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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SOME ASPECTS OF RESEARCH IN THE FIELD OF ENGINEERING AND ITS FINANCIAL SUPPORT, WITH PARTICULAR REFERENCE TO CIVIL ENGINEERING AND RELATED FIELDS[1]

WHATEVER may be the objectives of Section M of the American Association for the Advancement of Science, it can be concluded with some assurance that connection with a society that is so concerned with the advancement of science makes it not inappropriate to select for the topic of the vice-presidential address, "Some Aspects of Research in the Field of Engineering and Its Financial Support." To distinguish the class of research considered from industrial research and research that is related to such matters as manufacturing, the limitation, "With Particular Reference to Civil Engineering and Related Fields," has been made.

At the beginning, the purposes and control and support of research suggest a classification into (1) research that is so directly related to financial interests of those individuals or corporations in charge and control of the work that it may well be financed by its promoters and supporters, who in turn will receive the main reward of advantage and profit, and (2) research that is more directly related in advantage and value to the public at large or to portions of it or to individuals who may at some time or other utilize the knowledge and advantages of the research but who may not have aided directly in its conduct or support.

The two classes named are, of course, not always distinct from each other, not mutually exclusive in methods and results used and obtained by one another. The privately conducted research gives by-products of scientific information and even includes investigation to discover and establish scientific principles, much of which is given to the public, to the great advantage of scientific progress. The research under public or quasi-public control contributes re-

[1] Address of the retiring vice-president of Section M —Engineering, of the American Association for the Advancement of Science, New York, N. Y., December 29, 1928.

sults that frequently are of great advantage to industry and through their utilization may bring large financial advantages to individuals. The purposes of the two classes and the distribution of the products in the main may be considered distinct and separate as related to this discussion.

AGENCIES OF RESEARCH

Industrial research and research that is supported and promoted by those who expect to profit by the products of investigation have increased by leaps and bounds in recent years, to the great advantages of the industries and also to the benefit of the public at large. In industries that may be called engineering industries this is particularly the case—electrical engineering, metallurgical engineering and many lines of manufacturing of an engineering nature have received continued contributions from research of this character. The industrial research laboratory has expanded greatly in recent years and the quality and extent of its output have been really wonderful. Fortunately, too, its future may be expected to be substantial and fertile, with profit to its supporters and with advantage to the public.

Municipal and state research laboratories have contributed to the advancement of knowledge in fields of governmental engineering activities. Research supported by our larger cities has developed and improved to a remarkable degree the methods and practice in the filtration and other purification and control of public water supplies, and likewise scientific knowledge and means and methods of treatment and handling of large volumes of sewage in such a way that sanitary conditions will prevail in its disposal have been studied and great progress has been made in the practices of disposal of wastes by the research work of municipalities and state organizations. The scientific knowledge of highway construction has been advanced greatly in the last ten years by the productive research activity of state highway departments and the U. S. Bureau of Public Roads.

In lines of more general engineering research, in fields that affect public interests and private and individual interests as well, are the research agencies of a public and semi-public character. The U. S. Bureau of Standards is an outstanding example of the investigational agency that makes it a part of its duties to carry on research activity in the field that affects the work of individuals and groups of interests in a public way with results made available to all, in small matters as well as large. Several engineering experiment stations of state universities and colleges and many of the engineering colleges less formally are doing work of the same character in various ways and along various lines. Many professors of engineering, perhaps in smaller ways and without adequate facilities, are contributing to the advancement of engineering knowledge. Private laboratories too have given many important bits of engineering science. For the second class of research activity, then, the class whose benefits accrue directly to the public and to individuals and to the interests of groups of individuals, these research agencies of the public type offer opportunities for future usefulness which should be fully utilized but which must be stimulated and supported if the needs of the public are to be met.

Another agency that has been very useful in this second class of research activity is the engineering society and its committees. Of the national engineering societies aiding and encouraging research work, the American Society of Civil Engineers for a number of years has made an effort to stimulate engineering investigations, and has to its credit a number of valuable researches in its field for which financial support as well as encouragement has been given. The investigation of steel columns and of impact in highway bridges, the researches in irrigation hydraulics and in concrete and reinforced concrete arches may be mentioned, as well as the work on stresses in railroad track, which has been carried on in collaboration with the American Railway Engineering Association and the American Railway Association. The first joint committee on concrete and reinforced concrete, originated by this society and joined by representatives of three other national organizations, gave great stimulus to experimental work in concrete and reinforced concrete and digested and rated the mass of results, utilizing the product in a report that helped to establish standard and safe practice in concrete construction, and the second joint committee has carried on its work in a similar way.

The American Society for Testing Materials has been prolific in stimulating and reporting researches in its field, giving the results freely to the public and safeguarding their publication with the effort to maintain an independent, unbiased point of view. The engineering science so produced and reported has proved of great value to the engineering public, and a large part of it has been very advantageous to building and structural work. Another society, the American Concrete Institute, has been giving more and more assistance in the stimulation and reporting of scientific information on the properties, action and utilization of products made up with cement and other materials. These three societies are mentioned as representing the kind of agencies that may be expected to be helpful in the conduct of research in the future.

Two methods of procedure have been used in the work of the societies referred to and their research

committees: (a) conduct of investigation by the committee itself or under the direction of a member of the committee, with the society furnishing the funds for its support or obtaining part of it from other sources; (b) the committee functioning by outlining, stimulating and arranging for investigational work and finally collecting, interpreting and reporting the results and applying them to the problem and formulating principles that may have been established. Both these methods have been found useful and their continuation may well be accepted.

Distinction between Classes of Research Activity

Perhaps it may be well to distinguish between the two classes of research activity that have been named: (a) that privately conducted and having the product privately controlled, and (b) that more publicly conducted and having the product freely usable by all.

First, let it be understood that nothing derogatory to the first class is intended. Its propriety and its value are appreciated, and the further development of its activity is assured. This is written rather to stress the need of the development and extension of the second class and to make a plea for its encouragement and its larger financial support in order to insure to the public the full advantages of this class of research.

The first class, then, has for its objective purposes of financial gain, its results to be private and confidential and its use restrained by patents or other forms of ownership. In the engineering field, this class of research is useful, for example, in industrial processes and in details of manufacturing. Its main purpose may be called selfish and perhaps will be actuated by the commercial instinct, though, of course, the utilization of the results may benefit the public and the by-products may be given freely to the scientific world.

The second class of research activity has a more direct connection with the general public and with individuals not connected with the research agency. For one thing, many of the results may be useful in a professional way. To illustrate, the engineer or the architect may utilize the principles, the methods, the scientific findings, to serve a client, who may be an individual, a corporation, a municipality. Naturally the client can not by himself spend the money and the time in an investigation to develop the knowledge needed in the design and construction. The engineer does not profit from the use of the information in a way that will warrant his maintaining the research activity, even though the new knowledge may give added prestige to his profession. This professional aspect of research is of the highest importance to the engineer, for the practice of engineering at the present day is based upon engineering science and this engineering science must be fed by research or the art of engineering will become stagnant.

Another aspect of the question is the need for independent, unselfish, unbiased attack and treatment of many research problems that otherwise would not be studied and for the fuller and more general investigation of them with a view to advancing engineering science and establishing principles in the engineering line that will be of service to mankind in this field. Then, too, many people have some mistrust of information that comes from commercial sources, even though the research has been ably conducted. A main reason for the support of this second class of research activity is that it will provide an attack and study of problems otherwise overlooked or neglected, that the results may be accepted as unbiased and the conclusions as independently and judicially determined, and that the knowledge will be disseminated and be freely usable by the public.

Financial Support of Research

Some comments on the financial side of research activities may be apropos. Research costs money. There must be adequate funds to support it. Its cost is increasing and the research problems to be attacked are becoming larger, more complicated and more expensive in their nature. Reference is not made here to the smaller, unpretentious matters but to the larger projects, requiring more elaborate treatment, many of them on large-scale structures or life-size samples and conditions. The conduct of research on important projects involves the expenditure of large sums of money. In reviewing the situation in the field of engineering, the committee on research of one of the national engineering societies expressed itself as being struck with the great opportunities for research work in a variety of research projects in its field, research that would undoubtedly be productive of valuable results and would bring returns many times the cost, and the committee further said that scientific information on these projects was urgently needed, but it came to the conclusion that funds could not readily be found at the present time to finance such work in an adequate manner.

The type of engineering research here referred to requires expert direction and expert workmanship. It is not the place for the amateur. Successful conduct of the large and complicated investigation implies skilled insight, trained aids, experienced workers and organized activity. Not only is the laborer worthy of his hire, but the expenditure of funds and time and the very life of the investigation itself make it essential that in these projects the research staff

shall be of the highest skill and ability. All of this goes to show that without adequate financial support the work will languish, falter and fail.

What are the sources of funds, for investigations of this type? The engineering college may have some small funds available for minor matters of experimentation. The engineering experiment stations of state universities have conducted important research projects with funds received from state appropriations, and the products of these investigations are very creditable to the stations. State highway departments and the U. S. Bureau of Public Roads have, of course, utilized very effectively available funds under their control in conducting important research work, with results that have great value. The Bureau of Standards, covering as it does a wide field, has made many important research contributions on a great variety of subjects. But valuable as is the output derived from financial support obtained in these ways, there are other sources of funds now utilized in research work of this character that are productive of valuable results.

The additional sources of financial support given research organizations should have recognition in this discussion. Their nature and scope may best be realized by the mention of a few examples. The important investigation of the fatigue of metals at the University of Illinois was financed largely by funds contributed by the Engineering Foundation and by manufacturers interested in the phenomena of fatigue of metals. The Portland Cement Association has for some years been providing funds for carrying on at and by the Bureau of Standards an elaborate and thorough research on the nature and properties of Portland cement as affected by raw materials and methods of manufacture, the study costing in the end probably several hundred thousand dollars—and this in addition to the outstanding work on concrete which has been conducted in the laboratory of the association, whose results have been given fully to the public. The research on stresses in railroad track under the joint sponsorship of the American Society of Civil Engineers and the American Railway Engineering Association, was started in 1914 with financial support from the two societies and in the later years has been supported by contributions from steel rail manufacturers and from funds granted by the American Railway Association. The structural steel column research, carried on at the University of Wisconsin, has been supported from funds provided by the Engineering Foundation and from contributions from bridge manufacturers. The test of the Stevenson Creek arch dam in California was made possible by large funds given by the Engineering Foundation and by contributions from power companies and industrial interests in the west, and the research was made effective and scientifically successful through the cooperation of the Bureau of Standards in sending an able and experienced tester of concrete structures (W. A. Slater) to conduct the testing work. In recent years the engineering experiment stations and other college research organizations have added to the amount and value of their research output by various cooperative arrangements with the industries and with engineering societies which have given financial support to projects that have the same general public character as those named above.

It will be evident to all that there is a limit to the funds that research organizations can contribute to general investigational work from their own resources, and that institutions like engineering societies have their own limitations in the financial support of research, though beyond their money contributions they may be of great service in encouraging the progress of research. The cooperative arrangements just referred to whereby supporting funds are contributed have proved satisfactory to all sides, and the method is well worthy of large expansion as a source of support in the future. The other methods of support already mentioned are also satisfactory and it is hoped will prove even more fruitful in the future. Since so much is needed, effort should be made to secure funds from every proper source.

Mention has been made of help received in large research projects from the Engineering Foundation. It may be appropriate here to add a further word about this stimulator and supporter of engineering research. The Engineering Foundation was formed as an adjunct of the four national engineering societies (usually called the four Founder Societies) to stimulate engineering research, to receive contributions and endowments, to aid research projects and even to conduct research. The foundation's endowment fund was founded by princely gifts by Ambrose Swasey, and others have added to the endowment. During its existence, the Engineering Foundation has financed many important engineering researches. It also serves as an agency for securing funds that may be expended currently for a special investigation. It is hoped that its endowment fund may be augmented many times in the near future by gifts like those of Mr. Swasey, for no enterprise offers higher results or greater advances to the engineering world and to its public than one that promotes the advancement of engineering knowledge as does a foundation like the Engineering Foundation. May this great agency be blessed with gifts of princely size adequate for the high service it can render.

It is well to note some characteristics of cooperative arrangements as safeguarding the value of the research to the public and upholding the independence and disinterestedness of the investigation and its findings, as required by some of the cooperating institutions. An advisory consulting committee considers the problem and the method of investigation, and may advise in the interpretation of results. The laboratory directs the investigation and controls the work and finally interprets the results and prepares the report. The results of the investigation are the property of the laboratory, and the institution will make publication if the value warrants. The product of the research is intended to be fully available to the public except that a patent may be applied for if this step is thought necessary to protect the interests of the public. It is seen that the purpose of the provisions is to conduct the research as a public activity, and that the advantages accruing to those who have financially supported it may be shared by others.

At another time I have said that pioneer American engineering depended almost wholly on ingenuity, experience, precedent, vision and judgment, and engineering science played a minor rôle. The increasing magnitude and difficulties of engineering projects, the need for greater permanency, economy and safety, and the greatly diversified nature of engineering work have emphasized the importance of basing engineering art more fully on engineering science. It will not be overlooked by any one that engineering will continue to need ingenuity, experience and judgment, and rules, precedent and vision, but more and more, as time goes on, will it be dependent on science and that accumulation of applied science that may be grouped under the term, "engineering science." And engineering science must be fed upon research, and thus research is essential to its advancement, to its fuller growth.

No attempt has been made here to name problems or projects that need the light of research thrown on them. The belief may be expressed, however, that the members of Section M recognize the great value and need of research in engineering lines and appreciate the importance of adequate provision of funds for the purpose. It is the hope of the retiring vice-president that Section M in some way may give effective aid in bringing this need to the attention of those who may be able and willing to contribute liberally to the support of engineering research.

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CELLULAR DIVISION IN RELATION TO CANCER[1]

CANCER is a disease characterized by division and multiplication of cells. In the unrestrained condition the tendency of cells is to grow and multiply. In tissue or cell culture each cell divides twice and the colony doubles in volume. A colony, originally one cubic millimeter, will form approximately one cubic centimeter in twenty days. After sixty days the volume of tissue would be more than one cubic meter, and in less than one hundred days, one million cubic meters. Indeed, Carrel has estimated that, if the tissue cultures which he has kept growing for sixteen years had not been restrained, the mass would be not only larger than the planet, but even greater than the universe.

Cells are endowed with far greater potentialities than they display within the human body. There the immense capacity for growth possessed by the cells of the human tissue must be kept under restraint while these cells live as part of the organism within the body. The resting condition of adult tissue depends upon the composition of the fluids or humors in which they are immersed, or, to put it in other words, the environment of the cell determines the rate of its growth and division.

In the light of this, cancer is characterized by more or less suppression of normal balanced cell activities with accentuation of that of cellular multiplication. Suppression of multiplication is removed and there is a release from normal growth gradients which determine body structure. Inhibition is replaced by the embryonic qualities of multiplication.

In cancer we have to do with a state, not a thing—with a state of cell wherein the cell is allowed to grow and multiply without the usual restraint common to adult body tissue. A most important study, therefore, is the mechanism whereby restraint of cell growth may be obtained.

In the consideration of cell division we have to take thought of the mechanism and organization of the cell. It is well in this regard to have a model for thought in order to consider the changes which take place, exactly as the physicists have their model of the atom and the chemists have their model of the molecule. The simplest structure capable of sustaining life is the unit with which we have to do, as the physicists have to do with the atom and the chemists with the molecule.

[1] An address before the Wilmington section of the American Chemical Society, illustrated by moving pictures of cell division. October 17, 1928.