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Niels Bohr, the Quantum and the World

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Niels Bohr's life as a scientist began about 1905 and lasted almost sixty years. 1905 was the year when Einstein published his paper on special relativity and on the existence of the light quantum; it was only a few years after Planck's discovery of the quantum of action. Bohr had the great luck to be present at the beginning, or perhaps mankind has had the great luck to have him at that turning point. What a time to be a physicist! He began when the structure of the atom was still unknown; he ended when atomic physics reached maturity, when the atomic nucleus was put to industrial use for the production of electric power, to medical use in cancer treatment and, unfortunately, to military and political use as the most destructive weapon man has ever conceived.

The work of Niels Bohr can be divided into four periods. In each he exerted a tremendous impact on the development of physics. The first is the decade 1912–1923, from his meeting with Ernest Rutherford until the foundation of his famous Institute of Theoretical Physics in Copenhagen. In this period Bohr introduced the concept of quantum state, created an intuitive method of dealing with atomic phenomena, and was able to explain the Periodic System of elements. In the second period, 1923–1929, he gathered around him in his new Institute some of the world's most productive physicists, who, under his leadership, developed the ideas of quantum mechanics. The third period, 1930–1940, was devoted to the application of the new quantum concepts to electromagnetic phenomena and the exploration of the structure of the atomic nucleus. Then came the Second World War and the last period of his life, in which he acted as the great leader of physics, deeply concerned with and involved in the social, political and human consequences of the new discoveries.

The second period was the time in which the quantum became fully understood. It was a heroic period without any parallel in the history of science, the most fruitful and most interesting one of modern physics. There is no paper by Bohr himself that characterizes this period as did the 1913 and 1922 papers for the first period. It was, rather, his great strength to assemble around him the most active, the most gifted, the most perceptive physicists in the world. His Institute was perhaps the first truly international institution devoted to scientific research. In lively discussions, the deepest problems of the structure of matter were brought to light. One can imagine what atmosphere, what life, what intellectual activity reigned in Copenhagen at that

time. Here was Bohr's influence at its best—he found a new way of working. 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 that can hardly be described. In the course of only a few years the basis was laid for a science of atomic phenomena that grew into the vast body of knowledge known to us today. During that period, Bohr coined the concept of complementarity which was to describe the relation between the observed phenomena and the atomic "reality" which they are supposed to describe. The results of different experimental arrangements turn out sometimes to be seemingly contradictory: they reveal complementary aspects of the object under investigation, aspects that defy a description in classical language, but that are predicted by quantum mechanics. All through his life Bohr was attracted by the philosophic significance of the concept of complementarity in physics and also in other manifestations of human cognition.

In the third period he turned to nuclear physics. Bohr introduced the important concept of the compound nucleus to explain nuclear reactions. The fission of uranium was discovered when Bohr was deeply involved in his studies of nuclear structure. Obviously this phenomena captured Bohr's interest, and he wrote fundamental papers on this process that had a decisive influence on the development of nuclear energy.

The work on uranium fission inevitably brought Bohr into a realm where physics and human affairs are hopelessly intertwined. He was unusually sensitive to the world in which he lived. Before many others, he was aware that science could not be separated from the rest of the world. The events of world history brought home this point earlier than expected. By the 1930s, the ivory tower of pure science had already been broken. It was the time of the Nazi regime in Germany, and streams of refugee scientists came to Copenhagen and found help and support from Bohr. Bohr's Institute was the center for everybody in science who needed help, and many a scientist found a place somewhere else—in England, in the United States—through the help of Bohr's personal actions. Then came the years of the war. Denmark was occupied by the Nazis in April 1940. Bohr was in close contact with the Danish resistance. He refused to collaborate with Nazi authorities. Soon forced to leave Denmark, he escaped to Sweden and then came via England to the United States.

In the fourth period of his life, Bohr joined a 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 his idealism, his foresight and his hope for peace inspired many people at that place of war to think about the future and to prepare their minds for the tasks ahead. He believed that, in spite of death and destruction, there was a positive future for this world, transformed by scientific knowledge.

At that time Bohr actively engaged in a one-man campaign to persuade the leading statesmen of the West of the danger and the hope that might come from the atomic bomb. He wanted to raise nuclear technology to an international level to avoid a nuclear armaments race between powerful nations and a nuclear holocaust.

He saw Roosevelt and Churchill and other important men, and he learned quickly the difficulties and pitfalls of diplomatic life. Although he was quite able to convince a number of important statesmen, including Roosevelt, of his ideas, his meeting with Churchill turned out to be a complete failure. Bohr's great political concept did not come to any fruition.

Neither did other attempts succeed of raising nuclear technology to an international level in order to avoid a nuclear armaments race between powerful nations. Bohr ended his efforts towards international understanding on nuclear weapons with his famous letter to the United Nations, written in 1950, in which he laid down his thoughts about the necessity of an Open World. He pleaded for openness between all nations and political systems in regard to human contacts, to new ideas, and in regard to a mutual understanding of the problems faced in different parts of the world. He predicted an ever increasing nuclear arms race if such understanding cannot be realized. His predictions turned out to be tragically correct.

In the last decades of his life, Bohr spent much time in the organization of international activities in science. He participated actively in the founding of the Scandinavian Institute of Atomic Physics and the European Center of Nuclear Research in Geneva. In many ways CERN is based on the same ideas as Bohr's Institute in Copenhagen fifty years earlier, on the idea of international scientific collaboration. But now it was executed on the largest scale, in experimental and theoretical physics.

Physics became a large enterprise; large numbers of people and large machines were necessary to carry out physical research. Bohr recognized this as a logical continuation of what he and his friends had started. He was not afraid of big science if it is imbued with the same spirit as before. 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 the search for more knowledge about the universe.

He spent the last years following the results of new research, helping to get support for science from governments wherever he could, and reformulating his philosophy of complementarity. He was proud of the rebirth of European science after the ravages of war and he enjoyed his life as the grand old man of Physics.

When Niels Bohr died, an era ended—the era of the great men who created modern science. But it was Bohr himself who helped to shape the spirit and the institutions for the continuation of the scientific endeavor into the future. And it is up to us to realize his ideals in the future. He, more than anybody, knew that to succeed in this, two tasks must be fulfilled: to continue the quest for deeper insights into the riddles of nature with the same insistence and enthusiasm as he did, and to avert the threatening catastrophes engendered by today's gross abuses of military and technical applications of our great science.