful revelations of spectrum analysis, originating with Bunsen and Kirchhoff, they have been proved to be very largely common ground. And through the broader generalizations inaugurated by Willard Gibbs, Helmholtz and others, they are now both somewhat in danger of being annexed as a subprovince of rational mechanics.

To one whose work has fallen more especially in the fields of precise astronomy, geodesy or metrology, it might seem a just reproach to chemistry that it is a science whose measurements and calculations demand, as a rule, no greater arithmetical resources than those of four-place tables of logarithms and anti-logarithms. The so-called 'Constants of Nature' supplied by chemistry are, in fact, known with a low degree of certainty, a degree expressed, say, by three to five significant figures. A small amount of reflection, however, will convince one that the phenomena with which the chemist has to deal are usually far more complex than those which have yielded the splendid precision of astronomy, geodesy and metrology. Moreover, it should be observed that the certainties even of these highly perfected sciences are very unequal in their different branches. It appears more correct, therefore, as well as more just, considering the central position it occupies and the wide range of its ramifications, along with the vast aggregate of qualitative and quantitative knowledge it has massed, to assert that the precision of chemistry affords the best numerical index of the present state of physical science. That is, when reduced to the most compact form of statement, the certainties of physical science are best indicated, in a general way, by a table of the combining weights of the eighty-odd chemical elements.

When one contemplates the numbers of such a table, and when one adds to its suggestions those which flow from the various periodic groupings of the same numbers, he can hardly avoid being inspired by the day dreams of those who have looked long for the atomic unity of matter. But however the grand problem which thus obtrudes itself may be resolved finally, it appears certain that this table must stand as one of the great landmarks along the path of progress in physical science.

It was justly remarked by Laplace in his 'Système du Monde' that 'L'Astronomie, par la dignité de son objet et par la perfection de ses théories, est le plus beau monument de l'esprit humain, le titre le plus noble de son intelligence'; and we must all admit that subsequent progress has gone far to maintain this high position for the most ancient and interesting of the older sciences. One finds little difficulty in accounting for the early rise of astronomical science and for the universal interest in celestial phenomena. Their immanence and omnipresence appeal even to the dullest intellects. But it is not so easy to account for the remarkable fact that although astronomy deals chiefly with the relations of bodies separated by immense distances, progress in its development has thus far been at least equal to, if not in advance of, the progress of physics and chemistry, which have to deal with matter close at hand. Without attempting a full explanation of this fact, it may suffice to observe that the principal phenomena of astronomy thus far developed appear to be relatively simple in comparison with those of the other physical sciences; and that the immense distances which separate the celestial bodies, instead of being an obstacle to, are a fortunate circumstance directly in favor of, the triumphant advances which have distinguished astronomical science from the epoch of Galileo down to the present day.

Not less noteworthy than his high estimate of the position of astronomy in his time are Laplace's anticipations of the course of future progress. Our admiration is kindled by the clearness of his vision with respect to ways and means and by the penetration of his predictions of future discoveries. Advances in sidereal astronomy, he rightly thought, would depend chiefly on improvements in telescopes; while advances in dynamical astronomy were to come along with increased precision in the observed places of the members of the solar system and along with the growing perfection of analysis. It is almost needless to say that Laplace's brilliant anticipations have been quite surpassed by the actual developments. Observational astronomy has become one of the most delicately perfect of all the sciences; dynamical astronomy easily outstrips all competitors in the perfection of its theories and in the certainty of its predictions; while the newly developed branch of astrophysics supplies the last link in the chain of evidence of the essential unity of the material universe.

The order of the dimensions and the order of the mass contents of the visible universe, at any rate, have been pretty clearly made out. In addition to the vast aggregate of direct observational evidence collected and recorded during the past century, numerous theoretical researches have gone far, also, to interpret the laws which reign in the apparent chaos of the stars. The solar system, with its magnificent subsystems, has been proved to exhibit the type of stellar systems in general.

In a profound investigation recently published, Lord Kelvin has sought to correlate under the law of gravitation the principal observed data of the visible universe. Assuming this universe to lie within a sphere of radius equal to the distance of a star whose parallax is one thousandth of a second of arc, he concludes that there must be something like a thousand million masses of the magnitude of our sun within that sphere. Light traveling at the rate of 300,000 kilometers per second would require about six thousand years to traverse the diameter of this universe, and while the average distance asunder of the visible stars is considerably less, it is still of the same order. It is only essential, therefore, to imagine our luminary surrounded by a thousand million such suns, most of which are, in all probability, attended by groups of planets, to get some idea of the quantity of matter within visual range of our relatively insignificant terrestrial abode. And the imposing range of the astronomer's time scale is perhaps impressively brought home to us when we reflect that a million years is the smallest convenient unit for recording the life history of a star, while the current events in that history are transmitted across the interstellar medium by vibrations which occur at the rate of about six hundred million million times per second. Measured by its accumulation of achievements, then, the astronomy of to-day fulfils the requirements of a highly developed science. It is characterized by a vast aggregate of accurately determined facts related by theories founded on a small number of hypotheses. In the past it has called forth the two greatest of all systematic treatises, the 'Principia' of Newton and the 'Mécanique Céleste' of Laplace. It has probably done more also than any other science, up to the present time, to illuminate the dark periods during which man has floundered in his struggle for advancement; and the indications are that its prestige will long continue.

But there are spots on every sun; and lest some may infer, even humorously, as Carlyle did seventy-odd years ago, that our system of the world is 'as good as perfect,' attention should be called to some noteworthy defects in astronomical data and to some singular obscurities in astronomical theory. Here, however, great caution and brevity are essential to avoid poaching on the preserves of our colleagues of the sections. It may suffice, therefore, to merely mention, under the head of defective data, the low precision of the solar parallax, the aberration constant, the masses of the members of the solar system, and the uncertainty of our time unit, already referred to. Two instances, likewise, which belong to the general field of physics as well, may suffice as illustrations of obscurities in astronomical theory. Stated in the order of their apparent complexity, these obscurities refer to the law of gravitation and to the phenomenon of stellar aberration. Probably both are related, and one may hope that any explanation of either will throw light on the other.

So long as no attempt is made to reconcile the law of gravitation with other branches of physics, progress, up to a certain point, is easy; and probably great advantage has resulted from the fact that dynamical astronomers have not been seriously disturbed by a desire to harmonize this law with the more elementary laws of mechanics. Perhaps they have unconsciously rested on the platform that gravitation is one of the 'primordial causes' which are impenetrable to us. There are some indications that even Laplace and Fourier did so rest. But, however this may be, it has grown steadily more and more imperative during the past century to explain gravitation, or to discover the mechanism which provides that the force between two widely separated masses is proportional to their product directly and to the square of the distance between them inversely. All evidence seems to indicate that the ether must provide this mechanism; but, strangely enough, so far, the ether has baffled all attempts to reveal the secret. The problem has been attacked also on the purely observational side of the numerical value of the gravitation constant. But the splendid experimental researches for this purpose throw no light on the mechanism in question, and, unfortunately, they bring out values for the constant of a low order of precision.

With regard to stellar aberration, it must be at once admitted that we have neither an adequate theory nor a precisely determined fact. The astronomer has generally contented himself with the elementary view that aberration is a purely kinematical phenomenon; that the earth not only slips through the ether without sensible retardation, but that the ether slips through the earth without sensible effects. This difficulty was recognized, in a way, by Young and Fresnel, and, although the subject of elaborate investigation in recent decades, it has proved equally baffling with Newtonian gravitation. As in the case of the latter also, the numerous attempts made to determine the constant of aberration by observational methods have been rewarded by results of only meager precision. Possibly the time has arrived when one may raise the question, Within what limits is it proper to speak of a gravitation constant or of an aberration constant?

If we agree with Laplace that astronomy is entitled to the highest rank among the physical sciences, we can accord nothing short of second place to the sciences of the earth. Most of them are, indeed, intimately related to astronomy; and some of them are scarcely less ancient in their origins, less dignified in their objects, or less perfect in their theories. Primarily, also, it should be observed, geophysics is not simply a part of, but is the very foundation of, astronomy; for the earth furnishes the orientation, the base-line, and the timepiece by means of which the astronomer explores the heavens. Geology, likewise, in the broader sense of the term, as we are now coming to see, is a fundamental science not only by reason of its interpretations of terrestrial phenomena, but also by reason of its parallel interpretations of celestial phenomena; for there is little doubt that in the evolution of the earth we may read a history which is in large degree typical of the history of celestial bodies. In any revised estimate, therefore, of the relative rank of the physical sciences, while it would be impossible to lower the science of the heavens, it would appear essential to raise the sciences of the earth to a much higher plane of importance than was thought appropriate by our predecessors of a hundred years ago.

As with physics, chemistry and astronomy, the wonderful progress of the nineteenth century in geophysical science has been along lines converging towards the more recondite properties of matter. All parts of the earth, through observation, experiment, induction and deduction, have yielded increasing evidence of limited unities amid endless diversities. Adopting the convenient terminology of geologists for the different shells of the earth, let us glance rapidly in turn at the sciences of the atmosphere, the hydrosphere or oceans, the lithosphere or crust, and the centrosphere or nucleus.

The atmosphere is the special province of meteorologists, and although they are not yet able to issue long-range predictions, like those guaranteed by our theories of tides and terrestrial magnetism, it must be admitted that they have made great progress towards a rational description of the apparently erratic phenomena of the weather. One of the peculiar anomalies of this science illustrates in a striking way the general need of additional knowledge of the properties of matter; in this case, especially, the properties of gases. It is the fact that in meteorology greater progress has been made, up to date, in the interpretation of the kinetic than in the interpretation of the static phenomena of the atmosphere. Considering that static properties are usually much simpler than kinetic properties, it seems strange that we should know much more about cyclones, for example, than we do about the mass and the mass distribution of the atmosphere. In respect to this apparently simple question meteorology seems to have made no advance beyond the work of Laplace. There are indications, however, that this, along with many other questions, must await the advent of 'a new Principia.'

The geodesists, who are the closest allies of the astronomers, may be said to preside over the hydrosphere, since most of their theories as well as most of their observations are referred to the sea level. They have determined the shape and the size of the earth to a surprising degree of certainty; but they are now confronted by problems which depend chiefly on the mass and mass distribution of the earth. The exquisite refinement of their observational methods has brought to light a minute wandering in the earth of its axis of rotation, which makes the latitude of any place a variable quantity; but the interpretation of this phenomenon is again a physical and not a mensurational problem. They have worked improvements also in all kinds of apparatus for refined measurements, as of base-lines, angles and differences of level; but here, likewise, they appear to approach limits set by the properties of matter.

The lithosphere was once thought to be

the restricted province of geologists, but they now lay claim to the entire earth, from the center of the centrosphere to the limits of the atmosphere, and they threaten to invade the region of the astronomers on their way towards the outlying domain of cosmogony. Geology illustrates better than any other science, probably, the wide ramifications and the close interrelations of physical phenomena. There is scarcely a process, a product or a principle in the whole range of physical science, from physics and chemistry up to astronomy and astrophysics, which is not fully illustrated in its uniqueness or in its diversity by actual operations still in progress on the earth, or by actual records preserved in her crust. The earth is thus at once the grandest of laboratories and the grandest of museums available to man.

Any summary statement, from a non-professional student, of the advances in geology during the past century, would be hopelessly inadequate. Such a task could be fitly undertaken only by an expert, or by a corps of them. But out of the impressive array of achievements of this science, two seem to be specially worthy of general attention. They are the essential determination of the properties and the rôle of the lithosphere, and the essential determination of the time scale suitable for measuring the historical succession of terrestrial events. The lithosphere is the theatre of the principal activities, mechanical and biological, of our planet; and a million years is the smallest convenient unit for recording the march of those activities. When one considers the intellectual as well as the physical obstacles which had to be surmounted, and when one recalls the bitter controversies between the Neptunists and the Vulcanists and between the Catastrophists and the Uniformitarians, these achievements are seen to be amongst the most important in the annals of science.

The centrosphere is the *terra incognita* whose boundaries only are accessible to physical science. It is that part of the earth concerning which astronomers, geologists and physicists have written much, but concerning which, alas! we are still in doubt. Where direct observation is unattainable, speculation is generally easy, but the exclusion of inappropriate hypotheses is, in such cases, generally difficult. Nevertheless, it may be affirmed that the range of possibilities for the state of the centrosphere has been sharply restricted during the past half century. Whatever may have been the origin of our planet, whether it has evolved from nebular condensation or from meteoric accretion; and whatever may be the distribution of temperature within the earth's mass as a whole; it appears certain that pressure is the dominant factor within the nucleus. Pressure from above, supplied in hydrostatic measure by the plastic lithosphere, supplemented by internal pressure below, must determine, it would seem, within narrow limits the actual distribution of density throughout the centrosphere, regardless of its material composition, of its effective rigidity or of its potential liquidity. Here, however, we are extending the known properties of matter quite beyond the bounds of experience, or of present possible experiment; and we are again reminded of the unity of our needs by the diversity of our difficulties.

In his recently published autobiography, Herbert Spencer asserts that at the time of issue of his work on biology (1864) 'not one person in ten or more knew the meaning of the word * * *; and among those who knew it, few cared to know anything about the subject.' That the attitude of the educated public towards biological science could have been thus indifferent, if not inimical, forty years ago, seems strange enough now even to those of us who have witnessed in part the scientific progress subsequent to that epoch. But this was a memorable epoch, marked by the advent of the great intellectual awakening ushered in by the generalizations of Darwin, Wallace, Spencer and their coadjutors. And the quarter of a century which immediately followed this epoch appears, as we look back upon it, like an heroic age of scientific achievement. It was an age during which some men of science, and more men not of science, lost their heads temporarily, if not permanently; but it was also an age during which most men of science, and thinking people in general, moved forward at a rate quite without precedent in the history of human advancement. A new, and a greatly enlarged, view of the universe was introduced in the doctrine of evolution, advanced and opposed alike, vigorously, chiefly by reason of its biological applications and implications. Galileo, Newton and Laplace had given us a system of the inorganic world; Darwin, Spencer and their followers have foreshadowed a system which includes the organic world as well.

The astonishing progress of biology in recent times furnishes the most convincing evidence of the unity and the efficiency of the methods of physical science in the interpretation of natural phenomena. For the biologist has followed the same methods, with changes appropriate to his subject-matter, only, as those found fruitful in astronomy, chemistry and all the rest. And whatever may be the increased complexity of the organic over the inorganic world, or however high the factor of life may seem to raise the problems of biology above the plane of the other physical sciences, there has appeared no sufficient reason, as yet, to doubt either the validity or the adequacy of those methods.

Moreover, the interrelations of biology with chemistry and physics especially, are yearly growing more and more extended and intimate through the rapidly expanding researches of bacteriology, physiology and physiological chemistry, plant and animal pathology, and so on, up through cytology to the embryology of the higher forms of life. Through the problems of these researches also we are again brought face to face, sooner or later, with the problems of molecular science.

And finally, what may be said of anthropology, which is at once the most interesting and the most novel of the physical sciences, interesting by reason of its subject matter, novel by reason of its applications? Some of us, perhaps, might be inclined to demur from a classification which makes man, along with matter, a fit object of investigation in physical science. Granted even that he is usually a not altogether efficient thermodynamic engine, it may yet appear that he is worthy of a separate category. Fortunately, however, it is not a rule of physical science to demand immediate answers to such ulterior questions. It is enough for the present to know that man furnishes no exception, save in point of complexity, to the manifestations of physical phenomena so widely exhibited in the animal kingdom.

But whatever may be our inherited prejudices, or our philosophic judgments, we are confronted by the fact that the study of man in all his attributes is now an established domain of science. And herein we rise to a table-land of transcendent fascination; for, to adapt a phrase of an eminent master in physical science, the instruments of investigation are the objects of research. Herein also we find the culminating unity, not only of the physical sciences, but of all of the sciences; and it is chiefly for the promotion of these higher interests of anthropology that we are assembled in this cosmopolitan congress today.

It has been our good fortune to witness in recent decades an unparalleled series of achievements in the fields of physical science. All of them, from anthropology and astronomy up to zoology, have yielded rich harvests of results; and one is prone to raise the question whether a like degree of progress may be expected to prevail during the century on which we have now entered. No man can tell what a day may bring forth; much less may one forecast the progress of a decade or a century. But, judging from the long experience of the past, there are few reasons to doubt and many reasons to expect that the future has still greater achievements available. It would appear that we have found the right methods of investigation. Philosophically considered, the remarkable advances of the past afford little cause for marvel. On the contrary, they are just such results as we should anticipate from persistent pursuit of scientific investigation. Conscious of the adequacy of his methods, therefore, the devotee to physical science has every inducement to continue his labors with unflagging zeal and confident optimism.

R. S. WOODWARD.
COLUMBIA UNIVERSITY.

MICRO-ORGANISMS OF SOIL AND HUMAN WELFARE.*

MAN has gained dominion in the earth not as a birthright, but by many struggles and by numerous conquests. Slowly during the ages he has gained accessions of knowledge and has succeeded in making more and more use of the forces of nature. The introduction of the art of printing enabled him to make readily and to keep permanently a record of his accomplishments; the discovery of the mariner's compass added immensely to his domain; the application of steam multipled a thousand times his power, and now the subjection of the electric forces makes him a veritable master over time and space. As a help in gaining knowledge applicable to the practical affairs of earth and life the microscope stands unrivaled. Its relations have been incomparably important in regard to the knowledge of man himself and to those things immediately connected with his daily existence and health. Bacteriology is a branch of microscopy or at all events could not have been developed without the aid of the microscope, and in this connection alone the instrument has been useful beyond any other piece of mechanism whatever in alleviating ills to which flesh is heir and in promoting and prolonging life.

So far bacteria have been more especially studied as disease germs. Witness the advance which has been made on account of those studies in medicine and surgery, in the efficiency of quarantines and in the prevention of epidemics. It is argued now in some quarters that even old age is a germ disease, and that immortality on earth is a possibility when bacteriology and its allied sciences come to perfection. I am to ask your attention at this time to some of the microorganisms of the soil and their relation to soil fertility. This is a technical subject. While it is not possible to treat it as a popular theme, it should not be difficult to show that there are matters here which, whether we are aware of it or not, intimately and immeasurably affect every human being on earth.

First a few words as to the organisms themselves. They are minute living creatures belonging to the vegetable kingdom, hence called plants, however unlike they are to the leafy structures usually alluded to by that name. Their most striking peculiarities are their exceedingly diminutive

* Presidential address read at the Buffalo meeting, August 24, 1904, of the American Microscopical Society.