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THE ROLE OF SCIENCE INSTITUTIONS IN OUR CIVILIZATION[1]

By Dr. WILLIAM D. COOLIDGE

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Mr. President, Members of the Board of Directors of Ursinus College, Members of the Faculty, Members of the Student Body, Dr. Pfahler, Ladies and Gentlemen:

WE are met here to-day to dedicate this new temple of science—to dedicate it to the service of mankind and to give it a name—a name worthy of the inspiring tradition which shall with the years grow up around it.

In our evaluation of the importance of this event we are more in danger of under- than over-estimation. We can, of course, judge the future only by the past. So let us think of the consequences of similar occasions which have already taken place. To mention only a few examples drawn from the field of physical and chemical science:

Once upon a time there was doubtless a dedication ceremony for the physics institute of the University of Wurzburg, and it was in that laboratory that Roentgen later discovered the x-rays and published his results in a series of papers which have had so profound an influence on science and on our civilization. It is of course the man rather than the institution to whom we give most of the credit. The fact remains, however, that the institution attracted him and he was, perhaps unconsciously, inspired by its traditions.

In the same way consider the importance of the founding of the Royal Institution, where Faraday did

[1] Founders' Day address at the dedication of the Pfahler Hall of Science, Ursinus College, October 13.

his work on electromagnetic induction; and of the Albany Academy, where Joseph Henry made his great contributions in this same field. Our whole electrical industry is based on the work of these two men. Here again, although we give most of the credit to the men, as before, we can well question whether they would have had this same tremendous influence in our civilization had not others before them created and dedicated to science the laboratories in which their work was done.

Sometimes, as in the case of Madame Curie and her discovery and isolation of radium, we see the work done under such miserable physical conditions that we may well feel that it could have been done much easier somewhere else. The fact still remains, however, that the creation and the dedication of the institution in question were links in a chain without which the work would probably not have been done by the person and at the time period in question.

Countless other similar instances could be cited in which the dedication to the cause of science of a new laboratory or the creation of a new scientific society has constituted the beginning of a great tradition.

Over forty years ago, in the General Electric Company, a group of four men consisting of Elihu Thomson, E. W. Rice, C. P. Steinmetz and A. G. Davis, were so impressed by the consequences of the fundamental scientific work carried on in college laboratories that they started what was one of the first *industrial* research laboratories in this country—a step which has since been followed by some two thousand other manufacturing organizations.

I have been in close touch with the General Electric Research Laboratory from the beginning, and, since taking over its direction, I have been greatly impressed by the strength of the tradition which has grown up around it—a tradition derived from the great men who had the vision to start it and to sponsor it through its early years, and from Dr. Willis R. Whitney, who directed it throughout the formative period of its existence, who saw the value of cooperation and secured it, who saw to it that recognition was always given to the individual and not merely to the institution, who insisted that all worth-while results should be published promptly, instead of being kept secret in what had been the time-honored way. During my incumbency in this office I have been constantly aware of the force of that tradition—a force like that inherent in the momentum of a heavy and rapidly moving body. Had I been so disposed at any time, I would have found it very difficult to do anything which would have tended to weaken that virile and inspiring tradition.

Just as the tradition of our laboratory started with the characters and achievements of the men whose names were first associated with it, so the tradition of this laboratory starts with the characters and achievements of the men responsible for its existence and takes on to-day an intimate association with the life of the man whose name you have given it.

I feel competent to speak to you on the value of that name to the tradition of this laboratory.

It is the name of a great pioneer in the application of physical science to the diagnosis and treatment of human disease. It is the name of a man to whom countless sufferers from human ills owe their lives, their health and their happiness. It is the name of a man who has not only practiced and advanced an art, but who has greatly enriched the science underlying that art. It is the name of a man who has contributed not only to the practice but also to the teaching of that science and that art. It is the name of a man who has lived richly, enjoying not only his work but also his environment, traveling not only for his own pleasure at the time, but also that he might, through the photographic art and his patience and skill in the hand-coloring of his slides and movie films, share these artistic delights with his friends. From the personal standpoint let me add that he has for many years been to me an honored and respected friend and an inspiration. I have always felt grateful for the fortunate turn of events which resulted in my acquaintance with some of the great men in the medical profession, and high in my list of these stands the name of Dr. George E. Pfahler.

The science laboratory of to-day is the temple in which we come directly in contact with nature herself. Here to the patient, honest, reverent and open mind, she reveals herself, at least to the extent that the seeker after truth is capable of understanding her.

I think that the complex equipment which we are often forced to use in the laboratory, like the priest in the Ancient Oracle, stands somewhat between us and nature and diminishes the reverence which we would otherwise feel. After all the intervening years, fifty to be specific, one regular physics laboratory experiment at Massachusetts Institute of Technology stands out clearly in my memory because of the closeness of contact with nature which it seemed to give me. It was the experiment of the simple pendulum, in which the student takes a brass ball and measures its diameter and then attaches to it a string, of which he measures the length. Next he attaches the free end of the string to a rigid support and then with a watch determines the time of oscillation of this device as a pendulum. Simple calculation of the data gives the acceleration due to gravity, and from this and the gravitational constant, a quantity likewise obtainable in the laboratory, one may readily calculate the mass of the earth. The only equipment which I used was the brass ball, some calipers, the string, the measuring stick and the watch; and still, with the gravitational constant known, it enabled me to weigh the earth.

You are to-day dedicating this laboratory to the cause of science, that is, the acquisition and teaching of knowledge relating to the physical world in which we find ourselves. Such knowledge contributes in so many ways to our happiness and our comfort.

The search for it would be worth while even if it did nothing more than satisfy the yearning of the human mind for knowledge of our environment.

We long to know the extent of the physical universe, how it came into being, the gross changes which it is undergoing and whither it is tending.

We have wondered how the stars, including our own sun, can be continually radiating such vast amounts of energy and still maintaining through the centuries such enormously high temperatures. Our own sun, for example, delivers energy to the earth at the rate of 2.5×10^{18} calories per minute. Now the world production of oil for 1939 was 2,100,000,000 barrels and the heating value of this is about 2.5×10^{17} calories. The energy which the earth receives from the sun in one minute is then ten times the heat of combustion of the entire 1939 world production of petroleum. And we are receiving but a tiny fraction, only about one two-billionth, of the total energy radiated from the sun. It is only within the last few years and through modern research on atomic structure, that we have been able to give even a plausible explanation of how this can continue.

We have wondered about our own earth, where it came from and how old it is. Spectroscopic observations made in the physics laboratory, coupled with similar observations made in the astronomical observatory, tell us that our earth is composed of the same chemical elements as those found in the sun. This and other evidence tells us that the earth was originally a part of the sun. The answer as to the age of the earth has also come from the science laboratory. The best of the various methods used is that based upon the radioactivity of uranium, an element which breaks down spontaneously into radium and this in turn into lead. (One hundred uranium atoms thus yield one lead atom in 66,000,000 years.) If then we determine the ratio of lead to uranium in uranium-bearing rocks, we have a simple measure of their age. In this way we arrive at an age for the earth of about two thousand million years.

We marvel at the myriad forms of animal and vegetable life and, still more, we marvel at the mystery of life itself. The science of biology by correlating the chromosomes and the genes and the mechanism of the reproductive processes goes far in explaining the variety of forms, but as yet has no explanation to offer concerning the life principle itself.

In my college days we talked of the atomic and molecular hypotheses. Since then, physical science has advanced so far that we are now able to count and weigh individual atoms and molecules. Not only this, but we are now able to break atoms up into still smaller particles—electrons, protons and neutrons.

These particles come from the nucleus, which has a diameter a hundred thousand times less than that of the atom itself. We ask ourselves how it is possible for the positive and negative charges of these protons and electrons to exist in such infinitesimally close proximity without mutual annihilation of charge. We ask ourselves, "What is the nature of the forces which bind these particles?" and the answer to this fundamental question may well have far-reaching consequences.

We wonder how the so-called virus diseases are propagated and what is a virus. Recent medical research, aided by such modern scientific tools as the ultra-centrifuge and the electron microscope, is now making real headway with this problem.

Prior to the time of Aristotle, such questions might all have been referred to the Delphic Oracle, but in the science laboratories we refer them to nature herself, changing experimental conditions until, without breaking her laws, she can give the answer.

Interest in our environment is all-embracing, including everything from the astronomical in size down to the smallest constituent of matter.

Many of our questions may never be answered, and it is probably well for our happiness that nature guards her secrets as closely as she does, since so much of our pleasure comes from our efforts to become better acquainted with her. To the superficial mind it may appear that we already know many of her secrets, but he who looks deeper sees that in many cases we have hardly done more than to give names to her manifestations.

It is as though each of nature's secrets were guarded by a combination lock which can be opened only after each of its many components has been put in its proper place. Consider, for example, the relation between the various chemical elements. It was found many years ago that they could be so arranged in groups in a table as to bring out a periodic recurrence of physical and chemical properties and that these were, with few exceptions, simply related to their atomic weights. The latter were in turn very nearly, but not quite, whole multiples of that of the lightest of the elements. The studies of J. J. Thomson and Aston with the mass spectrograph showed that each element was in general present in several isotopic forms differing slightly from one another in atomic weight. This brought us somewhat closer to an understanding of the relation between the elements, but the real answer came only through the chain of events consisting of the discovery of the nature of the x-rays by Laue, the development of the x-ray spectrometer by the Braggs, and the measurement by Moseley, with the help of the spectrometer, of the wave-lengths of the characteristic x-radiations emitted by the various elements. With the help of this last information we were able to see that the various chemical elements were all made from the same building blocks and differed only in the number and arrangement of these blocks. The picking of this particular lock occupied a time period of many years, beginning with the work of Mendelejeff and ending with the work of Moseley and involving the efforts of many others. In this, as in perhaps every other case where an important physical principle has been discovered, success was due to the painstaking efforts of many men, each of whom built on the work of his predecessors.

Herein lies the importance of faithfully recording all scientific progress and making it readily available to those who may later build upon it. This has been conscientiously done for many years by many different peoples. Even as far back as perhaps 2000 B.C. the Cretans probably made an effort to do it. They wrote on clay tablets, which are still intact, but which we unfortunately are unable to read. They knew some astronomy, for they are famed as navigators, and tradition credits them with the ancient Minoan calendar. The Egyptians acknowledge their indebtedness to them for certain medical prescriptions, and the Greeks borrowed aromatic and medicinal herbs from them.

The present rapid progress in science is due in no small part to laboratories like this one, consecrated not only to the task of seeking new knowledge, but also to the handing on to successive generations of the knowledge of the past, not as a matter of dead history but as a springboard for further advances.

In this last connection we see marked differences in the quality and effect of science instruction, involving the attitude of both teacher and pupil. The teacher may present the subject either as a completed book or as a preface, and the student may either receive it as a finished work or question it even as a preface.

As a student in a German university many years ago, I saw the professor on a very high pedestal above the student. He came in, gave his lecture and went out, with no chance to question him at the time. In a Russian university more recently I saw something quite different—the professor clearly not on a pedestal but rather on the same level with the student, a condition much more conducive to a questioning attitude, without too much respect for authority, on the part of the student. Too much respect for authority is bad, as it can easily lead to the impression that the tree of science is full-grown—has reached its maturity—when as a matter of fact it's not only growing faster than ever but at an accelerating rate, for every new branch added to it gives rise to other branches and each of these in turn to more.

Authority derives from a generalization based on known facts, and the respect which it merits is then related to the number and significance of the supporting facts. It must not be forgotten, however, that it may always be upset by a single new fact. There was, for example, seemingly excellent authority for our earlier ideas on the conservation of mass and on the conservation of energy. This has been recently upset, however, by the discovery that mass and energy are mutually interchangeable.

To mention a much more common type of example from the field of magnetism: It seemed possible that an improved permanent magnet might result from cooling the constituent material through an elevated temperature range in a steady magnetic field. Such experiments made with various alloys showed no appreciable gain, however, indicating seemingly that magnetic domains in this type of material could not be usefully oriented in this manner. Too much respect for the authority built up on these experiments would have barred the progress which took place recently when further experimentation showed that a certain alloy differing but little in composition from those which had previously been submitted to the treatment in question was greatly improved by it, yielding a permanent magnet in most respects two to three times as good as the best of its predecessors.

The big steps in science have for the most part come from the work of fresh inquiring young minds—minds not overawed by the authority of their teachers—minds so young that experience hasn't yet taught them that new things can't be done.

I am glad to see that various sciences are to be housed together in this building instead of being widely segregated, for they are all parts of one whole, and the knowledge and the methods and the tools of each can be helpful to the others.

And these tools of which I speak play a tremendous role. To take for example a recent one, the cyclotron. Before its advent we had only a couple of radioactive materials—only those occurring in nature. To-day, thanks to the cyclotron, we have over three hundred artificially made radioactive elements. This has not only greatly increased our fundamental knowledge of matter, but has produced a battery of new tools in these various radioactive products themselves which can be used either as therapeutic agents or as tracers for the study of physiological processes, diffusion rates, chemical equilibria, and other purposes.

In the electrical field we have, among other modern tools, the vacuum tube amplifier which not only plays so important a role in radio and in the electrical art generally, but in the medical field makes possible the portable electro-cardiograph and facilitates the demonstration and recording of electric currents generated in the human brain.

Another tool taken from the physics laboratory which has made valuable contributions in many ways is the ionization chamber. In the field to which Dr. Pfahler has devoted himself, it is now universally used to measure x-ray and gamma ray dosage. This has increased the effectiveness of radiation therapy and enabled specialists throughout the world to compare their results intelligently and to talk a common language in the field where previously confusion reigned.

Many other tools could, of course, be mentioned, each of which has contributed greatly to several different branches of science.

The tools of science serve to increase the range and scope of our senses, increasing our power of perception and making it possible for us not only to observe but also to record and measure physical phenomena.

The great Danish physicist, Niels Bohr, calls attention to the fact that each of our various senses has been developed to such a degree that further increase in sensitivity would be useless to us. Our scientific tools help our senses not so much by being more sensitive in the best working range of the latter but mainly by extending the range.

Consider, for example, the entire field of radiant energy extending from the long wave-length radiowaves down through heat and light to the shortest wave-length x-rays—a range of 60 octaves. Of this only one octave is perceivable by our unaided eyes. For our knowledge of the other 59 octaves we are dependent on such tools as the fluoroscope, the photographic film, the bolometer and the radio-receiving set. The eyes give us no direct information outside of a narrow band of wave-lengths, nor do they tell us anything concerning the distribution of energy in the spectral region with which they deal. For this information we are dependent upon the spectroscope and the thermopile or bolometer.

The light-gathering power of the lens of the eye is limited by its diameter. The 100-inch telescope gathers so much more light that it reveals to us nebulae two million times fainter than the faintest star just visible to our unaided eyes.

Through the optical microscope we have entered a whole new world of living and inanimate objects, and now the electron microscope gives us a further fifty-fold useful magnification. This last device is of too recent a vintage for us fully to appreciate its potentialities. But it is already opening our eyes to things which had never before been seen, as for example, the bacteriophages, those viruses which prey upon the various bacteria.

Our ears respond to sound vibrations through a range of about ten octaves. Our knowledge of sound vibrations outside this range has been greatly extended by the microphone and oscillograph and by the use of the local oscillator and the heterodyne principle. Such devices have also given us the quantitative information which our ears fail to supply. Our knowledge of mechanical vibrations taking place at remote points has also been greatly extended through the use of the microphone and the telephone receiver. This combination permits us to hear a fly walk on a distant object about as well as though he were walking on one of our eardrums, and likewise brings to us through a wire the conversation of a person who may be thousands of miles distant. In similar ways the other senses have been extended by the tools of science.

We are, of course, interested in science not only for the intellectual pleasure connected with its development and for its aid in amplifying and extending our senses and thus broadening our horizons, but also for the useful everyday applications which can be made of it. These last relieve us of drudgery, increase our bodily comfort and lengthen our span of life. While enjoying them we may occasionally sigh for "the good old days," but few of us ever voluntarily relinquish the comforts and conveniences of modern life. Government rationing is required to enable us to enjoy again the blessings of those "good old days." The product of the science laboratory has in many cases had a tremendous impact on our civilization.

It is not so long ago that about 1,800 pounds of living animal tissue was required to produce a horsepower. Now, through the work of science and engineering laboratories, we are able to produce an explosion-type engine weighing less than one pound per horsepower. The 1,800-pound source of a horsepower was of necessity a patient plodder on the face of the earth. The airplane engine takes us up into the air and makes possible the crossing of the Atlantic, even between daylight and dark.

The radio makes possible the sending of intelligence to the far corners of the earth in a small fraction of a second.

In these and other ways science has made the earth in effect so small that isolation is no longer possible, and the process has taken place so rapidly that we have as yet failed to make the necessary readjustment.

Science has been blamed by some for the misuse of its product, and you will remember that in England Dean Inge even proposed a moratorium on science. The present emergency will serve to show the danger of such procedure to any nation subscribing to it without definite and effective guarantees that all other nations would do likewise.

Furthermore, there has never been a danger to an individual or a nation in knowing too much—the danger always comes from knowing too little.

The development of science is now proceeding rapidly, both in educational institutions and in the industrial research laboratories of the country. It is, in the past, mainly to the college laboratory that we have looked for the development of new scientific facts and principles, leaving to the industrial laboratory the practical applications of such new knowledge. More recently there has been a marked tendency for the college to become both application and patent minded, this with the entirely praiseworthy purpose of earning money to finance its research. This has seemed to me a regrettable tendency, for the reason that it unavoidably brings the element of secrecy into this portion of the work of the university and so builds up a certain barrier, partly real and partly psychological, between it and industry. To a certain extent it puts the two institutions on a competitive, rather than on a mutually complementary, basis. It is to the university that industry should look to train men for its laboratories in the fundamentals of science, and if this work is to be well done, fundamental research must be carried on by members of the teaching staff of the university, for without this the teaching will lack freshness and vigor and inspirational quality. Financial support must, of course, be provided, and should come from the public either in the form of a government subsidy or as a contribution from industry to be in turn liquidated by the public.

The fundamental experiments underlying a great industry, and often greatly affecting the daily life of a people, are always so simple in character that they, and their place of origin in the science laboratory, are soon almost forgotten.

For example, the radio in all its varied forms is based upon the theoretical work of Maxwell and the simple confirmatory laboratory experiments of Heinrich Hertz—simple experiments involving the discharge of an electric spark between two brass rods with the consequent production of a microscopic spark between the closely spaced ends of a circular metal hoop placed at a distance. These experiments showed that electrical energy could be transmitted and received across empty space. It was, of course, a far cry from these experiments, bridging a gap of only a few feet, to present-day radio. But all our multitudinous peace- and war-time applications of radio started from those simple beginnings.

In the same way consider the dependence of the automotive industry upon some substance having the properties of vulcanized rubber. The primitive wooden wheel is still used for the oxcart, and the metal-tired wooden wheel for the horse-drawn vehicle, but for present-day speeds we must have vulcanized rubber or its equivalent. This takes us back to the simple experiment of Goodyear, who completely changed the physical properties of natural rubber by adding to it a little sulfur and a little heat, thus imparting to it the wonderful mechanical properties without which so much of present-day mechanization would be impossible.

To-day we see the majority of the scientists of the world, both university and industrial alike, recruited for use in offensive and defensive warfare, and we see science playing so vital a role that it may win or lose the struggle. All the sciences are involved. Some of this work is being done in groups which were already in existence in university, industrial, commercial, government and other laboratories; while another part is being done in new groups recruited for the purpose, mainly from the staffs of our colleges.

A tremendous contribution to the war effort is being made by our colleges not only through the activity of their scientific staffs in developing important new materials and new devices but also through the use of their teaching facilities. The importance of this last can hardly be overestimated, for we must not only have the necessary new mechanisms of warfare but we must also have an adequate number of people conversant with their use and their maintenance; and the essential basic training of these people is best given in the colleges.

While the necessity for the scientific effort involved represents in magnitude the greatest tragedy which civilization has ever encountered, much of it will have lasting value, and in many important lines research is being prosecuted at a rate which would be quite out of the question in peacetime. This is especially true in the fields of physics and chemistry. Most of this work is of so confidential a nature that it can not be publicly discussed at this time.

In the x-ray field I can say that until within the last year and a half but few radiographs had ever been made using more than a couple of hundred thousand volts. As a result of the war, industry is now employing many one-million volt radiographic outfits. These are portable and mechanically and electrically flexible and permit the ready examination of steel castings and welds up to a thickness of as much as eight inches.

Furthermore, we have recently built, with the help of Dr. Donald Kerst, of the University of Illinois, an induction electron accelerator for twenty million volts, and are now building a larger one designed to operate at voltages up to a hundred million. This last machine, used as a source of x-rays, should enable us to determine what radiographic and other useful results can be accomplished by such high-voltage radiation.

This same device should also render available for physical, chemical and medical experimentation cathode rays corresponding to these same enormous voltages. In the medical field these cathode rays may have a good deal of therapeutic interest in the treatment of deep-seated tumors, since they will have sufficient penetration and since, unlike x-rays and gamma rays, their effect will be a maximum near the end of their range—properties which should facilitate the destruction of a tumor without damage to the overlying tissues.

The fluoroscopic application of x-rays is also being developed rapidly for use in industry, where it makes possible the ready examination of small metal castings. Without this non-destructive method it has sometimes been necessary to expend much machine work on a casting before a fatal hidden defect was revealed. Such wastefulness of labor is now avoided by the fluoroscopic inspection.

In the medical field we have seen an x-ray development take place during this war which will have great permanent value. It consists in the photography with the camera of the fluorescent screen image and, in the case of chest examinations, it will reduce the cost of the photographic film required to about one tenth that of the usual direct method of radiography and with but little sacrifice, we are told, in diagnostic value. This will make economically possible the chest radiography of all army recruits and the frequent chest examinations which are so desirable in the case of our young people. Many other important examples will come to light after the emergency.

Science institutions bring their votaries together, and so facilitate cooperative effort. The science laboratory and the scientific society alike facilitate the helpful interchange of ideas, thus giving both pleasure and assistance. Some individuals are by preference lone workers, but fortunately for human progress the scientist is usually a gregarious animal, taking pleasure in being with his own kind, that is, with those who can understand and appreciate his work. And by such contact he gives and receives help.

The question is sometimes raised as to whether the day of the lone scientific worker is past. While the answer is *no*, it is certain that with the great increase which has taken place in recent years in the number of science laboratories and in the number of people working in them, the percentage of our scientific progress due to the lone worker has undergone a corresponding decrease.

The science institution also helps by lending dignity to the profession of the scientist, thus playing no small role in scientific progress. The degree conferred by the institution is a badge of distinction which serves as a spur both to the acquisition of the knowledge of the past and to subsequent achievement.

In closing may I express the hope that the tradition of this laboratory, so auspiciously begun, may grow in stature and in luster with the years, and that it may be a credit to the founders of this institution and to the distinguished name this institution now bears.

Sir William Osler, lifelong advocate of medical research and himself one of its finest exemplars, in 1908, stirred by the shifting of the medical center of the world from Vienna to Berlin and by his longing to see it move again, this time across the Atlantic, wrote a letter in which he fancifully but eloquently quoted these words from "Minerva Medica":

> We Gods have but one motto—those that honor us—we honor. Give me the temples, give me the priests, give me the true worship—and I will come. . . . Where the worshippers are the most devoted, not, mark you, where they are the most numerous; where the clouds of incense rise highest, there must my chief temple be, and to it from all quarters will the faithful flock.

So now, as we dedicate this new altar to science, in the name of another great exponent of medical research, may we not feel that we are adding to the fulfilment of Osler's dream of a third of a century ago? Let us hope that here Minerva may find a new and welcome shrine, where the clouds of incense will rise ever higher, fed by an ever increasing and ever more devoted band of worshipers at the altar of truth.

SMITHSONIAN ENTERPRISES

By Dr. C. G. ABBOT

SECRETARY, SMITHSONIAN INSTITUTION

In the main hall of the old brown-stone Smithsonian building are found several of the reasons why the Institution is being frequently called upon to assist the armed services. In this hall was opened, in January, 1941, an exhibit which presented all branches of Smithsonian interests in a striking way. At either end of the hall is a world map. One map displays the world-wide distribution of Smithsonian publications. The other shows that none of the seven continents nor the seven seas has failed to be the scene of many expeditions, for collecting or for basic investigations, in which the Smithsonian has worked alone or has prominently participated.

This world-wide scope of Smithsonian interests and knowledge, associated with the intimate acquaintance with the ethnology, resources, language and climatic