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SCIENCE AND SERVICE[1]

THE service of science to humanity was initiated when the early philosophers began to discover and record the more simple truths of nature. Then, as now, the "sciosophists," defined by David Starr Jordan as "apostles of systematized ignorance," rejected all evidence without attempting to prove or disprove, and condemned the exceptional mind that was compelled by an inner urge to attempt to penetrate into the mists that concealed the unknown.

Through many centuries human thought was confined largely to channels predetermined by the religious and political concepts of the more intelligent. To this privileged group freedom of expression by others was intolerable, and a seeker after truth other than that provided and established by authority was fair game to be hunted down and destroyed. Progress came as an undercurrent of truth that slowly gathered strength and volume, until, like the warm waters of tropical ocean currents penetrating the colder regions, it weakened the congealed crust of ignorance and prejudice, and, combining with the sunshine of scientific research, gradually dispersed systematic opposition to the growing appreciation of natural phenomena and laws.

The story of the onward march of scientific research in quest of truth is not unlike that of the white race in the conquest of America. A few fearless souls penetrated the wilderness and blazed the trails that others might follow; some fell martyrs to their zeal, but more came after; facts were determined, laws established, which in time contributed to the welfare of the race.

Science has made great progress, but its conquest of the unknown and of the unprogressive doctrines of the sciosophists is still far from complete. When we consider the many vital problems that are being discussed and the indifference and limited training of a large proportion of supposedly intelligent people, it seems only well under way. The search for truth and the interpretation of facts and their verification and application must continue, with ever-enlarging conceptions until the ultimate destiny of our race is fulfilled.

Millikan has well said: "The purpose of science is to develop without prejudice or preconception of any kind a knowledge of the facts, the laws and the processes of Nature." The search for truth based on this scientific method is one of the greatest inspirations and incentives to high and thorough endeavor. The

[1] Address of the retiring president of the American Association for the Advancement of Science, Washington, D. C., December 29, 1924.

searcher may be engaged in any field of human knowledge, including religion, history, literature, natural science or government; his motive may be of the highest type of pure delight in investigation and discovery for the sake of truth, or it may be sordid and egotistic; but his results, after being subjected to the exacting tests of general discussion and criticism, will find their place in the general scheme of the advancement of the physical, mental and spiritual well-being of man.

The scientist need not enter into controversies with the theologian or the sciosophist. He may make mistakes and interpret nature incorrectly, and he will never become so infallible or omniscient as to be sure that he has the entire or exact truth, but, as in the past, he may add a little here and a little there, until a great inspired mind grasps the multitude of facts and interprets from them a fundamental general law of nature. A structure of theory or hypothesis is then reared that may endure for a generation or two, until a continually growing knowledge requires some modification that may strengthen it, or lead to its partial or complete rejection.

An illustration of work to be done by the specialist may be drawn from my own investigations relating to primitive life. In 1876 I spent a month tracing the distribution of the "Potsdam Sandstone" about the Adirondack Mountains of New York, and in collecting fossils from the sandstone and the immediate superjacent Hoyt limestones. I was told the following winter by the geological authorities of the day that there was little use of attempting to discover traces of life in rocks lower than the Potsdam, as they rested upon the Archean. During the forty-eight years that have passed since then I have always had in view the discovery of older and still older evidences of primitive life. The Upper, Middle and Lower Cambrian faunas were all found in orderly succession beneath the Potsdam, and finally bacteria and algal deposits far below in the pre-Cambrian. Sixteen years ago I discovered a locality in the lower Middle Cambrian Burgess shale of the Canadian Rockies in which the fossils were marvelously preserved. This deposit yielded a wonderful series of marine invertebrates showing clearly that at this early time the evolution of the life in the sea had progressed far beyond our previous conceptions of it, and that, with the exception of the cephalopods and vertebrates, there has been very little development in the classes of animal life during the millions of years between the time of the Burgess shale fauna and the present. Recently there have come to light fossils in the upper portion of the Lower Cambrian that indicate that the types of the Burgess shale fauna were then in existence.

Beneath the Lower Cambrian on all the continents there is a great unconformity between the basal beds and the superjacent pre-Cambrian formations that have been grouped in the Proterozoic and Archeozoic eras. Although we have found traces of bacteria and algal growth in the Proterozoic, it is not considered that these forms were the progenitors of the Cambrian faunas. In fact, the search for primitive pre-Cambrian evidences of life other than that which may have existed in fresh water lakes and streams has come to a standstill at the great unconformities beneath the Cambrian and the Proterozoic. I do not know of a trace of the great primal marine life of the ocean basins from which the Cambrian faunas are descendent, except the few fragments that have been found in the Proterozoic; nor have we found evidence of the deposits of undoubted marine sediments on the present land areas that are older than those of the lower Cambrian. This leaves the field open for the research student of the future to discover the earlier forms of life that in a slow evolution through millions of years finally developed into the highly organized invertebrates of early Cambrian time.

Research students in all branches of scientific endeavor soon discover that with every accession of knowledge new problems open up that will demand attention and effort for years to come. I recall full well as a young man consulting with older scientists and getting the impression that they thought a large proportion of the great scientific problems had been settled; and they often denounced most bitterly the younger men who dared to question the accepted conclusions of their scientific studies.

The sciosophists will rail at and denounce the scientific method, as he can not or will not comprehend it, but it is clearly the only method by which the errors of the present and truth of the future may with certainty become known. "Beyond the conclusion reached through competent study of nature and natural law by cautious and highly trained investigators, it is not possible for any one to go, except as the searcher after truth himself pushes further ahead in his quest."

Such a broad organization as the American Association for the Advancement of Science must consider ways and means by which it may do its part in the great readjustments of thought and action constantly going on, which will aid or obstruct the advance of mankind towards a more just and ever finer civilization. In view of the accumulation of scientific data and the number of active research workers in all advanced countries, what can our association and its members do to be of the greatest service? As stated by our constitution, the objects of the association are "to promote intercourse among those who are cultivating science in different parts of America, to cooperate with other scientific societies and institutions, to give a stronger and more general impulse and more

systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness." Our membership already includes trained and amateur scientists, educators and intelligent laymen, about 13,000 of them, and it is increasing with the years more rapidly in proportion than is the population of the United States.

For three fourths of a century the members of the association have contributed individually and in groups to the advancement of many branches of science, and some of them have more or less successfully undertaken to interpret to the average intelligent person the story of nature so far as it has been made known by scientific research. All these activities have been helpful, and valuable service has been rendered by the association as a whole, especially by bringing together large groups for the consideration and discussion of the scientific problems of the day.

The title of the association implies association for a definite purpose, "the advancement of science." This in our modern life means also the physical, mental and moral advancement of the human race, not only our immediate associates and fellow Americans, but every human being on the earth's surface, and, for that matter, every form of life that is not predatory or inimical to the welfare of humanity. Is the association now doing its part in the formation of public opinion and in the guidance of social movements; is it in touch with the layman, or is it a professional organization that is slipping away from its great opportunity of informing and arousing the interest and enthusiasm of the American people and the intelligent people of all countries? These questions are important, for to-day a story of science clearly and simply told is welcomed by the press, the author of textbooks, the lecturer, the encyclopedist and agencies for the dissemination of information in all nations.

The association should act as a liaison agency between professional science and the public. It also should act as the liaison agency between the various sciences. The greater the specialization the greater the need of cooperation. In the advance of science, siege tactics have taken the place of guerilla warfare of former days. The big industrial establishments like the Western Electric Company, the General Motors Research Corporation, the General Electric Laboratories and many others show how much more can be accomplished by the combined efforts of experts in various fields of science. This must be carried much farther than an occasional symposium or joint meeting between different departments of the association. The important problems of the day require the cooperation of men from various sciences. For instance, to make an inventory of future energy supplies of the world would require cooperative study by geologists, chemists, physicists, engineers, biologists and sociologists.

More attention must be paid to the unity of nature in order to counteract the artificial divisions which are the natural result of specialization in research. We need men and women who can tell the story of life as a whole, as a zoological story, and who can combine the parts and picture its evolution, character and broad relations, and this applies as well to all scientific, historical and social fields of research.

There is something wrong when ten minutes is the limit for presentation of a valuable paper, with practically no time available for discussion. A few papers, ably discussed, and *leave to print* for others would probably add more to the value and interest of the program than a multitude of papers hurriedly presented, with no opportunity for discussion. For the irreconcilable specialist, the special society or the local general society is open. Again, the poorly prepared paper and even the masterpiece ineffectively delivered is an almost criminal action when we consider the time and effort involved in getting a large group into one place to hear and consider it. Such a loss of time and energy should not be imposed on professional men or laymen. A method should be devised to correct it. Modern life has developed great traffic and social problems that will ultimately be solved, and the association will solve its problems if a group of vigorous, clear-thinking, trained members take them up. I say members, as I think the segregation of women scientists would be an injury to science and the association. Will you attack these problems or will you sit idly by and permit your opportunities to pass into other hands? This was done once and the great work of the National Research Council was initiated and developed by a trio of men who had vision, purpose and inflexible determination to be of service to their country and humanity.

Is the association doing all that it could in connection with the great problem of conservation? Do we realize that our future national progress and the progress of all peoples will be determined, not so much by the acquisition and appropriation of new resources, as by the degree to which we are able to perpetuate and more efficiently to utilize those we already have. Such progress is absolutely dependent upon scientific research and education; it would be difficult to name a single branch of science that is not concerned. The research workers and educators who are members of this association can render no greater service than by concentrating an increasing amount of their effort on the multitudinous phases of this problem.

The United States' unprecedented growth and her present commanding economic position have been made possible by abundance of natural resources. In-

dividual and public economic policies have been predicated on this abundance. Minerals, forests, fur and game animals, agricultural soils, range lands, fish, and water resources were all seemingly inexhaustible in supply, and all have been appropriated and exploited recklessly and wastefully. The cream has been skimmed, and, all too often, the milk has been thrown away.

The whole philosophy of exploitation has been based on the theory of making maximum profits for the exploiter, rather than the ideal of greatest service and lasting benefit to the people of the world as a whole. The resources seemed unlimited, and it was assumed that future requirements would adjust themselves automatically and that posterity would take care of itself.

Now the point has been reached where it is evident that the resources have a limit. Expansion can not continue indefinitely, nor can even the present scale of consumption be maintained as population increases, unless steps are taken to replenish the supply. The pressure of scarcity and increasing costs of exploitation demand the elimination of wastes, the intensive utilization of the resources that are left, and the discovery or creation of new supplies.

A large percentage of our good agricultural soils have been appropriated, and the further expansion of crop production to feed our growing population must come largely through utilization of the poorer land or through more intensive cultivation and fertilization of existing farms. Even more is this true of our pasture and range lands, the *per capita* area of which has been reduced by almost one half since 1890.

Using almost as much timber as all the rest of the world combined, the United States passed the highest point of *per capita* consumption nearly 20 years ago. Even now four times as much is consumed as is grown each year, and only one fifth of the forest land is set apart definitely for timber production. In spite of the growing shortage of timber and the mounting costs of bringing it from remote regions, scores of millions of acres of once productive forest land are lying idle, and we are still wasting two thirds of all the wood that is cut.

The story of our wild life and our waters is little different. Birds, fish, shell-fish, fur bearers, game animals, all have reached an alarming stage of depletion as a result of destructive exploitation. Streams, lakes and coastal waters have been polluted. Many of the streams and lakes which could afford a perpetual source of food, power, irrigation water, recreation, water for drinking, sanitation and other domestic uses, as well as channels for cheap transportation, have been reduced in flow or filled with sediment, following forest destruction or unwise cultivation or pasturing on their watersheds.

All of these are renewable resources. With wise use none of them need have been depleted, and most of them can be made even more productive than they have been in the past. Few would go so far as to contend that such replenishment is unnecessary or undesirable. Many, however, consider it impossible, and even assert that major reductions of the waste in utilizing existing resources are impracticable. The reasons are said to be economic: more intensive farming will not pay, reforestation is too slow and costly, there are no profits in utilizing waste materials.

Yet economic impracticability is frequently only a longer name for ignorance. The discovery of new principles or new methods may make it economically practicable to intensify farming. Better understanding of silvicultural principles and closer study of the life history of our forests will show us how to utilize that resource without jeopardizing its continued productivity, and without increasing the economic burden on the users. Thorough technical knowledge of the product, whether farm crops, timber or what not, will enable us to utilize profitably a great deal that is now wasted.

Our mineral resources, as a general proposition, can not be renewed through human effort, at least in the present state of knowledge. But even with them, the available supplies can be extended almost indefinitely through the discovery of new methods of extraction, or through the discovery and utilization of substitute materials.

To obtain the results desired it is evident that the great masses of humanity have yet to be educated in the scientific method of thought and action, not only in darkest Africa, but here in the United States and in all countries. This is the greatest task immediately before us. All scientific men and women may do their bit—*first,* by training themselves to observe accurately, to think straight and then to record clearly and honestly, and to draw warranted conclusions based on the facts presented, "free from previous preconception and prejudice"; *second,* by reviewing the mass of technical information with which they are familiar and telling the story they have learned in simple, clear language, free from obscure, complicated, technical and verbose wording. These simple suggestions apply not only to research workers in science, but to all the professional classes as well, theologians, doctors, lawyers, statesmen—especially lawyers and politicians, and of course professional teachers in schools and colleges.

That the scientist should have the virtues of charity, tolerance, broad-mindedness, patience, persistence and a very high regard for his fellow man is absolutely essential if he is to reach the heights and be of the greatest service. Agassiz and Pasteur were great scientists and great souls, and gave service by teaching as well as by their example of living on a high plane of thought and action. Some other men have

been brilliant contributors to knowledge, although their general manner of living may have been an injury rather than a service to mankind. We need to be grateful for the constructive service of each life, and our criticism of those who have passed and of those who are still active needs to have a broad friendliness as its basis. I believe, too, that a good scientist should be a good Christian, and a good Christian should be a good scientist in his method and work, as both are seeking the truth and the fundamental principles underlying their respective fields of endeavor.

Besides the necessity for each individual to train and conquer himself and to exercise such influence as may be possible on those within his immediate environment, there is great need for him to engage in cooperative public work, by associating with others of similar aspirations, and bringing legitimate influence to bear on all agencies that are concerned in any way with the educational system of the people, from the kindergarten to the university, from the leaflet of the advertising promoter to the great newspapers, magazines and books that make up the thousand and one publications of our day. His influence must also be brought to bear upon the important visual agencies of the motion-picture screen and every other form of illustration, as well as on all those agencies that are seeking to develop "the consciences, the ideals and the aspirations of mankind." The scientific method must be applied to all these factors if we have faith in its ideals.

Is it not practicable for the association to organize a progressive, live committee of men and women to deal with the popularizing of scientific knowledge? It might arrange special sessions for the public to which the layman could go with the feeling that they were for his entertainment and his instruction and not solely to arouse the interest of specialists in their particular field of research. Of all human beings, the child is the greatest and most active investigator of all that pertains to his environment. Why not provide for a junior section of the American Association, and last and in some respects the most important, a woman's section and sessions, at which all the scientific problems of peculiar interest to woman could be considered? We have a strong nucleus of women members, but they should be one of the great influences within the association for developing and carrying forward its work. Then there is the much discussed business man, who has a more or less hazy conception of science and scientific method, depending on whether he considers it affects his interest for good or evil. He would be a better business man, a better citizen and more successful in all his relations in life if he had a working knowledge of scientific method and principles at his command.

Every member of our association should work individually and collectively according to his or her opportunity and ability in supporting the scientific method and in insisting that, in all education of every kind and degree and for all classes, the purpose is to develop without prejudice or preconception of any kind a knowledge of the facts, the laws and the processes of nature in all natural and human relations. The natural weakness and incompleteness of all things of human origin will frequently baffle, mislead and confuse, and may even apparently bring temporary defeat, but in the long run there is no other way to eradicate sciosophy, advance the physical, mental and moral welfare of the race and justify our existence and opportunities for service as sentient human beings.

The Pilgrim fathers knew little of science, but they brought the great principles of law, truth, freedom and faith in God to America. Are we doing all in our power to perpetuate and develop them in connection with the multiplex activities of the world of to-day?

CHARLES D. WALCOTT
SMITHSONIAN INSTITUTION

THE FOUNDATIONS OF THE THEORY OF ALGEBRAIC NUMBERS[1]

ONE approaches with considerable hesitation a task in which on the one hand he is to give to the general reader some notion of an abstract scientific subject, while on the other hand he is to write something worth reading by the specialist in this subject. The task before me is to write something that is fit reading for the non-mathematician which is fit for the mathematician to read. My thesis has to do with the foundations of a theory which is of much interest to scientists and to mathematicians. I shall try to present it in such a way that one may foresee the methods that are adopted in the development and extension of this particular mathematical subject and may observe the generalizations that as a rule are applicable to mathematical theories. I shall attempt further to show that the truths established in mathematics must be used to standardize the truths, if such exist, of the general laws and principles that are derived for other sciences, and, in a measure, for all branches of human knowledge. Emphasis is also made of the importance of the universality of the truths that are found in the study of mathematics. A simple example

[1] Address of the vice-president and chairman of Section A—Mathematics, American Association for the Advancement of Science, Washington, December 31, 1924.