Distribution: limited

SC-85/CONF.811/11
PARIS, 26 November 1985
English only

UNITED NATIONS EDUCATIONAL,
SCIENTIFIC AND CULTURAL ORGANIZATION

Round-table in commemoration of Niels Bohr Centenary

Niels Bohr - A survey of some of his contributions
to science and international co-operation

Unesco House, Room VIII, 28-29 November 1985

NIELS BOHR AND THE TWENTIETH CENTURY

by

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(The views expressed by the author do not necessarily
reflect the standpoint of Unesco.)

Niels Bohr and the Twentieth Century

Our age is certainly one of the most creative and revolutionary periods of history in almost every field of human activity, especially in science and its application to industrial production, but also to agriculture, medicine, and last but not least, warfare.

In recent times, scientific research has spread to many areas beyond Western Europe and North America. Some of the most important ideas in physics, for instance, have come from Asia and other areas outside the western world. The number of research scientists has increased fantastically and enormous scientific laboratories have appeared in many countries.

In our century, studies in the history and philosophy of science expanded enormously and the role of the philosophy of science became of great importance.

During this period, there was a fusion of physics and chemistry and many of the most important ideas in molecular biology were introduced by physicists.

The application of quantum physics and relativity led to fundamental changes in astronomy and cosmology, giving a new image of the whole universe and its evolution. Since the creation of general relativity and the development of nuclear physics and the physics of elementary particles, the fusion of physics with astronomy and cosmology has been firmly established.

In connection with scientific and technological development, there was also a fundamental transformation of ethical, philosophical, political and artistic tendencies.

Interaction between scientists of different disciplines was also deeply affected, in particular by the work of physicists in chemistry, biology, astronomy and cosmology.

The field of medicine has also benefited in a fundamental way from the development of many branches of physics, since the end of the 19th century. Later, the discovery of many different kinds of radiation and particles, as well as the use of artificial radioactive elements and of tomography, changed radically the techniques of medical sciences. Many therapeutic techniques based on the physical discoveries of the 20th century deeply modified medicine's approach to the prevention, diagnosis and cure of disease - even more, perhaps, than the discovery of X-rays at the end of the 19th century.

Niels Bohr was one of the outstanding physicists and natural philosophers of our century, and in fact in the whole history of science. He and his younger co-workers, Heisenberg, Pauli, Dirac and others, developed the ideas of Planck and Einstein, the founders of quantum theory, in order to explain the structure of matter and the nature of physical fields. Thus, Bohr's work led to the development of quantum mechanics and its probabilistic methods, beginning the greatest revolution in the history of physics. One of the main initial results of the new quantum theory was to explain the nature of chemical bonds, thus leading to the afore-mentioned fusion of physics and chemistry.

Starting from de Broglie's conception of matter as waves, Schrödinger, following an independent path, formulated his famous wave equation, whose probabilistic interpretation by Max Born allowed its fusion with the quantum mechanics of Bohr, Heisenberg, Pauli and Dirac.

Bohr played a central role in the initial phases of quantum mechanics and quantum electrodynamics. The theory of physical measurements in both these areas is largely based on Bohr's ideas.

Bohr was the pioneer of the fusion of physics and chemistry through his discovery of the deep meaning of Mendeleev's classification of chemical elements. As a matter of fact, he described the roles of the

electron's charge and of atomic numbers in his very first paper on atomic structure. The development of the whole theory of the structure of atoms, molecules and atomic nuclei owes him a great deal.

Bohr understood the fundamental importance of Pauli's exclusion principle, not only in the explanation of the Mendeleev classification, but in the whole of quantum theory.

With his unique capability of combining experimental data and their theoretical co-ordinations with an astonishing intuition and a deep knowledge of the philosophy of science, Bohr changed man's entire current mode of thought about physics and chemistry and stimulated developments that led to molecular biology.

The extension of the wave formalism to the electron with spin 1/2 by Pauli was later extended by Dirac into the relativistic quantum mechanics of the electron, leading to the discovery of the positron and to the existence of sub-atomic particles and anti-particles.

Further development of the quantum theory was achieved with the creation of the quantum theory of fields by Heisenberg and Pauli, thus allowing the production of a quantum theory of electromagnetic fields and also of elementary particles, which enabled scientists to deal both with particles of integer and of half-integer spins.

Niels Bohr was one of the greatest philosophers of nature and science of all times, comparable with Galileo, Descartes, Newton, Leibniz, Faraday, Maxwell, Boltzman, Gibbs, Einstein and the founders of modern biology and psychology.

In his scientific work, Bohr had to cope with fundamental problems of the scientific method and of the epistemology and philosophy of science, and he had to create new tools for philosophical analysis of the foundations of science. In his analysis of the relationship between experimental methods and theories and the philosophy of science, he understood clearly that the construction of the physics of atoms, atomic nuclei and elementary particles necessitated a deep analysis

of human knowledge and a thorough criticism of experimental methods in the whole process of physical science, biology and psychology, as well as astronomy and cosmology.

Bohr followed continuously not only the development of all physical sciences but also of philosophy, biology and psychology. He kept close contact with work in all those fields, and he had a deep feeling of the unity of science and of its relation to logic, mathematics and philosophy, the latter being considered from both Western and Eastern points of view. The variety of his interests was astonishing, and he had an acute appreciation of the history of science.

Bohr expressed his basic principle of complementarity in the following way:

> "Evidence obtained under different experimental conditions cannot be comprehended within a single picture, but must be regarded as complementary, in the sense that only the totality of the phenomena exhausts the possible information about the objects."

Bohr's conceptual framework of complementarity not only had a profound impact on quantum physics but also indicated new trends of research and epistemological positions in the social sciences. As he liked to point out, complementarity in the field of anthropology could be understood in the sense that man is at the same time the actor and the spectator. In psychology, complementarity consists in the fact that the analysis of feelings and emotions cannot dissociate the subject from the object.

Perhaps even more important were his reflexions on complementarity in the biological sciences. Bohr proposed a synthesis between the mechanistic and vitalistic approaches in biology. Furthermore, Bohr's concern with the problems of causality and temporality in biology occupied a central position in his later years.