

NIELS BOHR

a memorial tribute

By Victor F. Weisskopf

WE are assembled to pay tribute to Niels Bohr. Niels Bohr is the symbol, he is the origin, he is the main architect of our work. It was through him, by him, and with him that all this on which our work and our existence stands was created. He was a great man. What is greatness? A great man is one who creates a new period, a new way of thinking, and truly he and his life correspond to this definition. The influence of what he started is seen in every aspect of our life. Modern science has reshaped our world. It became the determining factor in our thinking, in our culture, even in politics, and it establishes the direction in which mankind will move in the next decades. The real significance of the development which was initiated by Bohr cannot yet be judged by us. We are too close to his life. Only from a distance can one see how much Mont Blanc towers over the other mountains of the Alps.

Niels Bohr was born in 1885. His life as a scientist began about 1905 and lasted 57 years. What a time to be a physicist! He began when the structure of the atom was still unknown; he ended when atomic physics, which he created, had reached maturity. Science, and in particular physics, was not in 1905 what it is now. Let us have a look at physics at that time.

It was an interesting time. It was the year when Einstein published his concept of special relativity; it was a period in which many new phenomena were discovered, but not understood. It was only a few

years after Planck's great discovery of the quantum of action. Very few people at that time had noticed Planck's new paper, let alone understood what it meant. It was a time when chemistry and physics were wide apart. Chemistry, on the one hand, was the science of matter and its specific properties. The atom was a concept of chemistry—the atom of gold, of oxygen, of silver: different specific entities whose existence was noted, but not understood. Physics, on the other hand, was a science of general properties, of motion, of strain and stress, of electric and magnetic fields, and the two sciences were far apart. One was not yet able to answer the question: "Where do the properties of matter come from?" Bohr had the great luck to be there at the beginning, or perhaps mankind had the great luck to have had him there at that turning point.

The work of Niels Bohr can be divided into three periods. In each one he exerted a tremendous impact on the development of modern science, in three different ways, at three different times. The first period is the decade from his meeting with Rutherford in 1912 to the year 1923. It began with the publication, in the year 1913, of his work on the quantum orbits of the hydrogen atom. He proposed to explain the unexplained properties of the atom by introducing the concept of quantum states—a concept which was already prepared by Planck and Einstein, and which he applied to the structure of the atom. There is hardly any other paper in the literature of physics from which so many new ideas

On November 23, 1962, five days after the death of Niels Bohr, a ceremony to honor his memory was held at CERN, the international laboratory located near Geneva, Switzerland, which Professor Bohr had aided materially in creating a decade ago. This tribute was presented at the CERN memorial session by V. F. Weisskopf, professor of physics at the Massachusetts Institute of Technology, who has been on leave of absence for the past two years while serving as director general of CERN. Professor Weisskopf has recently agreed to continue at CERN in that capacity for an additional one-year term—until August of next year.

and discoveries grew. There is hardly anyone so revolutionary. His concept of atomic quantum states was apparently in complete contradiction to the picture of the planetary system which followed from the experiments of Rutherford. But this was a contradiction containing in it the answers to the most fundamental questions.

This famous paper marked the beginning of a series of new insights. In the ten years following its publication, many things not previously understood fell into place: the structure of the spectra of elements, the process of absorption and emission of light, the reasons for the periodic system of elements, the puzzling sequence of properties of the 92 different atomic species. It was the period in which quality, the specificity of chemical substances, was reduced to quantity, to the number of electrons per atom. All this rested on Bohr's quantum assumption, at that time still a provisional hypothesis. Bohr's contemporaries, however, took the allowed and forbidden quantum orbits of the electron quite literally, although Bohr warned them in his papers and at meetings that this could not be the final explanation, that there was something fundamental to be discovered first in order to understand really what was going on in the quantization of the atom.

We now come to the second period of his work: the years 1923 to 1932. This was the great period in which the quantum was fully understood. It was a heroic period without any parallel in the history

of science, the most fruitful and most interesting period of modern physics. There is no single paper by Niels Bohr himself which characterizes this period as did the 1913 paper in the first period. Bohr found a new characteristic way of working. He did not work as an individual alone, he worked in collaboration with others. It was his greatest strength to assemble around him the most active, the most gifted, the most perceiving physicists of the world. At that period, we find with Bohr at his famous Institute for Theoretical Physics, in Copenhagen, people such as Klein, Kramers, Pauli, Heisenberg, Ehrenfest, Gamow, Bloch, Casimir, Landau, and many others. It was at that time, and with those people, that the foundations of the quantum concept were created, that the uncertainty relation was first conceived and discussed, that the particle-wave antimony was for the first time understood. In lively discussions, in groups of two or more, the deepest problems of the structure of matter were brought to light. You can imagine what atmosphere, what life, what intellectual activity reigned in Copenhagen at that time. Here was Bohr's influence at its best. Here it was that he created his style, the "Kopenhagener Geist", the style of a very special character which he imposed onto physics. We see him, the greatest among his colleagues, acting, talking, living as an equal in a group of young, optimistic, jocular, enthusiastic people, approaching the deepest riddles of nature with a spirit of attack, a spirit of freedom from conventional bonds, and a spirit of joy which can hardly be described. As a very young boy, when I had the privilege of arriving there, I remember that I was taken a little aback by some of the jokes that crept into the discussions, and this seemed to me a lack of respect. I communicated my feelings to Niels Bohr and he gave me the following answer: "There are things that are so serious that you can only joke about them."

In that great period of physics, Bohr and his disciples touched the nerve of the universe. The intellectual eye of man was opened on the inner workings of Nature that were a secret up to this point. The concept of quantum state was cleared up, its fundamental wholeness, its indivisibility which, however, has that peculiar way of escaping ordinary observation because the very act of such observation would obliterate the conditions of its existence. Bohr, whose penetrating analysis contributed so much to the clarification of these problems, called that remarkable situation "complementarity". It defies a pictorial description in our accustomed classical terms of physics, but it re-

veals a much richer world than our classical experience has led us to expect.

Once the fundamental tenets of atomic mechanics were settled, it was possible to understand and to calculate almost every phenomenon in the world of atoms, such as atomic radiation, the chemical bond, the structure of crystals, the metallic state, and many others. Before that time, this world was full of forces: electric, adhesive, chemical, and elastic; then, all these forces were reduced to one—to the electromagnetic force. In the course of only a few years, the basis was laid for a science of atomic phenomena which grew into that vast body of knowledge known to us today.

Then follows the third period of Bohr's work: the time between 1932 and 1940. The year 1932 was an important year in the development of physics. In that year, the neutron was discovered, the positron and artificial radioactivity found, and also the first particle accelerator was put into use. Bohr's Institute, now well known all over the world, became the center of theoretical physics. After the solution of the fundamental problem of the quantum, theoretical physics went on in two new directions. One was the application of the quantum concepts to fields, to electromagnetic fields and, later, to nuclear fields. This attempt is not yet quite completed today, and many deep problems concerning the structure of the sources of fields, the elementary particles, are still unsolved. It was vigorously pursued during that period in Copenhagen in close collaboration with Pauli, Dirac, and Heisenberg. Bohr himself, in a famous paper published with Rosenfeld, established the physical basis of the new concepts in field quantization. This work is a typical example of Bohr's concern with the physical content of mathematical theories.

The other direction of research in this period was towards the exploration of the innermost part of the atom, the atomic nucleus. In the previous periods, the nucleus was considered only as the massive center of the atom. In the third period, the structure of the nucleus was a subject of interest, since more and more facts were known about phenomena connected with the innermost part of the atom. These facts were quite puzzling at the start, but, under Bohr's active leadership, it soon was discovered that the same laws of quantum mechanics also govern the world within the nucleus. However, there was a more complicated problem to be faced because of the appearance of new and much stronger forces which hold the nucleus together, the nuclear forces. When the world of physicists was puzzled by the enormously large number of quan-

tum states found in nuclear reactions, it was again Bohr's concept of the so-called "compound nucleus" which made it possible to understand how the large number of states is connected with the strong interaction between the constituents of the nucleus. Bohr's work, and the stimulation from the discussions at Bohr's Institute, created a new science of nuclear structure which led to the understanding of nuclear phenomena, and also of a problem of old standing: the source of energy in the sun and in the stars.

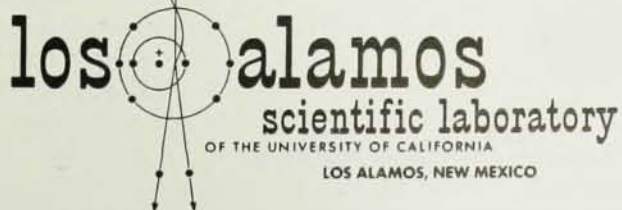
We now reach 1940, the beginning of the Second World War. What follows now in the life of Bohr is, in some ways, even a greater testimony to the greatness of this man. What follows now can no longer be told in purely scientific terms. Bohr was not only a great scientist, he also was a man of unusual sensitiveness and feeling for the world in which he lived. The relation of science with the world of men was for him an important question. He was aware, earlier than many others, that atomic physics is, and would be, a decisive part in civilization and in the fate of mankind—that science cannot be separated from the rest of the world. The events of world history brought home this point earlier than expected. By the 1930's, the ivory tower of pure science had already been broken. It was the time of the Nazi régime in Germany, and a stream of refugee scientists came to Copenhagen and found help and support from Bohr. He asked some to stay with him at that time; James Franck, Hevesy, Placzek, Frisch, and many others found a haven in Copenhagen where they could pursue their scientific work. But not only this, Bohr's Institute was the center for everybody in science who needed help, and many a scientist got a place somewhere else—in England, in the United States—through the help of Bohr's personal actions. Then came the years of war; Denmark was occupied by the Nazis in April 1940; pure science was at an end. Bohr was in close connection with the Danish Resistance. He refused to collaborate with Nazi authorities. Soon he was forced to leave Denmark; he had to escape to Sweden, and then came via England to the United States. There he joined the large group of scientists in Los Alamos who, at that time, were working on the exploitation of nuclear energy for war purposes. He did not shy away from this most problematic aspect of scientific activity. He faced it squarely as a necessity, but at the same time it was his idealism, his foresight, and his hope for peace that inspired so many people at that place of war to think about the future and to prepare their



Photographic interpretation by J. Frederick Laval

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minds for the tasks ahead. He helped us to see that, in spite of death and destruction, there is a positive future for this world of men transformed by scientific knowledge. But he did more than that. He came into contact with people in power; he saw Roosevelt, he saw Churchill. He did many things that today might seem naïve. We all were naïve at that time when we hoped that the bomb would be abolished after the war, and that a durable peace would be established immediately, but it is this naïveté that carries the hope and the strength for a peaceful future. Today, we should be aware that it was that attitude, and the discussions and activities resulting from that hope, which contributed to the realities of today, and perhaps to the fact that we are still alive and can still look with some confidence to the future.

Then came the postwar years: from 1945 to the end. Physics had a different aspect. The war had made it obvious, by the most cruel of all arguments, that science is of the most immediate and direct importance to everybody. This had changed the character of physics. Physics became a large enterprise: large numbers of people, large machines were necessary to carry out physical research. Bohr recognized this as a logical continuation of what he and his friends had started. The new insights which he found were greater than the ivory tower of the universities in which some people wanted to contain this knowledge. He saw that out of these ideas would develop a great spirit which could encompass all fields of human activities, and so he saw the necessity of physics on a large scale, on an international scale. In no other human endeavor are the narrow limits of nationality or politics more obsolete and out of place than in science. Therefore Bohr was always aware of the leading role science must play in creating a lasting bond across national and political boundaries, in creating the beginning of a supernational society of human beings on earth. This is why he was actively engaged in the creation of international scientific centers: the Scandinavian center, NORDITA, in Copenhagen, and, last but not least, the CERN center. CERN exists because of Niels Bohr. It was Niels Bohr's personality, Niels Bohr's weight, and Niels Bohr's work that made this place possible. There were other personalities who started and conceived the idea of CERN. The enthusiasm and the ideas of the other people would not have been enough, however, if a man of his stature had not supported it, and not only supported it, if he had not participated actively in every important act of founding and developing, if he had not sat together with the

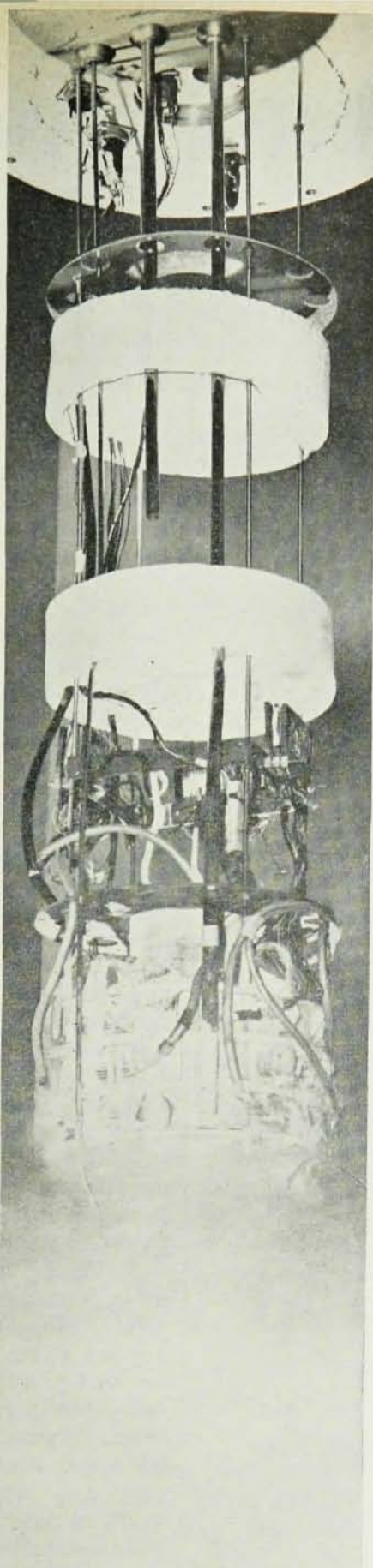
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others and worried about every detail. That was Niels Bohr.

The greatness of this man comes out in this period more than in any other. Bohr in his sixties was fully aware of the new developments in physics, of the new phase which began a decade ago, when the availability of high-energy beams made it possible to go beyond the structure of the nucleus and to explore the structure of the constituents of the nucleus, the world within the proton and the neutron. This new stage of our science is nothing else but the continuation of the great wave that he had started. Bohr was aware of this, and that was why he had put all his enthusiasm, his zest for life, his positive attitude in support of this new development and, in particular, in support of the new upsurge of fundamental physics in Europe. I remember only a year ago an example of how much he cared for the details of what was going on at CERN. He was asked for help because of some budgetary difficulties. He came and did a great deal to alleviate the problem; after the meeting, which took the whole day, when everyone was tired, he asked one of the members to go for a walk with him, and he spent two hours in the rain of Geneva explaining his views of the situation. It is hard to understand how a man of his age could have had such energy, such an enthusiastic interest in life; but it was a necessary condition to be able to do what he did. It was he who gave us this tremendous expansion of our vision of reality which shook the world to its foundations; it was also his spirit of optimism and enthusiasm which will enable us to overcome the dangers we face.

With Niels Bohr's death an era disappeared—the era of the great men who created our science. But it was Niels Bohr himself who helped to create the basis for the continuation of his spirit into the future; our institution, CERN, is a testimony to this. It puts us under the obligation to continue what he wanted to do.

His death symbolizes his life. It was only two weeks before his death that he came back from a vacation, fully recovered from a slight stroke he had had a year ago, and his doctors told him that he could go ahead and work as usual. So he did and he was very well, and even on Friday, two days before his death, he chaired a meeting of the Danish Royal Academy of Science; on Sunday he planned to have a party of friends at his house. He was happy and healthy, but when he lay down in the afternoon for a little rest, he did not wake up. That such a life was, and could be lived today, should be a great encouragement to all of us.