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Teacher and Master

On the Centenary of the Birth of Academician N.N. Bogolyubov

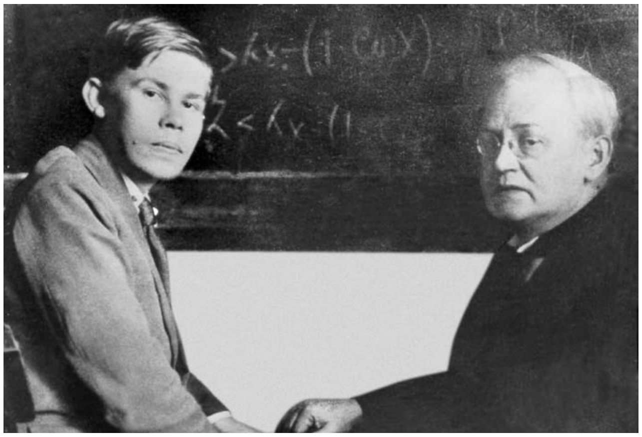
Nikolai Nikolaevich Bogolyubov (1909–1992).

Nikolai Nikolaevich Bogolyubov went down in history as the creator of contemporary theoretical and mathematical physics—a new integrated field of natural science. The scientific schools that he created in Moscow, Dubna, Kiev, and Lvov still exist and unite scores of leading mathematicians, scientists in mechanics, and theoretical physicists in Russia and Ukraine. Many scientists from the member countries of the Joint Institute for Nuclear Research and from other countries identify themselves with those scientific schools.

Contemporary theoretical physics and mathematical physics, fields which include a broad range of studies, have always been considered an integrated field of science at the institutes that Bogolyubov headed. He organized a laboratory of theoretical physics at the Joint Institute for Nuclear Research (Dubna); the Institute of Theoretical Physics (Kiev); departments of theoretical and mathematical physics at the Steklov Mathematical Institute (Moscow); departments of theoretical physics at the Institute of High Energy Physics (Protvino), the Institute for Nuclear Research (Moscow), and the Institute of Mathematics (Novosibirsk); the department of mathematical physics at Kiev State University; the department of quantum statistics at Moscow State University; and a mathematical department at the All-Russia Research Institute of Experimental Physics (Sarov). Bogolyubov founded the journals *Teoreticheskaya i Matematicheskaya Fizika* (Theoretical and Mathematical Physics) (1969) and *EChAYa* (Physics of Elementary Particles and Atomic Nuclei) (1970). He initiated a series of international conferences (congresses) in mathematical physics. Being for many years the director of the Joint Institute for Nuclear Research, academician-secretary of the Branch of Mathematics in the USSR Academy of Sciences, director of the Steklov Mathematical Institute, and director of the Institute of Theoretical Physics in Kiev, he basically influenced the shaping of scientific programs in the fields of contemporary mathematics, mechanics, and physics, including the physics of elementary particles and atomic nuclei.

In reviewing Bogolyubov's scientific career, we can say that he was distinguishable among the famous scientists of the 20th century, first of all, as a naturalist and educator, combining in his personality a mathematician, mechanical scientist, and physicist.

Bogolyubov was born on August 8 (21), 1909, in Nizhni Novgorod into the family of Nikolai Mikhailovich Bogolyubov, a professor of philosophy and psychology at the Nizhnii Novgorod Theological Seminary. His mother, Olga Nikolaevna, was a teacher of music. After the family moved to Kiev at the end of 1921, Nikolai attended Academician D.A. Grave's seminar for several months. In Kiev he started his scientific activity, attending, at the age of 13, Academician N.M. Krylov's seminar. In 1925 the minor presidium of the Ukrainian Main Committee of Science (Ukrglavnauka) made a decision to consider Bogolyubov, in view of his phenomenal gift in mathematics, a postgraduate student at the research department of mathematics in Kiev. During his first years in science, Bogolyubov, in collaboration with Krylov, his teacher and scientific supervisor, developed several sections of mathematics, primarily variational calculus, and created a new branch of mechanics, which he called nonlinear mechanics. Today the ideas of Bogolyubov's



N.N. Bogolyubov and Academician N.M. Krylov, 1930s.

school on nonlinear mechanics largely determine the theoretical development and various practical applications of nonlinear mechanics, including contemporary aviation and cosmonautics.

Based on a solid mathematical foundation, Bogolyubov in the late 1930s began to implement a new approach to the description of nature, which later gave rise to contemporary theoretical and mathematical physics. One of his first universal ideas was the maximum conceptual closeness of the classical and quantum levels in the description of nature. In 1939 Bogolyubov and Krylov substantiated this idea in an article dedicated to the application of the Fokker–Planck equation in classical and quantum mechanics. In fact, the work contained a research program that largely determined the future scientific activities of Bogolyubov and his students in statistical mechanics and quantum theory.

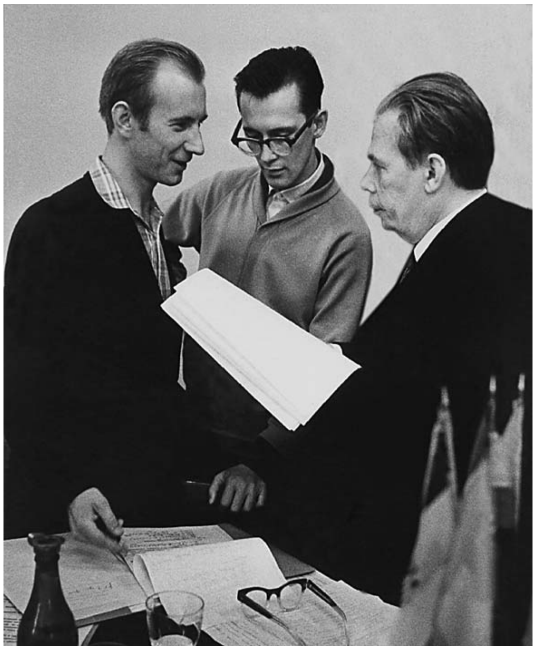
Bogolyubov outlined his universal approach to the integrated description of nature in his report on the theory of superfluidity at a scientific session of the Branch of Physical and Mathematical Sciences of the USSR Academy of Sciences in the fall of 1946. In this report he expressed another universal idea, suggesting a special canonical transformation, ever since called the Bogolyubov ($u-v$) transformation. This equation lies at the basis of his microscopic theory about the superfluidity of Bose and Fermi systems. For these works on statistical methods in mathematical physics and for the construction of dynamic theory in statistical physics, Bogolyubov was awarded the State (Stalin) Prize of the first degree in 1947.

In the spring of 1950, Bogolyubov and his colleagues were sent to Arzamas-16 to organize a computational framework for defense problems. From 1950 to 1953 he worked at the KB-11 Design Bureau, heading the mathematical department that calculated many variations of systems necessary for the creation of the thermonuclear bomb. For these thermonuclear works, Bogolyubov was awarded the State (Stalin) Prize in 1953.

His next very important step in developing a holistic approach to the solution of classical and quantum problems was in the second half of the 1950s and the 1960s, and it was summarized in the world-famous monographs *Problems in the Theory of Dispersion Relations* (jointly with B.V. Medvedev and M.K. Polivanov, 1956, 1958), *Introduction to the Theory of Quantized Fields* (jointly with D.V. Shirkov, 1957, 1959), and *Introduction to Axiomatic Quantum Field Theory* (jointly with A.A. Logunov and I.T. Todorov, 1969).

Today the sphere of application of Bogolyubov's universal approach to the description of nature both at microlevels and at macrolevels has been broadened

V.P. Dzhelelov, Bogolyubov, and D.I. Blokhintsev at the conference on the peaceful use of atomic energy. Geneva, 1958.



B.V. Struminskii, V.A. Matveev, and Bogolyubov. Dubna, 1969.

even more due to the development of quantum field theory options under ultimate temperatures, which, in fact, uses his quantum model of the thermostat, introduced in 1978. The contemporary formulation of Bogolyubov's axiomatic approach to quantum field theory was made public in his fundamental monograph *General Principles of Quantum Field Theory* (coauthored by Logunov, Oksak, and Todorov, 1987). Moreover, within his variation of axiomatics, Bogolyubov was the first to prove dispersion relations for pion–nucleon scattering, for which he had, in fact, to develop a new field of mathematics. In collaboration with his students, Bogolyubov showed the universality of the dispersion relation method both in quantum field theory (jointly with Logunov and Shirkov, 1959) and in statistical physics (in collaboration with S.V. Tyablikov, 1959).

One of Bogolyubov's most important contributions to quantum field theory was, according to many authoritative specialists, the *R*-operation theorem, which he proved in collaboration with O.S. Parasyuk and which was aimed to eliminate the so-called ultraviolet divergences in Feynman's diagrams. The development and application of *R*-operation later became an independent area in mathematical physics. No less important were Bogolyubov's ideas and research devoted to the mathematical problems of equilibrium statistical mechanics, in particular, the extrapolation of Bogolyubov's functional integral method not only onto quantum field theory but also onto quantum statistical mechanics.

Among Bogolyubov's encyclopedic achievements that developed into independent areas of contemporary quantum field theory was the discovery of renormgroup symmetry as an accurate characteristic of the renormalized quantum-field solution for basic Green functions. Bogolyubov constructed, in collaboration with Shirkov and Logunov, the renormalized group method, which has been applied successfully in many fields of theoretical and mathematical physics. The idea about invariant charge of electrons and the concept of the running coupling constant were the most important, and, naturally, these ideas found application in the concept of asymptotic freedom and later in non-Abelian gauge theory.

One of Bogolyubov's universal ideas with a deep general physical content is the introduction to the theory of elementary particles of a principally new quantum number, later termed "color." This idea, developed in collaboration with B.V. Struminskii and A.N. Tavkhelidze, later played an essential role in building the quark model.

Bogolyubov, A.N. Sisakyan, V.G. Kadyshevskii, B.A. Arbuzov, and V.P. Shelest. Dubna, 1976.

V.S. Vladimirov, A.A. Logunov, N.N. Bogolyubov, V.A. Ambartsumyan, A.N. Tavkhelidze, and A.N. Bogolyubov. Dubna, 1979.

It would not be an exaggeration to state that Bogolyubov's most grandiose idea, which has already manifested its general physical nature, is spontaneous symmetry breaking, caused by the degeneration of the basic state. It was first articulated in 1946 in connection with the superfluidity of helium-4. Later, Bogolyubov successfully applied it along with the method of quasi-averages in different problems of statistical mechanics, including the theories of superconductivity and ferromagnetism, as well as in describing nuclear matter and the properties of massive nuclei. After the publication of his works on the theory of superconductivity in 1957–1959, the idea of spontaneous symmetry breaking quickly left the confines of statistical mechanics and became applicable quite effectively in many fields of physics.

Bogolyubov's idea about spontaneous symmetry breaking along with $u-v$ transformation was reflected in the quantum theory of gauge fields as the Higgs mechanism, which is one of the essential elements of the Standard Model of elementary particles and interactions. Bogolyubov, in collaboration with Tavkhelidze and V.A. Matveev, applied the idea of spontaneous symmetry breaking to analyze the color symmetry of hadrons. We cannot exclude that local color symmetry breaking may be confirmed by possible experimental revealing of a phase transition of a population of colorless hadrons to a state of matter where quarks and gluons are free.

We should also mention Bogolyubov's fundamental results in the development of the variational principle in many-body theory, which allow us to consider pairing correlations (the Hartree–Fock–Bogolyubov method), including his pioneering hypothesis of the superfluidity of nuclear matter. This hypothesis was used to substantiate the existence of a superfluid phase in atomic nuclei and was subsequently developed by V.G. Solov'ev and his colleagues when they were studying the structure of complex nuclei.

The Dubna scientific school in the field of high-energy physics and relativistic nuclear physics, which was represented by Bogolyubov's disciples and supporters in many member countries of the Joint Institute for Nuclear Research, successfully continues its founder's traditions. Among Bogolyubov's disciples and followers are members of the Russian Academy of Sciences, the Ukrainian National Academy of Sciences, and the academies of sciences of other countries. We can add to the scientists already mentioned the names of V.S. Vladimirov; V.G. Kadyshevskii; A.A. Slavnov; N.N. Bogolyubov, Jr. (Russia); I.R. Yukhnovskii (Ukraine); Nguyen Van Hieu (Vietnam); M. Mateev (Bulgaria); and D. Stoyanov (Bulgaria).

It is very difficult even to mention all the aspects of this remarkable scientist's broad activities. He published more than 400 scientific articles during his 70-year career, some of which were included in the 12-volume collection of his scientific works, issued in 2005–2009 by the Nauka Publishing House.

Bogolyubov was endowed with a noble mission to become one of the creators of contemporary mathematical and theoretical physics as an integrated science and to lay the cornerstone in the foundation of the universal quantum-field theory of matter that surrounds us. The applications of his ideas are broadening with years.

The state highly appreciated the scientist's research, educational, and organizational activities.

He was awarded the title of Hero of Socialist Labor and the Lenin Prize two times and the USSR State Prize three times and was decorated with many government awards. Among his academic awards are the supreme awards of the USSR Academy of Sciences—the Lomonosov Grand Gold Medal and the Lavrent'ev Gold Medal and Prize. His name was given to an avenue in Dubna; his busts were installed in Nizhnii Novgorod and Dubna. The Institute of Theoretical Physics (Ukraine) and the Laboratory of Theoretical Physics at the Joint Institute for Nuclear Research were named after Bogolyubov.

He was widely recognized internationally: he was elected a member of many foreign academies, bestowed honorary doctoral degrees by some world-famous universities, and awarded international prizes and medals. Bogolyubov combined active scientific work and public activity. He was a deputy of the USSR Supreme Soviet of five convocations and an active participant in the Pugwash movement of scientists for peace.

In his opening address to the International Conference "*Problems of Theoretical and Experimental Physics,"* held in Moscow on September 27, 1999, and dedicated to the 90th anniversary of Bogolyubov's birth, RAS President Academician Yu.S. Osipov said:

> We may put Bogolyubov in line with universal geniuses in human history, such as L. Euler, K.F. Gauss, A. Poincaré, and D. Gilbert. He is comparable with them both in the broadness of his scientific interests and in the depth of penetration into the basic laws of nature, as well as in his influence on the further progress of science. We can clearly see that contemporary mathematics, mathematical and theoretical physics, and mechanics have been developing deeply influenced by his ideas, methods, and scientific achievements.

Decrees of December 2008 by the presidents of the Russian Federation and Ukraine, dedicated to Bogolyubov's centenary, emphasized the great scientist's unique role in the history of science.

An outstanding naturalist and educator, Bogolyubov made a huge contribution to world science. He is the creator of several actively working scientific schools in the fields of mathematics, nonlinear mechanics, theoretical and experimental physics, condensed matter physics, high-energy physics, and nuclear physics. The scientist's works actively contributed to the consolidation of contemporary mathematical and theoretical physics as an independent and actively developing field of science. The study of Bogolyubov's fundamental ideas show what a rich scientific legacy the great Teacher and Master left to his followers.

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