SCIENCE

VOL. 91 — FRIDAY, APRIL 5, 1940 — No. 2362

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS
New York City: Grand Central Terminal
Lancaster, Pa. — Garrison, N. Y.

Annual Subscription, $6.00 — Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary in the Smithsonian Institution Building, Washington, D. C.

PRESENTATION OF THE NOBEL PRIZE TO PROFESSOR ERNEST O. LAWRENCE[1]

By Professor RAYMOND T. BIRGE
UNIVERSITY OF CALIFORNIA

Mr. President, Mr. Consul-General, Dr. Lawrence, Ladies and Gentlemen:

SOUTH DAKOTA was admitted to the Union in 1889. It is thus a very young state, and one need not be surprised that as yet relatively few of its native sons have achieved great distinction. One of these few is Ernest Orlando Lawrence, who was born in Canton, S. D., on August 8, 1901. Ernest's father, Carl G. Lawrence, is now president emeritus of Northern State Teachers College, Aberdeen, S. D., and is living in Berkeley with his wife. The father of Carl Lawrence was Ole Lawrence, another school teacher, who, as an immigrant from Norway, settled at Madison, Wis., in the year 1840. Ernest's maternal grandfather, Erik Jacobson, also an immigrant from Norway, was a South Dakota pioneer.

Ernest Lawrence is the first native of South Dakota to be elected to membership in the National Academy of Sciences, an honor that came to him in April, 1934, when he was only 32 years old. He is now the first native of South Dakota to become a Nobel Laureate. By an interesting coincidence, one of Dr. Lawrence's intimate boyhood friends, Dr. Merle A. Tuve, is at present in charge of nuclear physics research at the Carnegie Institution of Washington, where a huge 60-inch cyclotron, similar to the large Berkeley cyclotron, is now under construction.

Dr. Lawrence obtained his elementary education in the public schools of Canton and Pierre, S. D., and did his undergraduate college work first at St. Olaf Col-

[1] Address at the Nobel Prize presentation, February 29, 1940.

lege and then at the University of South Dakota, where he was inspired by Dean Lewis E. Akeley to enter the field of physics. He undertook graduate work at the University of Minnesota, the University of Chicago and finally at Yale University, where he obtained his Ph.D. degree in 1925. At Minnesota he came under the influence of Dr. W. F. G. Swann, now director of the Bartol Research Foundation, Swarthmore, Pa., and an authority in the field of cosmic rays. This influence, which was profound, explains the transfers of Dr. Lawrence from one university to another, for they coincided precisely with similar transfers on the part of Dr. Swann.

After receiving his doctor's degree Lawrence remained at Yale, first as a National Research Fellow and then as an assistant professor. When Swann left Yale to become director of the Bartol Foundation, the University of California seized the opportunity to secure the services of a man who already was recognized as one of the most brilliant young physicists in the country. The University of California, after 12 years, still retains his services, in spite of numerous enticing offers that he has received from elsewhere.

The first published scientific paper by Dr. Lawrence is dated May, 1924. In the succeeding 16 years his name has appeared on 56 papers, an average of just three and one-half papers a year. This in itself is a remarkable record, but what is more remarkable is the number of papers by his students and associates—papers that do not bear his name, but that carry only too plainly the impress of his guidance and inspiration. His first paper, entitled "The Charging Effect Produced by the Rotation of a Prolate Iron Spheroid in a Uniform Magnetic Field," contains no trace of his future interests. One of these interests, however, appears in his doctor's thesis, which lay in the field of photoelectricity. Further work in this field was carried out both at Yale and at California. In fact, Dr. Lawrence's first Ph.D. student, N. E. Edlefsen, did his thesis in this field. We shall hear of Dr. Edlefsen again.

From the start of his scientific career, Dr. Lawrence showed an exceptional breadth of interest. While a National Research Fellow at Yale he measured the ionization potential of the mercury atom. This was, at the time, the most precise determination of its nature that had ever been made. Its importance is due to the fact that the result enables one to calculate the value of the so-called Planck constant, h, one of the four most important universal constants of nature, and the fundamental constant of the quantum theory. There is, however, another point of interest in this research. The ionization potential of the mercury atom is merely the energy required to tear an electron loose from a neutral mercury atom. Now the word "atom," as all of you know, means something that can not be divided, although, as all of you also know, carving up atoms into little bits is at present the favorite pastime of physicists. Hence when Lawrence thus pried loose an electron from a mercury atom and measured precisely the energy required to do this, he in one sense disintegrated the atom. But it takes only a relatively trifling amount of energy—some ten volts in the case of mercury—to remove one of these so-called external electrons from an atom, and nowadays we reserve the name disintegration for a process by which the nucleus of the atom is in some way changed, the resulting atom having, in general, completely different chemical properties and being, in fact, a different element. Such a disintegration requires energy equal to millions, rather than tens of volts to bring about, and it is the discovery of a practical method for obtaining by artificial means such high energies that has brought Dr. Lawrence his present fame.

Before, however, Lawrence had settled down to atom smashing in a serious way, he did other interesting things. One of these was the development, in cooperation with Dr. J. W. Beams, of a successful method for obtaining time intervals as small as three billionths of a second. After he came to California, Lawrence and his students applied this method, which involves the use of a Kerr Cell, to a study of the phenomena occurring in the early stages of the discharge of an electric spark. Since a single spark lasts for only about one millionth of a second, it is obvious that an extremely short "exposure" must be used to photograph the details of its development.

Another of Dr. Lawrence's inventions—if you wish to apply that term—was a new and very precise method for measuring e/m, the ratio of the charge to the mass of an electron. This ratio is another of the fundamental constants of nature. The detailed development of the method was carried out by one of his students, Dr. F. G. Dunnington, whose final result is possibly our present most accurate value of this important constant. So much for the work of Dr. Lawrence outside the field of atomic disintegration. The picture has been sketchy; yet I hope it has indicated the versatility of his ideas.

Then one evening almost exactly ten years ago to-day, Dr. Lawrence happened to glance at an article which had just appeared, by a German physicist, R. Wideroe. He did not actually read the article, but his attention was drawn to a diagram of the apparatus. With this apparatus, Wideroe, by the use of a 25,000 volt potential drop, had succeeded in imparting to atoms of potassium energy equal to that resulting from a 50,000 volt drop. As a matter of fact the particular idea used by Wideroe was not new—it had been suggested ten years earlier—but Wideroe was the first one to apply it successfully. Now Lawrence had for some time realized the growing importance of the field of nuclear physics, and had been looking for ways and means of successful experimentation in the field. This paper by Wideroe immediately suggested to him the general idea of producing the very high energy particles required for atomic disintegration, by means of a succession of properly timed "pushes," each of which might be relatively small. Then and there he began sketching various ways of carrying out this idea. Wideroe had used two hollow cylinders, lined up on the same axis. Lawrence sketched a series of such cylinders, but in the case of atoms of small mass, which are most effective in nuclear disintegration, the necessary length of the apparatus would then be too great. He next thought of the possibility of using a curved path. Now an electrically charged particle, entering into a magnetic field directed at right angles to the motion of the particle, proceeds to move in a circle with constant speed. Moreover, the time to move through a half circle depends only on the charge and mass of the particle and on the strength of the magnetic field. It does not depend on the speed of the particle. The greater the speed, the greater the radius of the circle in which the particle moves. This important fact, which Dr. Lawrence immediately noted by writing down a very simple mathematical relation, gave him the idea of the present essential features of the cyclotron. All this happened within a few minutes of the time he had seen Wideroe's paper. The next morning Dr. Lawrence told his friends that he had found a method for obtaining particles of very high energy, without the use of any high voltage. The idea was surprisingly simple and in principle quite correct—every one admitted that. Yet every one said, in effect, "Don't forget that having an idea and making it work are two very different things."

It seems to me that, in this connection, I can quote with profit some remarks made by Dr. W. D. Coolidge, director of the Research Laboratory of the General Electric Company, when he presented to Dr. Lawrence, in 1937, the Comstock Prize of the National Academy of Sciences. This prize, awarded only once in five years, is considered the greatest honor at the bestowal of the Academy. Dr. Coolidge first sketched the classical experiment of Lord Rutherford, in 1919, when by using the alpha particles ejected by a radioactive substance, he succeeded in changing nitrogen into a form of oxygen. This was the first true disintegration of matter produced by man, and as such, an experiment of epoch-making importance. As Dr. Coolidge notes, Rutherford succeeded in thus breaking up nitrogen and other light atoms, but to disintegrate heavy atoms, particles of still greater energy appeared to be needed. Such high-energy particles, to use as bombarding projectiles, could obviously be produced artificially, by allowing charged particles to fall through sufficiently high voltages. There would be, however, great difficulties in developing tubes to withstand such voltages. Dr. Coolidge then goes on to say:

> Dr. Lawrence envisioned a radically different course—one which did not have those difficulties attendant upon the use of potential differences of millions of volts. At the start, however, it presented other difficulties and many uncertainties, and it is interesting to speculate on whether an older man, having had the same vision, would have ever attained its actual embodiment and successful conclusion. It called for boldness and faith and persistence to a degree rarely matched.

That is the end of the quotation. Those who have worked with Dr. Lawrence during these past ten eventful years can well testify that it did indeed call for "boldness and faith and persistence to a degree rarely matched." The story of the development of the cyclotron reads like a fairy tale. To be told properly, many hours would be required.

But we are living in a practical world, and it is the results actually achieved by the use of the cyclotron, rather than the details of its development, that have caught the attention of every one, scientists and nonscientists alike. This fact was recognized by the Nobel Committee, when it awarded the prize to Dr. Lawrence with the citation—"for the invention and development of the cyclotron and especially for the results attained by means of this device in the production of artificial radioactive elements."

It is important to note at this juncture that the cyclotron was not the only method devised by Professor Lawrence for the production of high energy particles without the use of high voltages. Another method, already mentioned, employs a series of cylinders set on a common axis. Such a devise, called by Lawrence a "linear resonance accelerator," was actually constructed and used by him and several of his students for accelerating *heavy* particles to high energies. I have already noted that an apparatus of this type is not suitable for light particles, because of the required size. Still a third piece of apparatus, the double linear accelerator—a modification of David Sloan's remarkable x-ray tube—was tested at considerable length. The cyclotron, however, finally proved superior to any other device, and it is only because of this fact that eventually these other methods were dropped, and all attention concentrated on the cyclotron. Even as late as 1934 Lawrence believed that the double linear accelerator would surpass the cyclotron in its yield of neutrons, but such proved not to be the case. The cyclotron is thus not a lucky accident, but a piece of apparatus that has, after detailed development, finally proved its superiority to several other methods of attack devised by Dr. Lawrence.

The first cyclotron, only four inches in diameter, was constructed of glass and red sealing wax, in January, 1930, by Lawrence and Edlefsen, who, as previously noted, was Lawrence's first Ph.D. student at California. Actual resonance effects were obtained, and the first public announcement of the new method was made by Lawrence and Edlefsen at the meeting of the National Academy of Sciences at Berkeley, in September, 1930. A metal cyclotron of the same size was then constructed by Lawrence and M. S. Livingston, who was prominently identified with the development of the cyclotron during the next few years. With this almost toy-like instrument, as viewed in retrospect, a beam of hydrogen molecular ions was generated, whose energy corresponded to that produced by 80,000 volts, although the highest potential difference in the instrument was only 2,000 volts.

Spurred by his success, Lawrence next built an eleven-inch cyclotron. This instrument cost $1,000, plus some borrowed equipment. With it one and one quarter million volt hydrogen ions were obtained, the most energetic beam of particles ever produced in the laboratory up to that time. This beam of ions was used, during the summer of 1932, to disintegrate lithium, the first artificial disintegration of matter to be carried out in the western hemisphere. That year, 1932, was by all odds the most exciting in the history of modern physics. During it heavy hydrogen was discovered by H. C. Urey at Columbia University, the neutron was discovered by James Chadwick at the Cavendish Laboratory in England, and the positive electron, or positron as it is usually called, was discovered by C. D. Anderson at the California Institute of Technology. Each of these discoveries was later honored by a Nobel Award.

The University of California is especially interested in heavy hydrogen, for not only did Urey get his doctor's degree at Berkeley, but the existence of heavy hydrogen was predicted here, and after its discovery, G. N. Lewis was the first person to obtain it in high concentration. Samples of highly concentrated heavy hydrogen were then generously supplied for research work in all parts of the world. But nowhere did this new material prove more useful than right here in Berkeley. Employed as a bombarding projectile in the cyclotron, heavy hydrogen or deuterium, as it is now called, was found to be extraordinarily effective in producing nuclear disintegrations. Furthermore, the cyclotron is by far the most efficient device for generating neutrons in relatively large quantities, and neutrons, in turn, cause many new types of nuclear disintegration. Thus the development of the cyclotron has not only paralleled important discoveries elsewhere, but the cyclotron itself has made possible perhaps the most important applications of these discoveries.

The last great discovery that has since played an important role in the usefulness of the cyclotron is that of artificially induced radioactivity. This discovery was made by F. Joliot and his wife, Irene Joliot Curie, at Paris, in January, 1934. Again a Nobel Award promptly resulted.

But let us return to the development of the cyclotron. Although million-volt hydrogen ions had proved sufficient to disintegrate the light lithium atom, it was well known, as stated in the quotation from the presentation address by Dr. Coolidge, that much higher energies would be needed in order to disintegrate heavier elements. To produce particles of these higher energies, a cyclotron far larger than an eleven-inch instrument was obviously necessary. The figure, eleven inches, refers to the diameter of the vacuum chamber in which the ions revolve in circles of ever-increasing radius, until finally they are removed through a special port-hole in the wall of the chamber. Since this spiraling movement is produced by a uniform magnetic field, it is necessary that the pole faces of the magnet be at least as large as the diameter of the vacuum chamber. Now even the eleven-inch cyclotron employed one of the largest magnets then to be found in a scientific laboratory. Hence the construction of the much larger instrument now needed meant moving from the realm of physics into that of engineering; and that is just where most physicists would have stopped. Not so with Dr. Lawrence. He moved literally into the field of engineering, by appealing to our own Professor L. F. Fuller, at that time also vice-president of the Federal Telegraph Company. Dr. Fuller had just what Lawrence needed, a gigantic magnet built for a radio transmitter ordered by the Chinese government, but obsolete in type before delivery was possible. Thus a "white elephant" to Dr. Fuller became a godsend to Dr. Lawrence. With this magnet as the basis, the first really large cyclotron was built during that eventful year, 1932. The diameter of the pole faces is 37 inches, but the actually used portion of the original vacuum chamber was only thirteen inches in diameter. Numerous engineering as well as scientific problems had to be solved before it was possible to employ completely a 37-inch chamber, as is being done at present. In fact only those directly associated with the work of the Radiation Laboratory can appreciate fully the innumerable difficulties that have arisen and have, one by one, been conquered. As I have already indicated, the present cyclotron is primarily the result not of a moment's inspiration but rather of years of perspiring effort. The 37-inch cyclotron is now installed in the old Radiation Laboratory. It weighs some 75 tons.

The present world's largest cyclotron is the 220-ton instrument, located in the new William H. Crocker Radiation Laboratory. The vacuum chamber is 60 inches in diameter, and it produces 100 microampere currents of 16-million-volt deuterons. The beam, emerging into the air, has a diameter of a few inches, and penetrates some five feet. It is our nearest approach to a "death-ray." Just what is the constitution of such a beam? The heavy hydrogen nuclei composing it are moving, when they emerge from the cyclotron, with a speed of some 25,000 miles a second—about 13 per cent. of the velocity of light. The *number* of individual atoms, issuing from the cyclotron per second, is 600 million million! To obtain an equally dense beam of particles from radium would require something like *thirty tons* of pure radium, and even then the energy of the individual particles would not be nearly as great.

By causing the cyclotron beam to fall on a piece of beryllium, disintegration of the beryllium atoms is produced, accompanied by a copious emission of neutrons. These particles, equal in mass to the hydrogen atom, but with no electric charge, were produced originally by allowing the radiation from some natural radioactive substance, such as radium emanation, to fall on beryllium. To equal, in this way, the neutron yield of the cyclotron, some *200 pounds* of radium would be required—and radium costs nearly a million dollars an ounce! Thus the number of high energy particles produced by the cyclotron is of a completely different order of magnitude from that given by any other source. Herein lies the great practical value of the instrument.

When one turns more specifically to the uses of the cyclotron, the wealth of material is so great that it is difficult to know what to select for presentation, in the few remaining minutes at my disposal. It is doubtful if any scientific instrument invented by man has found more varied and more important applications. Lawrence originally designed the cyclotron in order to disintegrate atomic nuclei, and thus to gain information in regard to the structure of the atom. At the present time every element, without exception, has thus been disintegrated, a new element being in general produced. It one wants gold, Lawrence will take mercury and turn it into gold. But the process is far more costly than the value of the gold produced. In fact, the one great possibility of the cyclotron, as a money-making instrument, lies not in making gold, or platinum, or any other so-called precious substance, but in releasing nuclear energy. We now know that nearly all the energy of the universe is locked inside the nuclei of atoms, and we have found recently that even slowly moving neutrons have the ability to cause the nucleus of uranium to explode into two more or less equal parts. In this process some *200 million* electron volts of energy are released. To visualize this amount of energy, consider the fact that when an atom of carbon is burned to form carbon dioxide, about four electron volts of energy are released. As yet this uranium disintegration has not been developed into a self-sustaining process, such as is needed for the commercial production of energy. But with the far more energetic particles that Dr. Lawrence hopes to produce with a much larger cyclotron, other more suitable types of disintegration may well be found. The practical aspects of such an unlocking of nuclear energy, if it is accomplished, are so staggering that some of us shrink even from contemplating them.

With the cyclotron one can, as stated, transform every stable element into other forms. Some of the final products are themselves stable, but most of them are radioactive. The cyclotron is by far the best device for producing new radioactive substances. There are about 90 different elements, but most of these can exist in several different stable forms, known as isotopes. There are now some 386 known stable forms. In addition, there are about 335 artificially produced radioactive substances, of which 223 have been discovered by means of the cyclotron. More than half of the 223 have been found here at Berkeley. The remainder have been discovered by means of some one of the 21 cyclotrons now in operation at other institutions. An additional 17 cyclotrons are under construction. Directing or assisting in work of this kind at 25 different institutions are 47 men, trained for longer or shorter periods of time in the Berkeley laboratory.

Many of the artificially produced radioactive substances are proving of extraordinary value in medicine and in biology. Others are of great interest in themselves. I give just one illustration of the latter class. A few years ago it was believed that every element in the periodic table had been found, with the exception of the elements of atomic number 85 and 87, the hypothetical elements known as eka-iodine and eka-caesium, respectively. Then it became apparent that there was no valid evidence for the claimed existence of stable element 43, called masurium by its apparently deluded discoverer, nor for element 61, called illinium. Quite recently, Dr. Emilio Segrè, a member of the staff of the Radiation Laboratory, has definitely found a radioactive form of element 43, among the products produced by the cyclotron, and he has published several papers on this subject. I now have the privilege and the honor to make the first public announcement of another similar discovery. Dr. Dale Corson, a member of the Physics Department staff and of the Radiation Laboratory, aided by Dr. Segrè, Dr. J. G. Hamilton and Mr. K. R. MacKenzie, has found what appears to be clear evidence of a radioactive form of element 85, eka-iodine. All possible alternatives are not yet excluded, but the evidence is much stronger than that on which the announced discovery of several new elements has been based. Meanwhile the discovery of eka-caesium, element 87, has recently been announced from Irene Joliot Curie's laboratory in Paris. That leaves only element 61 still missing, and there is a strong probability that a radioactive form of this element will be found among the disintegration products yielded by the cyclotron beam.

The great importance of radioactive elements in medicine and in biology results chiefly from their use as so-called "tracer atoms." One can, for instance, make a radioactive form of sodium that does not differ chemically from stable sodium. Taken through the mouth in the form of common salt, these radioactive atoms travel with surprising rapidity to various parts of the body. Any one such atom may exist for many hours, or only for a fraction of a second, but the average life of an atom of radio-sodium is about 21 hours. When it does die—by transformation into a new element—each atom gives unmistakable evidence of its location by ejecting a high-speed particle, which may be recorded with a so-called Geiger counter. Thus the wanderings of *single atoms* may be accurately followed in chemical and biological processes. The eminent physiologist, Professor A. V. Hill, has told Professor Lawrence that, in his opinion, the use of such tracer elements will be recorded in history as a technique of equal importance with the use of the microscope. Just because of these facts, chemists, biologists, cytologists, bacteriologists, physicians and radiologists —to make only an incomplete list—are now working with these products of the cyclotron, in close cooperation with the regular staff of the Radiation Laboratory. Samples of radioactive material are being supplied to at least twenty such groups, some located on the Berkeley campus and others at institutions all over the world.

I now, for the second time this evening, have the privilege of making a first announcement of very great importance. This news is less than 24 hours old, and hence is real news. Carbon, as you know, is the most important element in plants and animals. Hence a radioactive form of carbon, with a long average life, is the one radioactive substance most desired by chemists and biologists, for use as a tracer atom. A radioactive form of carbon, of mass 11 and average life 30 minutes, is now known and in spite of its comparatively short average life, has already made possible important conclusions relating to plant growth. Now Dr. S. Ruben, instructor in chemistry, and Dr. M. D. Kamen, research associate in the Radiation Laboratory, have found, by means of the cyclotron, a new radioactive form of carbon, probably of mass 14, and average life of the order of magnitude of several years. On the basis of its potential usefulness, this is certainly much the most important radioactive substance that has yet been created.

Radioactive elements are used not only as tracer atoms. They are now being used also in the direct treatment of various diseases, and the results in certain cases, such as chronic leukemia, are distinctly encouraging. Finally, the neutron rays produced by the cyclotron are found to have many applications in both biology and medicine, quite aside from their importance to physicists. They have already shown very promising possibilities in the treatment of cancer, and other medical uses are constantly being found. In the medical work of the Radiation Laboratory, Dr. Ernest Lawrence is fortunate in having the coöperation of his brother, Dr. John Lawrence, a medical scientist of great ability. Although I have neither the time nor the competence to discuss in detail these manifold uses of the cyclotron and its products, I hope that I have given at least a glimpse of their extent. Already 163 papers have been published from the Berkeley Radiation Laboratory itself, and 76 different names appear on these papers.

The progress of science is the progress of instruments. A scientific theory is meaningless unless it can be tested experimentally. Such a test normally requires an appropriate instrument, and thus, for the testing of theories as well as for the direct observation of facts, instruments are indispensable. One needs only think of what would remain of astronomy without the telescope or of biology without the microscope. The cyclotron is now playing a similar role in the infant field of nuclear physics. But the cyclotron, as noted, has a unique additional value, due to the fact that it manufactures, in relatively large amounts, various products, each of which is itself already of tremendous importance in widely varying fields. It is therefore a real tribute to refer to Dr. Lawrence as an eminent inventor. This idea has already been expressed in a beautifully worded editorial in the *New York Times,* a portion of which reads as follows:

> The pioneers in experimental physics have always had to devise their own instruments of investigation. Men like Faraday, Hertz and Helmholtz are not listed among the great inventors. For the servants of science invent as a matter of course, rarely take out patents, and concentrate on research. Who thinks of Hertz's simple detector of electric waves as the first wireless apparatus, or of the apparatus with which Faraday discovered electromagnetic induction as the germ of the electric generator and motor? If Professor Lawrence were what is called a "practical" inventor and his cyclotron were of any immediate commercial use, he would take his place beside Watt, Arkwright, Bell, Edison and Marconi, which would probably exasperate rather than flatter him.

That is the end of the quotation.

I can not close without commending the completely unselfish attitude of Dr. Lawrence toward his associates. This is well shown by his first remark on being informed of the Nobel Prize Award—namely, "It goes without saying that it is the laboratory that is honored, and I share the honor with my co-workers past and present."

The development of the cyclotron has taken the united efforts of many most capable and willing workers, but it is the ability and the inspiration of Lawrence that have brought these workers together, and have held them together, in spite of every obstacle, until to-day the Radiation Laboratory represents as fine a piece of cooperative effort as exists in the annals of science. I therefore pay tribute to Dr. Lawrence not only as a scientist of real distinction, but as one who exemplifies the best in scientific ideals.

RESPONSE

By Dr. ERNEST O. LAWRENCE

PROFESSOR OF PHYSICS AND DIRECTOR OF THE RADIATION LABORATORY, UNIVERSITY OF CALIFORNIA

Mr. President, Mr. Consul-General, Professor Birge, Ladies and Gentlemen:

Words fail me in giving expression to my thoughts on this occasion. To convey to you, Mr. Consul-General, and through you to the Royal Swedish Academy of Science my profound gratitude for this great honor would be giving expression to only a part of what is in my mind; for I am mindful that scientific achievement is rooted in the past, is cultivated to full stature by many contemporaries and flourishes only in a favorable environment. No individual is alone responsible for a single stepping stone along the path of progress, and where the path is smooth progress is most rapid. In my own work this has been particularly true. From the beginning of the Radiation Laboratory, I have had the rare good fortune of being in the center of a group of men of high ability, enthusiastic and completely devoted to scientific pursuits. I wish it were possible this evening for me to pay tribute individually to them all, for it was our joint endeavors that made possible the work which has been so magnificently recognized by the Nobel award; but I must content myself with accepting this great honor with the happy thought that I am the representative of these valued associates and friends.

I know also that I speak for my colleagues in the Radiation Laboratory as well as for myself when I take this felicitous opportunity to acknowledge with sincere gratitude the generous help we have received from many sources. The day when the scientist, no matter how devoted, may make significant progress alone and without material help is past. This fact is most self-evident in our work. Instead of an attic with a few test-tubes, bits of wire and odds and ends, the attack on the atomic nucleus has required the development and construction of great instruments on an engineering scale. This has been possible only through generous assistance from several quarters—notably the Research Corporation, the Chemical Foundation, the Rockefeller Foundation and from the late William H. Crocker, regent of the university. These benefactors share the honor of this occasion because without their help the work of our laboratory could not have been brought to its present fruition.

I have suggested that scientific progress requires a favorable environment. The University of California rightfully takes pride in the Nobel award because the university as a whole has contributed immeasurably in diverse ways to the work of the Radiation Laboratory. I shall always be grateful for the wise and generous guidance and help that our work has received from the University Board of Research, and especially from Professor Leuschner, chairman of the Research Board, in the early years of organization of the laboratory, and above all may I acknowledge my deep appreciation of the support of the president of the university, who whole-heartedly has been all along such a stimulus to our activities. It may truly be said that this Nobel award is yet another tribute to his great academic leadership.

It is a source of gratification to us all that we have been able to contribute a little to our understanding of the nucleus of the atom. We are glad that already in these early beginnings discoveries have emerged of immediate practical significance—for, as Professor Birge has so graciously said this evening, the new radiations and radioactive substances have opened vistas for all the sciences, especially in medicine. And in the Radiation Laboratory we count it a privilege to do everything we can to assist our medical colleagues in the application of these new tools to the problems of human suffering.

At the same time we have been looking towards the new frontier in the atom, the domain of energies above a hundred million volts, for we have every reason to believe that there lies ahead for exploration a territory with treasures transcending anything thus far unearthed. To penetrate this new frontier will require the building of a giant cyclotron, perhaps weighing more than 4,000 tons—twenty times larger than the new medical cyclotron of the Crocker Laboratory. We have been working on the designs of such a great instrument and are convinced that there are no insurmountable technical difficulties in the way of produc-