Personalia

NIKOLAĬ NIKOLAEVICH BOGOLYUBOV

(on the occasion of his fiftieth birthday)

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AUGUST 21, 1959 marks the fiftieth anniversary of the birthday of one of the most prominent contemporary theoretical physicists, Nikolaĭ Nikolaevich Bogolyubov. His works have added a number of brilliant pages both to theoretical physics and also to mathematics and mechanics.

Bogolyubov was born in the city of Gor'kiĭ. Already during his school years his abilities attracted the attention of academicians D. A. Grave and N. M. Krylov; in 1923 he began to participate in the seminar of N. M. Krylov, and in 1924 he wrote his first scientific paper. In 1925, although not holding an undergraduate university degree, he was accepted as an exceptional case for post graduate work in the department of mathematical physics of the Academy of Sciences of the Ukrainian S.S.R. and already in 1928 he successfully defended his dissertation on "The Application of the Direct Methods of the Calculus of Variations to Investigation of Irregular Cases of a Simplest Problem." Two years later the Presidium of the Academy of Sciences of the Ukrainian S.S.R. awarded him the degree of Doctor of Mathematics, honoris causa for his work in the field of the calculus of variations and nearly-periodic functions. In 1939 he was elected corresponding member of the Academy of Sciences of the Ukrainian S.S.R., in 1947 he was elected corresponding member of the U.S.S.R. Academy of Sciences, a year later he was elected a full member of the Academy of Sciences of the Ukrainian S.S.R. In 1953 the U.S.S.R. Academy of Sciences elected him to full membership.

Bogolyubov began his scientific career as a mathematician. The works of his first period, some of which were carried out by him jointly with his teacher N. M. Krylov, deal with direct methods of the calculus of variations, to the theory of nearly-periodic functions and approximate solutions of boundary-value differential equations. Already during that period one of the characteristic features of Bogolyubov's scientific gifts had become clearly pronounced; he is, if one may use the expression, a specialist in problems which cannot be attacked by usual methods and require an approach new in principle. A number of results obtained by him at that time have long since become classical; Bogolyubov's mathematical papers have attained widespread international renown and recognition. One of his papers was awarded in 1930 a prize by the Bologna Academy of Sciences (the A. Merlani prize).

Beginning in 1932 Bogolyubov began together with N. M. Krylov the development of a completely new field of science on the borderline between physics, mathematics, and technology — the theory of nonlinear oscillations, which was named by them nonlinear mechanics. In this choice of subject matter a second characteristic feature of the whole scientific activity of Bogolyubov expressed itself: he never goes in for scientific "trivialities" no matter how pretty, but is able at any given moment to find the most important and most timely problem which, on the one hand, is ripe for solution and, on the other hand, needs a solution both as a result of the inner logic of development of science itself, and from the point of view of applications. The investigations in the field of nonlinear mechanics proceeded essentially in two directions: along the creation of methods of asymptotic integration of the nonlinear equations of oscillatory processes, and in the direction of the mathematical foundation of these methods, which amounts to the investigation of the general theory of dynamic systems.

From the mathematical point of view the first direction leads to the investigation of differential equations with a "small" or a "large" parameter and to the derivation of approximate formulas for practical applications. An analogous problem was encountered long ago in astronomy, but there conservative systems were considered exclusively, while both physics and technology, and particularly the very rapidly developing radio technology, required the solution of this problem specifically for nonconservative systems, primarily for generators of oscillations. After overcoming great difficulties of principle, Bogolyubov and Krylov succeeded in extending the method of perturbation theory to general nonconservative systems and in developing new asymptotic methods of nonlinear mechanics. These methods have a rigorous mathematical foundation and allow one (unlike, for example, Van-der-Pol's method) to obtain not only the first, but also the higher approximations. They can be utilized for the study of both periodic and quasiperiodic processes, and, moreover, the practical requirements with respect to the simplicity and the obviousness of the methods of calculation are completely satisfied.

The second direction consists of a qualitative investigation of the general problems of nonlinear mechanics and comes into contact with the abstract theory of dynamic systems. In this field a number of results of fundamental significance is due to Bogolyubov. Thus, he showed the existence of an invariant measure, introduced the concept of an ergodic set, and established theorems on the resolution of the invariant measure into "irreducible" invariant measures "localized" in ergodic sets. These results of his were later developed and generalized in the work of other investigators.

By the beginning of the 1940's Bogolyubov's papers had placed him among the most prominent mathematicians and researchers in the field of mechanics.

The investigation of asymptotic methods naturally led the scientific interests of N. N. Bogolyubov in the direction of statistical mechanics and statistical physics. This prepared him for the third, perhaps most fruitful period of his scientific activity, in theoretical physics, to which he brought his exceptional mathematical experience and brilliant technique.

The very first applications of asymptotic methods to the problems of statistical mechanics already enabled Bogolyubov to obtain very important fundamental results with respect to the establishment of equilibrium in a system in contact with a thermostatic oven, and also with respect to the effect of a random force on a harmonic oscillator. It was shown that, depending on the approximation used and on the choice of the time scale, the same random process can be regarded either as a dynamic process or as a Markov process, or, in the general case, as a certain non-Markov process. Using as an example the model of a harmonic oscillator interacting with a set of a large number of similar oscillators ("thermostatic oven") Bogolyubov investigated in detail the origin of the irreversible process of the establishment of statistical equilibrium. In doing this he succeeded in showing with complete rigor that after a sufficiently large time interval the distribution density approaches the well known Gibbs function.

A number of Bogolyubov's investigations is devoted to the statistical physics of classical systems. In these papers he developed the method of distribution functions and generating functionals for the solution of the fundamental problem of statistical physics — the calculation of thermodynamic functions in terms of the molecular characteristics of the substance. In these papers he gave a complete and wholly consistent theory of imperfect gases, which includes as particular cases all the approximate results previously known (the Ursell-Meyer expansion, the Debye theory etc.). The same method also provides a key to the development of the statistical theory of liquids.

The application of the formalism of distribution functions to the case of nonequilibrium processes enabled Bogolyubov to approach from a unified point of view the theory and the method of construction of kinetic equations for systems of interacting particles. This method was utilized to investigate the problem of deriving the equations of hydrodynamics from the classical mechanics of a system of n interacting particles. On the basis of very general assumptions it was shown that the first approximation gives the equations of motion for an ideal fluid, while the second approximation should give the equation for a viscous fluid. Many investigators used this method later to solve a great variety of specific problems of the physics of condensed systems.

The application of the method of distribution functions to the case of quantum systems enabled Bogolyubov to obtain a general method of constructing kinetic equations for systems of this type. In this way he succeeded in introducing essential modifications to the generally accepted scheme of binary collisions, and in bringing out the effects of the collective interaction of the particles of the system.

The well-known difficulties associated with the quantum symmetry of the density matrix led him to utilize in problems of statistical physics the method of second quantization, which at that time was not yet very widespread, (whereas at present it is one of the basic methods in the field). In this connection Bobolyubov developed the method of approximate second quantization, which allowed him in a number of cases to simplify appreciably the solution of the many-body problem without losing at the same time its specific qualitative features. When this method was applied to the theory of metals it led above all to the possibility of constructing a consistent scheme of the Shubin-Vonsovskiĭ polar model and turned out to be very effective for the solution of a number of specific problems of the quantum theory of ferromagnetism.

The basic series of Bogolyubov's papers on the theory of the degeneracy of imperfect gases is very closely associated with the above method. The investigation of the "condensation" of an imperfect Bose gas, which was first carried out by him in 1947, was the first step towards the formulation of the microscopic theory of the superfluidity of helium II. In that paper he demonstrated, in particular, the supremely important fact that the property of superfluidity may be possessed only by a gas with interactions, but not by a perfect gas. Moreover, it turned out that the most significant role was played by the interaction of particles with oppositely directed momenta. It is very essential that in spite of the weakness of the interaction, the usual perturbation theory here turned out to be inapplicable in principle, and the necessity arose of developing a completely new method of calculation.

Ten years later the subsequent development of the ideas and the methods of this paper enabled Bogolyubov (independently of the somewhat earlier work of Bardeen, Cooper and Schrieffer) to formulate a consistent microscopic theory of superconductivity. Fröhlich's idea of the decisive role of the interaction of the electrons with the lattice vibrations played an essential part in the understanding of the essence of the phenomenon of superconductivity. However, owing to the great purely mathematical difficulties no one succeeded for a long time in solving the problem on the basis of the Hamiltonian proposed by Fröhlich. This led Bardeen, Cooper and Schrieffer to simplify the problem drastically by making use of a model Hamiltonian. The method used by them for solving the problem was likewise open to a number of objections. The consistent solution obtained by Bogolyubov permitted one not only to explain in an exhaustive manner the phenomenon of superconductivity, but also to establish the fact that superconductivity can be regarded as the superfluidity of the electron gas in a metal. This fact is of fundamental significance, because for a long time superfluidity was considered to be a specific property of Bose systems. However, it now appears that, under certain conditions, systems of Fermi particles may also possess the property of superfluidity; in particular, the system of protons and neutrons forming the atomic nucleus may also turn out to be superfluid. In the course of these investigations Bogolyubov developed a new powerful method of solving the many-body problem, a method that represents a far-reaching generalization of the well-known Hartree-Fock method.

Perhaps the example of the theory of superconductivity illustrates most clearly one more feature which is very characteristic of Bogolyubov's scientific style. The most important problems of contemporary theoretical physics are characterized, as a rule, by exceptional mathematical complexity. As a result of this, even if no deficiencies of principle exist in the foundations of the theory, in a number of cases the computational difficulties are so great that they may transcend into difficulties of principle; this, in particular, is the situation in the nonrelativistic many-body problem. In solving problems of this type it is exceedingly important to provide the degree of rigor required for the correct solution of these problems. It is just such an ability, bordering on art and based on brilliant physical and mathematical intuition, which is the outstanding characteristic of Bogolyubov's scientific creative activity.

For the solution of problems in statistical physics Bogolyubov makes wide use of methods of quantum field theory (we note separately, in addition to the papers mentioned earlier, further papers on the investigation of the behavior of a particle in a quantized field, and also the method of quantum Green's functions currently being developed by him, which shows great promise). This is not accidental. Bogolyubov is perhaps one of the first to understand thoroughly the deep (and now seemingly natural and obvious to everyone) mathematical and physical relationship between the nonrelativistic many-body problem and quantum field theory. Here we see a clear demonstration of his ability to pick out in several branches of physics the common elements that at first sight might appear to be widely different, and it is this ability which makes possible the fruitful mutual transfer of ideas and methods. It is, therefore, not surprising that the work on statistical physics was followed by an extensive series of deep investigations into the foundations of contemporary quantum field theory.

Chronologically the first among these papers was the development of a new approach to quantum field theory. In renouncing the well known ideas of Heisenberg, Bogolyubov also rejected the usual Hamiltonian method, and formulated the theory only in terms of the scattering matrix on which he imposed the physically obvious conditions of correspondence with the unquantized theory, of relativistic invariance, of unitarity, and of causality. Within the framework of the usual assumptions (of the possibility of expanding the S-matrix in powers of the coupling constant, and of the adiabatic application and removal of the interaction) this method was found to be equivalent to the Hamiltonian method.

In carrying out this program, the insufficiency of the usual formalism of classical analysis for the description of concepts appearing in quantum field theory was demonstrated. As Bogolyubov has shown, physics was confronted in this field with the so-called generalized functions (the simplest example of which is the well known Dirac δ-function) which were introduced into mathematics not long beforehand. In this connection he developed the rules for operation with such functions (the operation of multiplication), as a result of which it turned out that the so-called "divergences" of the individual terms of the perturbation-theory series are due to incorrect mathematical handling of generalized functions. In this way he clarified for the first time the true meaning of the renormalization technique, which until then represented nothing more than a purely formal prescription. Further investigations of the renormalization procedure have led Bogolyubov to the discovery of the group of finite renormalizations, which turned out to be extremely convenient for the effective improvement of perturbation theory formulas, and which is now widely used in specific calculations both in quantum field theory itself, and also in the nonrelativistic many body problem.

In 1956 Bogolyubov gave the first rigorous proof of the dispersion relations between the real and the imaginary parts of the scattering amplitude. This should be recognized as a fundamental achievement, since the dispersion relations represent so far the only known exact result in quantum field theory which is not associated with the expansion of anything into a series. It is therefore particularly important to know what are the basic physical principles from which they can be derived. This question is precisely the one the physical discussion of which requires mathematical rigor. The proof given by Bogolyubov enables one to utilize the dispersion relations for checking the fundamental hypothesis of the locality of the interaction. For this proof it has been necessary to utilize a subtle mathematical technique, quite unusual in theoretical physics, which synthesizes the methods of the theory of generalized functions and the theory of functions of several complex variables. By now this mathematical technique has been mastered by a large number of theoreticians, and the whole field of investigations associated with the study and the use of dispersion relations and spectral representations is now undergoing a period of very active development.

In addition to his scientific activity, Bogolyubov devotes a large amount of attention to the training of new scientific forces and to scientific organizational work. Since 1936 he has held chairs first in the Kiev State University, and now in the Moscow State University. During four years (1946-1949) he was dean of the Faculty of Mechanics and Mathematics of the T. G. Shevchenko Kiev State University. N. N. Bogolyubov has directed the work of a number of divisions of the Academy of Sciences of the Ukrainian S.S.R.; more recently he has been heading the division of theoretical physics of the V. A. Steklov Mathematical Institute of the U.S.S.R. Academy of Sciences and is the Director of the Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research.

Bogolyubov has been responsible for the education of many accomplished scientists who now themselves have pupils. He has supervised the completion of approximately 50 theses for the candidates' and the doctors' degrees. Bogolyubov has created schools of nonlinear mechanics (in Kiev) and of theoretical physics (in Moscow, Dubna, and Kiev). The ranks of his pupils are continually replenished by talented youths. One cannot fail to be surprised by the extraordinarily many-sided character of N. N. Bogolyubov's abilities. With equal success he directs both abstract mathematical investigations and also work on the most practical problems, for example, in the theory of solids.

N. N. Bogolyubov is the author of approximately 200 scientific papers and 15 monographs. His scientific and public activities have been highly appreciated by the scientific community, by the party, and by the government. N. N. Bogolyubov is a laureate of the M. V. Lomonosov prize, twice the laureate of the Stalin prize, and in 1958 he was awarded the Lenin prize. He has been decorated six times, of this twice with the Order of Lenin.

List of N. N. Bogolyubov's principal publications

A. Articles

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[3] On the Approximation of Functions by Trigonometric Sums. Dokl. Akad. Nauk S.S.S.R. **6**, 147-152.

[4] On the Theory of Indicating Instruments. J. phys. radium, ser. 7, **1**, 77-92 (1930) (with N. M. Krylov).

[5] On Some New Methods in the Calculus of Variations. Ann. Math., ser. IV, **7**, 249-271 (1930).

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[18] On an Application of Perturbation Theory to the Polar Model of a Crystal. JETP **19**, 251-255 (1949) (with S. V. Tyablikov).

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[22] On the Invariant Formulation of Quantum Field Theory. Dokl. Akad. Nauk S.S.S.R. **74**, 681-684 (1950) (with V. L. Bonch-Bruevich and B. V. Medvedev).

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