# SCIENCE

FRIDAY, NOVEMBER 29, 1918

CONTENTS



MSS. intended for publication and books, etc., intended for review should be sent to The Editor of Science, Garrison-on-Hudson, N. Y.

## THE PURPOSE OF RESEARCH

ONE of the articles of the constitution of the Society of Sigma Xi provides that the president shall explain to the members-elect the aims and objects of the society, and it is in accordance with this requirement that I now have the pleasure of addressing those who have been, by our active membership, adjudged worthy of enlistment with us in the army of investigators and research workers whose goal is the discovery of all truth.

Our constitution sets forth that the society exists for the purpose of encouraging investigation in science, pure and applied, and limits its membership to those who have shown either noteworthy achievement as original investigators or who have given promise of marked ability in research; and if the reward of membership has not proved to be sufficiently adequate and compelling in the promotion of investigation, the society must, if true to its purpose, devise other ways of securing and developing the spirit of research, which is its excuse for existence.

With this in mind, I think, Professor Stieglitz, of the University of Chicago Chapter, has recently proposed that the society at large establish at least three Sigma Xi fellowships, with an income of at least $1,000 each, as a practical method of stimulating and strengthening ardor for research, since the award of a national Sigma Xi Fellowship would stamp the recipient as one of whom much is expected and would

[1] Presidential address to members-elect, Alpha Chapter, Sigma Xi Society, April 20, 1918.

encourage and enhance the working powers of the successful candidates.

Professor Mann, in his forthcoming report to the Carnegie Foundation, on Technical Education, discusses the various methods by which improved scholarship may be secured and he alludes to the part played by the possibility of membership in Phi Beta Kappa, Tau Beta Pi and Sigmi Xi, as valuable incentives to persistent application. But Professor Mann has sadly confused the ideals of the three societies when he puts them on the same basis. Scholarship, as Phi Beta Kappa and Tau Beta Pi know it, is vastly different from the scholarship that Sigma Xi exists to foster, and there are among you those whose mentality and methods of work, whose scholastic record would undoubtedly shut out from either of the first two but entirely justify your membership in the last. To be able to pass examinations of a conventional type, to follow along well-marked paths, even with occasional obstructions is in marked contrast, educationally, from blazing a new way. You have been judged, either on the evidence of actual accomplishment or on the promise of marked ability, to be capable of leading, rather than of following, of making discoveries for yourselves rather than of assimilating the results of others' work. The field included in the ideals of the society is unlimited. Science, either pure or applied, certainly includes everything that affects life and living, provided the matter be approached in a scientific spirit, and while the society in the past has emphasized pure science and is likely to do so even more in the future, so that the membership has been found largely among those who are searching for evidences of the abstract laws of scientific truth, it has also welcomed those who have applied such laws to the benefit of industry and of human development.

Professor Noyes, of the University of Illinois Chapter, has recently dwelt on the higher character of what he calls "discoveries" as compared with "inventions" though he grants that the society exists for the furtherance of both. He compares the value and genius of Faraday, a true discoverer, with the work of Morse, who applied only the earlier researches in electrical and magnetic induction to the construction of the telegraph. He refers to the basic discovery of Newton and disparages the applications of that discovery made by Newton's followers. In the same way, Pasteur's epochmaking discoveries in bacteriology and epidemiology might be compared with the applications made by his followers, Lister, Behring, Roux, Flexner, Metchnikoff and a host of others.

But the great majority of us can not hope to make discoveries and it may reasonably be asked whether the aim of the society will not be met quite as well by applying scientific law to practical problems as by persistently enquiring into some scientific field, a little corner of which seems to offer a chance for new discovery. Professor Titchener, some years ago, dwelt on the need for the true research worker to be unselfish, to forget the thought of reward either through some practical application or through financial appreciation and he held out to members the idealized promise that only in the consciousness of faithful service to an abstract desire for truth could reward be looked for.

But to an engineer, accustomed by training and habit to look on science and scientific laws as valuable only when capable of application and in these times when the whole world has been awakened to the fact that men skilled in research are indispensable to the prosecution of our world war, when the value of these very applications is everywhere recognized and when workers

are abruptedly snatched from the peacefulness of their quiet laboratories to tumult of the very battle-field itself, a plea for greater recognition in our membership of those whose interests lie in the practical side of science and a summons to a broader outlook in that field of enquiry may be permitted.

It is of course not forgotten that discoveries must always precede invention and that the smallest triumph in pure science may have unexpected and far-reaching results, so that the devoted investigator will always with us remain an honored and appreciated member. But in a world where unhappiness, injustice and distress are constantly in evidence, where conflict between classes is always on the point of breaking out, and where inefficiency and waste are everywhere, what greater service can the altruistic scientist do than to reduce the causes of the apparent sources of misery to known terms so that there may be some hope of reducing their effect if not of shutting them out altogether. The great Teacher promised that the poor we should always have with us. But it is not too much to look forward to that, through the more equable distribution of wealth, through better ways of fitting workmen to their tasks, through approved methods of reforming misdemeanants and of punishing criminals, we may greatly diminish the number of the poor. Why should not some of the researches of the society be made in the field of sociology, since we now honor with membership those who have studied practical problems in psychology. Why not in industries as well as in engineering?

Three fields, and doubtless there are others equally important, have suggested themselves to my mind as belonging to the category that I have tried to suggest: that of labor efficiency, that of industrial production, that of technical education.

The question of the efficiency and control of labor has always been perplexing to engineers and generally to employers. At the close of this present war, if the many predictions now being made have any basis whatever, the right answer to the labor problem must be found or else the whole world will be again bathed in blood in a still fiercer conflict, involving the very right to live, between employer and employee. It is predicted, as you know, not merely that all autocratic government will disappear, but also that labor will "come into its own," whatever that means. Recent happenings in Russia have not given evidence of the success of a government when the governors are narrowminded, unused to the consideration of large problems and unable to think of more than the present. Why should not this Society of Sigma Xi investigate some of the labor problems, as yet unsolved, in the hope of so definitely fixing fundamental laws that their permanence and binding character would be understood and perhaps made the basis of understandings otherwise impossible.

There would be many advantages in the trained scientific mind coming to the consideration of such a question as "Can a woman do the same amount of physical work as a man?" and settling it without reference to sentiment or public clamor. Some years ago, Mr. Frederick W. Taylor undertook to develop a body of scientific law that should govern the organization and operation of any industry and he gave to his studies the appropriate term, "Scientific Management," because, he said, such control is distinctively scientific in that it aims to correlate and to systematize all the best of modern developments in factory administration and to push development further in accordance with the principles discovered. It rests on laws and principles rather than on policies.

He emphasized the need for the adjustment of each individual to his special task, the need for better training for its better accomplishment and the predetermined and conscious stimulation of the workman to his greatest degree of exertion consistent with his continued health by means of a special reward in the form of a bonus for superior accomplishment. How to adjust an individual to any special task is plainly a matter for scientific study and the work of the late Professor Münsterburg, incomplete though it was, shows the vast possibilities of this kind of work. The recently devised tests for the fitness of aviators are of the same sort and the newly promulgated order of the War Department that all soldiers shall be tested by trained psychologists and the number of our faculty, members of this society, that have been taken for this purpose is another evidence of the feeling that there is a definite relation between the mind or attitude of the laborer and the work that he has to do.

One of the most important parts of Mr. Taylor's study was the investigation of the amount of work that a capable workman can produce in a day, a study carried on with a stop watch reading to fractions of a second and this led to an analysis of the elementary motions needed for any operation and to the elimination of all unnecessary ones. His work was however not exhaustive but rather suggestive and a great deal of investigation in his field remains to be done. Some attention has already been given to the inefficient management of household economy and to the possibility of applying the Taylor principles to domestic management. Our own department of domestic economy has published some suggestive bulletins on various phases of his subject although as in factories it is sometimes easier to point out the losses than it is to persuade the workers to avoid them. An amusing series of stories about "Efficiency Edgar" appeared in the *Saturday Evening Post* in 1916, giving an imaginary account of the possibilities of this important sort of efficiency housekeeping.

In the university we may not make our enquiries directly on the operation of factories but our university community is in many ways only a factory of a certain sort whose product is men and women instead of things and many factory problems may be studied here as well as elsewhere.

We might, *e. g.*, make scientific enquiry into such questions as:

What is the necessary rest period during the course of any working day?

Do students accomplish the same amount of work in the same number of days of a term, with and without vacations?

What tests can be applied to candidates for admission to the college of agriculture to determine their fitness for directing dairy work, or for agronomy, or for any other kind of agricultural work?

What inducements, that is, what kind of bonus, may be offered to students so that they shall be persuaded to really work for an education?

How shall a student know when he has reached the limits of his powers of application in the preparation of any lesson, so that a change of occupation is desirable?

How may competition be made use of in educational processes as in industry?

How much sleep does a student need?

How much food does a student need as compared with the military ration that has been found desirable?

Such studies would of course be widely different from the microscopic investigations of such subjects as:

"The Classification of the Larvæ of Ground Beetles," in zoology; "The Molecular Arrangements in the Camphor Series"

in chemistry; "The Fusarian Wilt in China Asters," in botany; or, "The Nature of Ionization of an Atom of Mineral Sulphide" in physics; to take a few of the subjects studied by those members admitted last year. But their general interest and value can not be gainsaid, nor can their fitness for presentation as evidence of the ability of the investigators for admission to the Sigma Xi Society be doubted.

Next to the many big problems of labor, crying for scientific treatment, come questions of industry. Industrial research is no new thing in America and the development of industrial Germany has been due to awarding governmental subsidies for chemical and other research workers. The Bell Telephone Company has had a research department for some forty years, advancing from a small beginning to a great institution, employing hundreds of scientists and engineers. In a recent address, the director of the research laboratory of the General Electric Company, Mr. Whitney, urged the value of research work in universities where the foundation for industrial advance can be well laid by trained workers. Dr. Steinmetz has urged many times the need of university training and has pointed out the fact that only because the demand for the results of scientific research has been so great that the universities have not been able to supply the demand the industries have had to enter the field of research themselves. He believes that some kinds of research can be best carried out by educational institutions, such as those requiring large amounts of time and attention, while others, requiring large amounts of material and power are better adapted to the industries. The latter also are more likely to limit the field of their investigations to some particular problem, to seek to meet some particular competition and to provide in some line a special efficiency.

The National Research Council is to-day, through coordination of research work, offering to the government the results of scientific studies of various war problems. The council has been able to assign properly qualified men to the solution of special problems as they have arisen. They have already pointed out the shortage of men properly equipped for high-grade research work and that the industrial efficiency of this country at the close of the war may be hindered by the failure of the universities to turn out men so qualified. In England the need for industrial research has led to various kinds of industry combining to maintain laboratories in which certain evident problems may if possible be solved. The Rockefeller Institute for medical problems and the Mellon Institute at Pittsburgh for the study of manufacturing operations are both splendid examples of the big returns that come from the application of pure science to problems of life and industry. In Professor Duncan's "Chemistry of Commerce," he says:

> Everywhere throughout America, wherever there is the smoke of a factory chimney, there are unsolved, exasperating, vitally important manufacturing problems, problems in glass, porcelain, starch, tanning, paints, drugs, meats, iron, oil, metallurgical products, problems wherever man deals with substances. It seems clear that these problems can best be answered by combining the practical knowledge and the large facilities of the factory with the new and special knowledge of the universities and by making this combination through young men who will find therein success and opportunity.

And what answer does Sigma Xi give to the call from industry for help in solving its insistent industrial problems? What work is going on in the chemical and physical and engineering laboratories that will bring direct aid to the sorely perplexed

managers of factories? But little, it must be confessed, though this may be from a failure of the industry to let its wants be known. Such subjects as "Arsenic in Filter Alum," "The Chemistry of Liquid Manure," "The Fertilizer Value of Activated Sludge," "The Effect of Gas-house Waste upon the Organic Matter in Streams" are recent general Sigma Xi studies in my own field. But special problems for particular manufacturers do not seem to reach the universities. Our eager workers do not seem to know of them and the practise seems to be growing of sending to the universities where laboratories and advice may be had agents of the industries, industrial Fellows, as they are called, to do work for special interests. Even the employees of the United States government come to the colleges and work on problems that the government needs to have solved.

The present war has brought to a crisis the failure of this country to provide for the manufacture of optical glass. Our navy has been begging from patriotic citizens their field glasses so that the ships of the navy shall not go blindly directed. England has felt the same lack and is meeting the urgency of the problem of manufacture by a special committee of scientists to whom has been referred such questions as "What are the desirable raw materials for optical glass?" "What are the optical properties of all the different kinds of glass?" "How should glass be tested for its optical properties?" "How should the surfaces of lenses be designed?" Why should not Sigma Xi workers give their attention to such practical problems?

In one of this year's *Atlantics,* is an article by Professor Ames, director of the Physics Laboratory of Johns Hopkins, describing in the most graphical way the applications of science to the carrying on of the war, as he himself saw it at the front. He confidently predicts the success of the Allies because, he says, at first the Germans profited by the advice of their scientists but now these have all been replaced by regular army officers, while, on the contrary, more and more have the operations of the Allies been guided by scientific advice. Professor Ames shows how geology, meteorology, physics and chemistry, each with many branches, are doing yeomen service and making success certain through the marked superiority of the Allies in the very kind of work that Sigma Xi exists to foster.

And finally there are problems of education to be treated with a scientific spirit. For educators are getting restless under the spur of constant criticism of methods and of results. So much is being said of the failure of universities to turn out men and women whose minds are really trained, who have more than a smattering of ideas in their heads, that faculties are asking themselves whether they are really alive to their responsibilities, and whether the time-worn theories of education may not need revision, in view of changed industrial and social conditions. Ex-president Eliot is a champion of revised teaching in the secondary schools, on the ground that present urban conditions do not train children to see and to hear accurately and that the present methods generally contain no significant element of sense training. He would cultivate mental vigor by association with bodily work and increase the power of mental concentration by work in carpentry and farming. Abraham Flexner goes farther and would eliminate all the old curriculum and build anew on the four foundation stones of science, industry, esthetics and civics, developing each from the child's senses and from laboratory training.

Perhaps a larger conception is found in

those who criticize the present methods for emphasizing the virtues of obedience and discipline and for failing to promote independence, and impulse, and constructive doubt, and spontaneous enquiry.

Undoubtedly modern educators substitute largely passive acceptance for creative thought, a substitution that is deadening rather than stimulating, and it is to the credit of Sigma Xi that thirty years ago it was founded to do its part in persuading students to see and to think for themselves and to make deductions, based on their own studies.

The old-fashioned teacher says that by the old régime was bred a sense of obligation, a respect for authority, a readiness to respond to the call of duty, traits that are sadly missed in the rising generation; while the opposition claim that these good qualities need not be sacrificed in the modern attempt to arouse individuals to mental alertness and self-reliance.

A few years ago, one of the former members of this chapter came to be in charge of a class in applied mechanics in a western university and he tried an experiment. Instead of teaching general laws by lecture and recitation, he gave out practical problems on pressures and on strength of beams and guided the students into a knowledge of the laws by which that particular problem could be solved. He reports a greater understanding of the principles than ever before and an unheard of enthusiasm for the subject. With so many of us teachers, why should not we turn our scientific minds on to the problems of effective teaching? It can not of course be altogether mechanical. We can not invent any adequate system of gauging the intelligence, or of regulating hours of study, of composing syllabi or of imposing quizzes, until work goes on with the pressure and dispatch of an engine room, the product accurately measured in kilo-watts or in foot-pounds. But we may properly make investigations into the subject with a view of getting the greatest return for the energy expended.

The questions of foundation and fundamental subjects needed in professional work is both delicate and important. Shall an engineering student spend twelve hours or five hours on analytics and calculus in preparation for civil engineering? is a question to be solved only by turning the technical school into a laboratory and experimenting on the subject. Shall physics be taught as theory or as a laboratory exercise and how many elementary principles of physics does an engineer really need? is another most pertinent question. Why does the engineer need to spend three years in his preparatory school on a modern language that apparently has no further bearing on his college course? is another perplexing question perhaps not so easily adjusted to laboratory tests. But experiments on inducements to study, on stimuli and incentives might be carried on almost without number. The general faculty have been considering inducements for the improvement of scholarship, all based on scholastic rank, on marks, an extraordinary spectacle that the faculty especially of arts, burdened with the task of imparting culture and mental discipline should think that scholarship can be compared and measured by numerical grades. What our society could do is to determine experimentally the best methods of teaching, the best methods of competition to compel students to rouse themselves and develop their ambition to excel. Once mothers gave their children in the spring nauseous doses of sulphur and molasses to purify their blood and for many years that magic phrase was sufficient justification for the practise. Is there not something of the same sort going on in educational matters, and how shall

the truth be known unless we, who have educational laboratories at our hands, make use of them.

May I then express the hope that among you, the newly elected members, there may be some who will find the subjects for their future experimental work, not in abstract research, without thought of reward, carried on in the sole interest of science, but rather in modern practical applications, in attempted solutions of the many insistent problems of labor, industry and of education, that the existence of the university may be more fully justified and the purpose of the Society of Sigma Xi the better realized.

H. N. Ogden

Cornell University

## INDUSTRIAL RESEARCH AND NATIONAL WELFARE[1]

I have no justification for expressing views about scientific and industrial research except the sympathetic interest of an observer for many years at rather close range. One looking on comes to realize two things. One is the conquest of practical life by science; there seems to be no department of human activity in which the rule of thumb man has not come to realize that science which he formerly despised is useful beyond the scope of his own individual experience. The other is that science like charity should begin at home, and has done so very imperfectly. Science has been arranging, classifying, methodizing, simplifying everything except itself. It has made possible the tremendous modern development of the power of organization which has so multiplied the effective power of human effort so as to make the differences from the past seem to be of kind rather than of degree. It has organized itself very imperfectly. Scientific men are only recently realizing that the principles which apply to success on a large scale in transportation and manufacture and general staff work apply to them; that the difference between a mob and an army does not depend upon occupation or purpose but upon human nature; that the effective power of a great number of scientific men may be increased by organization just as the effective power of a great number of laborers may be increased by military discipline.

This attitude follows naturally from the demand of true scienific work for individual concentration and isolation. The sequence, however, is not necessary or laudable. Your isolated and concentrated scientist must know what has gone before, or he will waste his life in doing what has already been done, or in repeating past failures. He must know something about what his contemporaries are trying to do, or he will waste his life in duplicating effort. The history of science is so vast and contemporary effort is so active that if he undertakes to acquire this knowledge by himself alone his life is largely wasted in doing that his initiative and creative power are gone before he is ready to use them. Occasionally a man appears who has the instinct to reject the negligible. A very great mind goes directly to the decisive fact, the determining symptom, and can afford not to burden itself with a great mass of unimportant facts; but there are few such minds even among those capable of real scientific work. All other minds need to be guided away from the useless and towards the useful. That can be done only by the application of scientific method to science itself through the purely scientific process of organizing effort. It is a wearisome thing to think of the millions of facts that are being laboriously collected to no purpose whatever, and the thousands of tons of printed matter stored in basements never to be read—all the product of unorganized and undirected scientific spirit. Augustus De Morgan denying the divinity of Francis Bacon says "What are large collections of facts for? To make theories *from,* says Bacon to try ready made theories *by,* says the

[1] A statement made by the Honorable Elihu Root at the initial meeting of the Advisory Committee on Industrial Research of the National Research Council, held in New York on May 29, 1918.