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PURE AND APPLIED SCIENCE[1]

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IN entering on the duties of the George Fisher Baker lectureship in Cornell University, I must first express my high appreciation of the great honor done to me by the university by its invitation, and of the great personal kindness and helpfulness of Professor Dennis in all matters concerning it.

Only a short time ago Mr. Baker, to whom this university owes so much, passed away, full of years and honor. Education in America has been singularly fortunate in attracting the support of many wealthy leaders of commerce and industry, and the results are to be seen in such magnificent buildings as this in which we meet, and in the facilities given for the interchange of students and teachers between different institutions and different countries. The visiting lectureship which George Fisher Baker founded in this university has been the means of bringing a number of European workers in various branches of science related to chemistry to Cornell and has given to them an unrivaled opportunity of seeing American university conditions at their best and of exchanging ideas with a new and keen group of students and colleagues.

With the possible exception of music, no form of human activity is so independent of national barriers as scientific research, and every step that brings into closer connection the scientific workers of different countries deserves a warm welcome. Judging by the enthusiasm and the affection with which my predecessors in this lectureship have spoken to me of their stay at Cornell, this scheme, which we owe on the one hand to Mr. Baker and on the other to Professor Dennis, must rank high among such efforts at international cooperation.

Previous lecturers have dealt with different branches of pure chemistry and of sciences allied to it, but I believe that I am the first whose teaching duties are definitely concerned with the application of science to industry, and I ask you to allow me to consider in

1 Introductory public lecture.

this opening address some aspects of the relations between pure and applied science.

As I left London, scientific men of many countries were assembled there to do honor to the memory of Michael Faraday, the occasion being the centenary of his discovery of electromagnetic induction. From that discovery has grown the whole of the modern electrical industry, for without it there would be no electric generators or motors, no radio-transmission, no generation of current except on the smallest scale. At the Faraday exhibition now open in London, the statue of the discoverer occupies the center of the large circular hall, and is surrounded by cases containing the apparatus used in his early experiments. From each of these extends a sector, illustrating the developments in electrical science and practice which may be considered to owe its origin to those experiments. Yet Faraday was an "experimental philosopher," one whose sole aim was to learn something of the workings of nature. He had in mind no practical application of his discoveries, and never concerned himself with the invention of machines. He was even skeptical of the possibility of using electromagnetic methods in place of the primary battery. His work was guided throughout by the purely theoretical conviction of the unity of natural forces, which led him to seek for the connection between electricity, magnetism, light, chemical action, and even, although at the time without success, owing to the minuteness of the effect, which was afterwards found in our own day, with gravitation.

It was not from any contempt for practical objects that Faraday confined himself to work in pure science. He was always ready to assist the state and public bodies by his advice when it was invited, notably in his work for Trinity House, the authority which in England controls the lighthouses on our coasts. At the same time, caring nothing for wealth, he refused to be tempted by the offer of large sums to enter industry and to devote his genius to immediate practical objects. Little as he would have expected it, industry has gained enormously by his decision to investigate fundamental principles. He actually produced, in the course of his experiments, the first dynamo-electric machine—a copper disk rotating between the poles of a magnet and supplying continuous current to a pair of brushes in contact with it—but he took no part in its development, although within a very few years machines based on his principles were constructed and brought into practical use by others.

The complexity of modern science, and the large number of workers in almost every field, make it unlikely that future Faradays will be able to open up a new region with the same completeness, but it remains true that practical inventions mostly arise as the unforeseen by-products of studies which had as their aim the discovery of relations between the phenomena of nature.

There has lately been presented to us an entirely different view of the relations between pure and applied science. A striking incident at the International Congress of the History of Science held in London this summer was the appearance of a number of scientific delegates from Soviet Russia, prepared with papers which were immediately published with the title of "Science at the Cross-Roads." In these papers the thesis was maintained that scientific research carried out for the satisfaction of intellectual curiosity is anti-social, and that henceforth research must be directed towards some practical end, having direct value for the community. This is not to say that science is to be confined to mere technology—the distinction attained by some of the speakers in their own fields of science would make such a statement a caricature of their views—but the possibilities of application are to be kept in mind throughout. This view of the science of the future, although taken, with the other principles of the Soviet system, from Karl Marx, had been maintained earlier by Auguste Comte, who held that the need for knowledge in certain fields of importance to society was so imperative that it was the duty of men of science to concentrate, at least for a generation or two, on the solution of a few problems, to the exclusion of researches dictated only by curiosity, of however high an intellectual order. Comte did not foresee the great unification of science, beginning with the doctrine of the conservation of energy, that was in progress during the later years of his life, and Marx, a much less profound thinker, was so obsessed by the purely economic problem as to fail to understand the real meaning of science.

The Soviet theory claims an historical basis. It is argued that all scientific research had its origin in practical needs. This is true of the first beginnings of science. The study of the stars was a necessity of pastoral races to guide their wanderings, and geometry, as its name signifies, was originally land surveying, necessary to the settled agriculturalists. But after these beginnings science took its own course. Astronomy and mathematics were studied for the new knowledge they gave, without care for possible applications. Plato's conception of pure science, which would limit its scope to the most abstract part of the mathematical sciences, was that of a philosopher and not of an experimental investigator, but it would be absurd to say that it was anti-social. Ever since the foundations of abstract science were laid by the Greeks, men have felt, instinctively or on the ground of a definite theory of life, that the disinterested search for knowledge was good in itself, and worthy of the best human effort.

Suppose, however, that we admit for the moment that the desire to satisfy intellectual curiosity is a selfish one, and that the world needs an answer to many problems that affect the welfare of mankind, does it follow that scientific research should be confined to those problems with the object of obtaining, by combined effort, the most speedy result? Experience teaches the contrary. The history of the transmission of messages by electric waves has often been told, but it would be hard to find a more striking illustration. Eighty years ago the electric telegraph was well known and understood. Let us suppose that electrical engineers had been asked to discover a method which would dispense with the wire or wires connecting the sending and the receiving stations. The supposition is absurd, for there was nothing in the known properties of the electric current to suggest such a possibility, but it is safe to say that if a team of workers trained in telegraphy had been instructed to find such a method they would have met with no success, even after years of combined effort. The actual history of the solution is very different. Faraday, who had no mathematical training and never used a mathematical symbol, nevertheless stated his conception of the electro-magnetic field in such a way that Clerk Maxwell was able to give it mathematical shape and to deduce the formal equations from which it followed that changes in electric or magnetic force must be propagated as waves. This was verified in 1888, nearly ten years after Maxwell's death, by the brilliant experiments of Heinrich Hertz. Electric waves had actually been observed earlier by Joseph Henry at Princeton, but the observation had not been followed up. Transmission over a distance of a few feet having once been achieved, the later development of wireless telegraphy and telephony, extraordinary as it is, has been mainly in the application of known principles by skilful engineers and inventors. The greatest single step in that advance, the invention of the thermionic valve or tube, which has made modern radio-transmission possible, arose from investigations of the emission of electrons from heated solids, investigations which appeared at the time when they were undertaken to be as remote as possible from any practical application. As the uses of the original invention multiply, and as greater and greater refinements of technique are required, the discoveries of pure physics in the most varied branches are pressed into service. The photo-electric properties of certain elements and compounds, the variation of the electric properties of quartz crystals with changes of pressure, and the action of organic liquids on the plane of polarization of light, are examples of such phenomena. All of them were discovered in the course of pure research in physics, without thought of practical use, and again illustrate the fact that important inventions are in the main the by-products, rather than the intended results of scientific research.

In an interesting address delivered to the Society of Chemical Industry in 1928, Dr. Irving Langmuir described how experiments, at first intended to improve the vacuum in incandescent lamps, led him into research on the liberation of gases from heated bodies, with results of great interest for pure science. The enlightened policy of Dr. Whitney and the General Electric Company made it possible for him to pursue this line of research, although it seemed unlikely to lead to any results of practical use. In the end, it led to the gas-filled lamp, an invention of very high value, but quite different from the original object of the research. It is in America particularly that great corporations, which possess exceptional facilities for research, such as the laboratories of the General Electric Company at Schenectady and those of the Bell Telephone Company at New York, have taken such a broad view of their functions as to allow members of their staffs showing great experimental ability to follow an interesting line of investigation even though it might appear to have no immediate practical object.

I must not be unfair to the Soviet delegates. They would readily admit that results of value may be reached by indirect means, but would claim that the investigator must always have utility in view, and must not regard himself as free to follow any interesting line of study that may happen to appeal to him. For the spontaneous activity of individual workers they would substitute the organized labor of skilled teams.

A feature of the Marxian theory of science is its virtual denial of the importance of genius. It will be found that every great discoverer has had precursors and contemporaries in the same field. Oersted, Ampère and Arago had discovered important relations between electric and magnetic effects before Faraday, whilst Joseph Henry independently made the same observation of electro-magnetic induction. The subject was engaging attention, and it is easy to argue that if Faraday or Newton had never lived the discoveries that we associate with their names would have been made by others without very much delay. In that there is an element of truth. Since the picture of the universe which science constructs becomes one that is accepted as true by all those who have the training necessary to appreciate it, we are bound to believe that those regularities which we call laws will be discovered in course of time. But the progress of discovery is enormously hastened by the advent of a man of genius. Ostwald's comparison of the genius with a catalyst is a good one. The catalyst does not alter the final state of a chemical reaction, but it may very greatly accelerate it. No one can examine the writings of Newton or Faraday without feeling that the transformation of science brought about by their work was of an entirely different order from that of even their most gifted contemporaries and that the pace of scientific discovery was almost immeasurably quickened in consequence. It is not an isolated experiment or series of experiments by Faraday that is now being commemorated, but a conception of the electromagnetic field based on those experiments, so perfect that it has been adopted by all later students. We can only regard it as a work of genius. It would be absurd to imagine that, if Shakespeare had never lived, "Hamlet" would sooner or later have been written by another hand or, if the task had proved too great for one man, then by a duly appointed team of writers. Scientific discovery is not strictly parallel with literary creation, but sufficiently so to make us conscious of the essential services of genius in that field also.

In the subsequent lectures of this course there will often be occasion to refer to the use of the microscope in the examination of minerals and metals. We owe these methods to a Sheffield amateur, Henry Clifton Sorby, who fully deserves to rank as a genius, although on a lower plane than Faraday. Free from all duties of teaching or administration, Sorby devoted himself to independent research in science, studying rocks, strata, meteorites, steel, plants, animals and archeological remains with that insatiable curiosity which marks the born discoverer. In every field he added new knowledge, but he is the undoubted founder of two branches of study, microscopical petrology and metallography, both of which have grown to great dimensions, and have proved essential tools in both pure and applied science. In a plea for "Unencumbered Research," published in 1876, Sorby urged that the research worker should be left entirely free to choose his path, with the assurance that the real investigator, if we can find some way of recognizing him when young, before he has been forced into a mould, will produce the best results if left unfettered.

This is not to belittle the team work which is so necessary in the application of scientific results to industry, agriculture, medicine or other practical ends. Those activities depend on science to an extent undreamed of in Sorby's time, and our great laboratories of applied science call for increasing numbers of research workers trained in pure physics, chemistry and biology, in addition to those whose education has been given a special technical bent. But we must have in the universities groups of "unencumbered" workers free to choose their own line of research and pursuing it for the love of scientific discovery alone, or the organized team work will before long flag and languish from lack of inspiration.

The art of smelting metals is an ancient one, and until the eighteenth century it was almost entirely empirical. The trade of the smith, in all its varieties of form, was one of the most rigidly preserved of crafts, since its success depended so entirely on the traditional skill of the craftsman. A few men of scientific insight, such as the German Agricola in the sixteenth century, had sought to reduce the knowledge of the art of smelting to some order, and to free it from the grosser errors and superstitions, but it was a few chemists of the eighteenth century, notably Réaumur in France and Swedenborg in Sweden, who made intensive studies of certain branches of metallurgy and sought to place them on a scientific basis. Their writings are of interest to us to-day. Nevertheless, the empirical character of the art persisted, and truly scientific metallurgy is of quite recent date. The influence upon it of researches in pure science is perhaps best seen by considering, not the smelting of metals from their ores, but their treatment to give useful products. In the steel industry, so long as cast and wrought iron and such steels as those used for cutlery were the only known materials, empirical methods answered well enough, but with the expansion of the industry brought about by the invention of new steel-making processes it became necessary to consider, for instance, the effects of carbon in modifying the properties of iron. The physical chemist was called in, and the first draft of the iron-carbon equilibrium diagram by Bakhuis Roozeboom in 1900 marks the beginning of a new era. About the same time, Heycock and Neville carried out an investigation of the alloys of copper and tin, using microscopical and thermal methods, and setting a standard of accuracy which profoundly influenced later work. It was now seen that changes may proceed in solid metals in such a way that, without any alteration in chemical composition, materials of entirely different properties may be obtained by varying the rate of cooling. The hardening of steel by quenching in water, in use for more than 3,000 years, is only one of many such processes which are employed in metallurgy. Gradually, the microscope and the thermoelectric pyrometer have come to be essential tools in metallurgy, and micrographic analysis supplements chemical analysis in all works laboratories.

Besides undergoing thermal treatment, metals and alloys are subjected to mechanical processes, such as rolling and wire-drawing, which profoundly modify their properties. Empirical knowledge and skill have done much for the perfection of those processes, but it has been found that they can not be utilized to the best advantage without an understanding of the internal mechanism of the change. Metals are made up of crystals, so the metallurgist has called to his aid the work of the crystallographer. Whilst the older geometrical crystallography could only indicate in a general way the nature of the changes during deformation, the newer study of crystals by means of their x-ray diffraction patterns throws a flood of light on the process. In consequence, the x-ray tube is taking its place with the chemical balance, the microscope and the pyrometer as one of the essential tools of the metallurgist. There are others. Many metals are greatly influenced by the presence of very minute quantities of impurities, sometimes so small that chemical detection is difficult or impossible. Here the quartz spectrograph, capable of following the spark or arc spectrum into the ultra-violet, renders great service, and is rapidly making its way into manufacturing plants as well as into research laboratories as a standard means of control. Magnetic measurements afford another means of studying the composition and internal condition of metals, so that we find, in some large steel plants, the estimation of the quantity of carbon dissolved in the bath of a large open-hearth furnace carried out by casting a small specimen and determining its magnetic properties, the method being accurate and at the same time simpler than a chemical analysis. In another class of manufacturing operations, magnetic measurements are used as a means of deciding whether steel objects, made in large quantities, have received the proper heat treatment, where formerly a number of objects from each batch had to be tested mechanically to destruction in order to obtain the information now gained at a fraction of the original cost. All these methods of testing have been adopted from the laboratories of pure science and have been turned to new uses. It is thus one of the services of pure science that it furnishes applied science with new tools of research and means of measurement. On the other hand, the increasing demand on the part of the workers in applied science for such tools acts as a continual stimulus to investigations in physics.

Some metals, notably tungsten, have in our own time passed from the state of chemical curiosities to that of important technical products, by methods which are essentially those of the physical research laboratory. No one can visit one of the great lamp or radio-tube works without feeling that the manufacturing department is essentially an enlarged laboratory, employing methods which only a few years ago were confined to the research worker. We have the paradoxical result that the physical constants of tungsten are known with much greater accuracy than those of the more common metals, whilst of the metal, iron, manufactured by hundreds of millions of tons, the data as to its properties in a pure condition are singularly imperfect.

An example of the changing character of applied science may be seen in the study of corrosion. The most important of our useful metals, iron, steel, copper, brass, aluminum and so on, are all liable to undergo corrosion, to an extent which involves colossal annual losses. Protective methods have been devised empirically, but of late years much has been done to develop the use of metals which are in a sense self-protecting, in that they quickly form a layer, probably only a few atoms thick, which resists chemical attack. The "stainless" steels belong to this category. Looked at theoretically, this form of protection may be traced back to the work of Faraday and Schoenbein on the passivity of iron, although the connection was not at first recognized. It is important for the manufacturer and the user to have some means of determining in advance how a given metal will behave under given conditions of exposure to corroding agents. With this object, many hundreds of thousands of tests have been carried out in scores of laboratories, every effort being made to obtain a standard test, but the results have been singularly disappointing. There is no form of rapid test which will indicate with certainty how a metal will behave when it is exposed for periods of years. Such empirical and *ad hoc* methods are now supplemented by studies of the fundamental nature of corrosion. The methods of the physical chemist have been adopted, and laboratories devoted to work on corrosion now combine measurements of the absorption of oxygen with those of electrolytic potential and of the microscopical examination of the formation and rupture of surface films. In this way an intimate knowledge of the process of corrosion is being gained, by the help of which the choice of resistant materials may be guided in the future with greater certainty.

In its turn, applied science reacts on pure science. The problems raised by the working of metals, for instance, have given a great stimulus to the study of the deformation of crystals, with a corresponding effect on molecular theory. Moreover, the needs of the technical laboratory and works lead to the construction of instruments of measurement which are continually improved for practical use, and are in turn adopted by the research workers in physics and chemistry. Such mutual influence counts for much in the advance of science. To turn now to another aspect of the subject.

That we can not fully appreciate a scientific principle or discovery without some study of its history is a truth more and more vividly realized by those whose business it is to teach science to students. A knowledge of the steps by which a scientific doctrine has been built up or an invention brought to perfection is necessary if we are to estimate aright its value and importance. As we must not undervalue the services of genius, so we must not, on the other hand, isolate a few famous discoverers and neglect their predecessors and contemporaries. The study of the history of a science is now widely recognized as an integral part of a training in that science. It would be well if the same view were taken in the teaching of applied science and technology, and in this field it is not difficult to enlist the interest of students. Here is also one means of bridging the gulf, so deplorably wide in the highly specialized education of the present day, between scientific and humanistic studies. The history of an applied science or of an industry depending on it may be brought very simply into relation with the state of society at successive epochs. May I again illustrate this point by a few references to the study of metals? A short account of the history of the first use of metals by man may well open a course of lectures on general metallurgy. The first metal known was gold, since it is found in the beds of rivers in the uncombined state, resists tarnishing and by its gay color and luster appeals to the decorative instincts of Stone Age man. It is too soft to be used for any purpose but that of ornament. Copper follows, at first used as the native metal, but later obtained—no doubt in consequence of the accidental fusion of the conspicuous green surface ores in domestic fires—by smelting. These masses of copper, which can be cast in an open mould and can be so hardened by hammering as to take and keep a cutting edge, inaugurate the first Metal Age. The next step, the production of the much harder alloy, bronze, which may be cast in closed moulds, is an immense advance, and its origin is one of the unsolved mysteries of metallurgical history. Iron, sporadically used from quite early times in the form of objects forged from meteorites, is only smelted at a later period, but the steady supersession of bronze by iron is important and may be sketched. A simple account of these archeological facts, showing how the objects characteristic of each stage bear, in the earliest forms, clear traces of their origin in the copying of older objects in a new material, encourages an interest in the history of the older civilizations. The part played in the movements of races and in the history of nations by the search for metals is an important one, and recurs again and again, as in the events which followed the discovery of gold and silver in Central and South America by the Spaniards, and in the Californian and Australian gold rushes of the last century. Or, turning to iron and steel, it may be shown how the introduction of the steam engine, which brought about the industrial revolution by substituting machinery for hand labor, was itself made possible by metallurgical improvements, notably by the substitution of coke for charcoal in the blast furnace and by the invention of puddling. In the second half of the last century, the Bessemer process began that enormous increase in the rate of growth of the heavy industries which has been one of the chief features of the economic history of the world in our own time. When the university, as at Sheffield, is situated in a town having a metallurgical history possessing special features and extending over several centuries, local history may be linked up with the technical teaching.

These illustrations are introduced not for their practical importance, but because they widen the interest of the student, and encourage him to include in his private reading some study of the history of industrial communities. Such a study, if well pursued, may prove in the end to have practical value also in enabling those on whom the responsibility of directing and controlling industry may fall to understand better the social and economic conditions in which they have to work. Where a Social Survey is in progress, students of science and technology having some background of historical knowledge can be among the most useful voluntary workers.

In the teaching of the history of a pure science, stress is naturally laid on its value for the understanding of that science in itself, but in a balanced education it would seem that it should have a further value. The development of scientific thought is such an essential part of the history of civilization that it should be prominent in the teaching of general history, but this view only makes its way slowly.

There is another aspect of the relation of science to the community. The public conception of science is commonly limited to the mathematical, physical and chemical sciences, with the many departments of biology and their applications and in recent years, psychology. The great field of social studies is usually, at least in Europe, regarded as outside the field of science, with the single exception of economics. However, if prediction be the test of science, economics has not been, in the last few years, conspicuously successful.

It has been the aim of many thinkers to build up a science of human society, to embrace not only economics but all the activities of man. Sociology, to use the name coined originally by Comte, is the most difficult of the sciences, because it deals with phenomena of far greater complexity than any of the physical or biological sciences. Few of its principles have yet been established, and it must still be regarded as a science in the making, but its importance is such as to deserve the attention of all students, in spite of the urgent claims made on their time by their chosen specialism. I believe that this fact is more generally recognized in America than in Europe, but nowhere is the treatment of social problems, such as those of politics and finance, scientific to the extent that would be desired by the sociologist, and it would seem that those who already employ scientific methods of reasoning with success in one field could render service in bringing about their extension to others.

Science, in its applications to technology, has made available to mankind forces incomparably more powerful than those of a few generations ago. The command over natural forces has so increased the scale of production that we appear to suffer from an excess rather than from a deficiency of products, agricultural as well as industrial. Yet, although the standard of life has risen, the community to-day is faced by problems as difficult and dangerous as at any time in the world's history, and the growth of industry has as yet by no means brought all the happiness that was once expected of it.

Moreover, the application of science to warfare has greatly increased its horror, and it is certain that in another war, if such should occur, all the resources of science would be pressed into service to increase that horror still further. The means furnished by science may be used for the great benefit of mankind or misused in such a way as to cause misery. Is it not, then, desirable that all who are concerned with the advance of science by research or with its application to practical uses should interest themselves in the difficult problem of its use for the benefit of mankind? In other words, must not the chemist or biologist seek to become, in however modest a way, a sociologist, seeing that he can not divest himself of responsibility for the uses to which science is put?

Here, again, applied science serves as a link. The progress of pure science occurs within a limited circle of specialists, and contact with the general public only becomes marked when some question having a popular appeal emerges, as in the present-day interest in astronomical speculations as to the structure and fate of the universe. On the other hand, the contacts between applied science and the community are perpetual, and every worker in such a field must have some consciousness of its social significance.

The fact that in science international barriers have disappeared, or are reduced now to the minor obstacles due to differences of language, makes it easier for the scientifically trained man than for another to appreciate what international conditions mean in the modern world. It is science that has speeded up communications by land, water and air, that has brought most countries within speaking distance of one another, and that has largely destroyed the strategic value of natural frontiers. In doing so it has solved some problems and created others. It has become clear that the natural resources of the world are not inexhaustible, and that unless steps be taken to conserve them by using them as efficiently as possible, our descendants will find them dangerously depleted within an easily calculable time. Those resources are of the nature of capital, and once consumed can not be renewed. It is far otherwise with the power derived from water or, as may be practicable in the near future, from the direct heat of the sun; with the annually renewable products of agriculture, or the analogous products, harvested at longer intervals, of forestry. A scientific view of the matter would stress the importance of making greater use of the second source of wealth, which has been, in most countries, so much subordinated to the former. I do not know how it may be in America, but in Europe our political leaders and our economic authorities are, in an overwhelming proportion, urban in outlook.

A great Scottish scientific teacher, Professor Patrick Geddes, has pointed out that there is not one Industrial Age, characteristic of the modern world, but that two may be distinguished. These he has called, borrowing an analogy from the archeology of the Stone Age, the Paleotechnic and the Neotechnic. In the first, of which the most conspicuous illustration is the condition of England in the generations following the invention of the steam engine, the discovery of means of accumulating riches faster than had been dreamed of before led to an enormous extension of industry, unplanned and without safeguards against its abuse. This meant the reckless exhaustion of coal and minerals, and in the earlier decades a callous disregard on the part of many industrialists of human health, comfort and safety. Evils grew up in the industrial regions which had to be fought by philanthropic effort and by legislation. Other nations followed suit at such a short interval that whilst some of the evils were avoided, yet on the whole an absence of planning for social benefit was as conspicuous as ever. Gradually, signs of a passage to the Neotechnic Age are becoming apparent. The more scientific use of fuel and the increasing replacement of the smoke and dirt of coal-fired furnaces by the bright cleanliness of electric heating marks the transition. A modern power station using water power may stand as a symbol of this age. The health and welfare of the workers become a first consideration. The conservation of natural resources, in minerals, forests and water is regarded as a national and an international duty. Intelligent planning takes the place of haphazard development for merely private advantage. Whatever may be the economic system of the future, it must surely involve such planning, with a recognition of duties that leaders of industry, whether private or public, owe to the community. Of the moral aspects of the transition, all-important as they are, this is not the occasion to speak.

It is naturally more difficult to maintain a strictly scientific attitude on questions of politics, social organization and finance than on those of atomic physics, since our personal interests are involved, but that the attempt should be made is a conclusion which forces itself on a student of science who lives and works in an industrial community. Most of all, at such a time of crisis as this, does the need of scientific thought impress itself on us. By widening the conception of science to include sociology, whatever form that incipient science may take, it should be possible to increase very greatly the influence of systematic observation and reasoning, which is what we mean by science, on human life.

From the point of view of the general influence of science the recent tendency to lay emphasis on the uncertainty of scientific prediction in atomic physics is unfortunate. The "principle of uncertainty" is really a confession of ignorance, and it is to be expected that as the theoretical treatment of problems in the structure of matter advances, means will be found of reconciling the difficulties now experienced. It would be unfortunate if an impression were to gain ground among the public that science has abandoned its claim to accurate prediction. The cases in which prediction fails, according to the principle just mentioned, are confined to a difficult section of physical science which has only recently come under discussion. It would be entirely premature, on the strength of such new conclusions, to abandon the principle of determinism which has hitherto served its purpose so well in the sciences.

The inspiration of modern science must come from the original investigators, seeking for nothing but a more profound understanding of the workings of nature, and provided with the facilities for observation and experiment. Linked with them in the most intimate contact that the organization of university and industrial laboratories can make possible, come the workers in applied science, connected closely on the other hand with the technologists, charged with carrying into practice the results of scientific research. It is neither necessary nor possible to draw sharp dividing lines between those classes, but they may be broadly distinguished. All may unite in doing honor to great discoverers, such as Faraday, for all alike may trace their activities back to the products of their genius.

SCHAUDINN

A BIOGRAPHICAL APPRECIATION[1]

By Professor JOHN H. STOKES, M.D.

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WE are assembled to-night to memorialize a man, and an occasion. Let us begin with the man.

Fritz Schaudinn was born at Roeseningken, a village in East Prussia, on September 19, 1871. Thirty-five years later, on June 22, 1906, he died of septicemia and collapse at Hamburg. Into this short life-span he compressed activity and achievement that placed him in the ranks of genius.

Of his family and antecedents practically nothing appears in the accessible published sketches and eulogies. His gymnasium education was carried through at Insterburg and Gumbinnen. In 1890 he began his preparation for a career in philology, but by the fifth semester at the University of Berlin was definitely embarked on his life-work as a zoologist, and by his thesis for the doctorate in 1894 committed himself to parasitology, then the infant of the zoo-medical sciences. In July, 1894, from Bergen, Norway, and again in a trip to the Arctic in 1898, he gathered material, published subsequently with Roemer as junior, for a massive communication on the fauna of the region. In October, 1894, he had been appointed assistant in the Zoological Institute in Berlin, and in 1898 achieved his docentship. During this period appeared a number of papers on the reproductive processes in Protozoa, which broke new ground repeatedly and foreshadowed distinctive investigative powers. His contributions with Siedlecki on the Coccidia were especially valuable, and Schultz has rated the account of the complete life cycle of *Eumeria Schubergi,* which appeared in 1900, as an example of the ideal in research, in that it has been impossible since to add one single fact to the material discussed by Schaudinn. In 1899 his contacts with medical protozoology began, in the confirmation and amplification of Ross's observations on the malarial parasite. A mission for the German government, which kept him at Rovigno from 1901 to 1904 to study the pathogenic protozoa, led to his appointment as director of the new division of protozoology in the Imperial Public Health Service. At this time the insistent publicity given by Schulze to Siegel's supposed protozoal cause of syphilis, the *Cytorrhyctes luis,* led to a request made by Köhler, president of the Gesundheitsamt, that Lesser, the head of the Clinic of Dermatology and Syphilis at Berlin, cooperate in a joint clinical and parasitologic study of the prob-

[1] Read before the Section on Medical History of the College of Physicians of Philadelphia at a meeting to commemorate the discovery of the cause of syphilis, November 9, 1931.