S. I. VAVILOV'S WORKS ON PHILOSOPHY AND THE HISTORY OF NATURAL SCIENCE

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S. I. Vavilov was one of those outstanding natural scientists who allot an exceptional amount of attention to the philosophical problems of science and the history of scientific knowledge. Even a thorough and detailed discussion of their special, professional work, work which brought them well-earned praise, will not give a correct and integral picture of the spiritual aspect of these scientists if their ideas relating to philosophy and the history of science are passed over in silence. Their interest in philosophical problems is not the product of a transitory enthusiasm. No, this interest does not weaken with the years, but increases and grows stronger. In the process it does not displace or push into the background the scientist's professional work, but deepens and broadens it, indeed, gives it classical significance and perspective. Such was the case in the life of S. I. Vavilov.

Studying Vavilov's work we see what a wide field of philosophical problems his mind worked on, and what brilliance his exploration in this area lent to special investigations.

Philosophy and physics were not isolated from one another in Vavilov's work, but were fused together into something united and indivisible. They aided and mutually depended upon one another. Vavilov based important gnosiological conclusions on his celebrated experiments dealing with the interference of extremely low-intensity light rays. On the other hand, when constructing his theory of the microstructure of light, he adapted philosophical ideas drawn from the animating source of materialistic dialectics to the development of a purely physical theory of luminescence.

An enduring interest in philosophy and the history of science dates back as far as Vavilov's youth. As a pupil of the Moscow Commercial School, he loved to give reports on philosophical themes in the self-instruction circle he founded. Second-hand booksellers could not help remembering the tall youth with close-cut hair who appeared a hundred times among their stores of books by the walls of Kitaĭ-gorod and Sukharevka, on Mokhovaya street. Here he searched out the classic works of science which, like landmarks, record the states of world knowledge.

The day arrived when Vavilov became acquainted with a book on whose cover he read: "Vl. Il'in, Materialism and Empirico-Criticism. Critical Notes on a Reactionary Philosophy." This book was destined to enter his life for good. It left an indelible impression on his philosophical convictions. We may say without exaggeration that it was Vavilov's favorite book. He wrote a number of works especially dedicated to this book of Lenin's, full of admiration for its wisdom, the fineness of its analysis, its masterful disclosure of the erroneousness of idealism, and its incomparable skill in posing new scientific problems and foreseeing the future of science.

Already in his early works Vavilov insistently emphasized the necessity for a creatively working scientist to have a consciously philosophical approach to his research work. He energetically combatted the "philosophical indifferentism" appearing in the first decades after the October Revolution on the part of a certain sector of natural science specialists. He showed that the philosophical premises of science and the world outlook of scientists are not extraneous and unimportant to science itself but have decisive value for its development. Vavilov emphasized that an indifferent, scornful attitude towards philosophy on the part of natural scientists is none other than "the result of a profound delusion and of the absence of a critical attitude first of all towards their own work" ("The New Physics and Dialectical Materialism," Collected Works, Vol. III, p. 38). In this connection he recalls the significant warning of F. Engels concerning those natural scientists who inveigh against philosophy but in fact remain the slaves of very bad philosophical systems. "Natural scientists inclined against philosophy assume," wrote Vavilov, "that conscientious scientific research is possible without any sort of philosophical premise. However, even a superficial analysis of a specific scientific work always reveals the philosophical background (of which the author may or may not be conscious) on the basis of which the work is carried out and conclusions are drawn. Furthermore, the philosophical premises are far from being unimportant for the conclusions and for the direction of future work: they can serve as either brake or stimulus to the development of science" (ibid., pp. 38-39).

Vavilov corroborates this with examples, showing the progressive value of materialistic philosophy for the development of science and the reactionary role of idealism. A man of modern natural science must abide by the principles of a modern scientific philosophy. Only dialectical materialism is such a philosophy. "That is why," indicates Vavilov, "no other philosophy besides dialectical materialism can be taken as the basis for progressive natural science, in particular for advanced physics" (ibid., p. 39).

With passion and zeal Vavilov summons Soviet scientists to "learn to follow the path of dialectical materialism"; he himself learned to do so and then confidently went along this, the only true path.

Vavilov's presentation of the necessity for inculcating dialectical-materialistic methodology into the research work of natural scientists helped our party in its fight for a Marxist-Leninist training of the cadres of the Soviet intelligentsia. It played an important part in swinging them to dialectical materialism.

Propagandizing the ideas of dialectical materialism, Vavilov in his works showed the theoretical power of Marxist-Leninist philosophy, the triumph of all of its basic tenets, the amazing far-sightedness of the Marxist classics in predicting science's course of evolution.

Vavilov shows in the achievements of the contemporary science of light and matter the correctness of materialistic dialectics and its law of the unity and war of opposites. He uses the discovery of the transformability of "elementary" particles of matter into one another, their changeability, and the establishment of the wave nature of microobjects to confirm Lenin's idea of the inexhaustability and deep-down infiniteness of matter. The establishment of the dependence of space and time properties on matter, its motion, and distribution serve Vavilov as a verification of the dialectical-materialistic teaching that space and time are basic forms of matter, inseparable from and determined by moving matter itself.

Vavilov tried to reveal the philosophical essence of each of those great contributions which contemporary physics, in its headlong race, was continually bestowing. He always knew the latest scientific news, and his quick and accurate mind succeeded in philosophically analyzing results which had only just come out of the laboratories and were still only the property of specialists. All this lent unusual freshness and originality to Vavilov's ideas.

In the course of the development of science its concepts, representations and theories change. The historical process of change in scientific representations of the structure and properties of matter, as of space and time, provided Vavilov with convincing material to illustrate the truth and omnipotence of Lenin's teachings on objective, relative and absolute truth. "Studies on the structure of matter," he said, "wave mechanics with its immense wealth of results, and the new studies on space and time—there we have three main roads over which the revolution in physics has rolled for 30 years. All three roads lead to dialectical materialism, revealing the authentic dialecics of nature, and Lenin's prognosis has turned out to be completely accurate" ("The New Physics and Dialectical Materialism," Collected Works, Vol. III, p. 36).

Vavilov understood very well that the successful philosophical generalization of the results of modern physics and its successful development are impossible without a combat with idealism. In a number of works he gave an accurate, concrete and convincing critique of various myths held by "physical" idealists. He devoted special attention to revealing the bankruptcy of the indeterministic ideas which the "physical" idealists were trying to establish with reference to quantum mechanics.

Demonstrating with zeal and ardor that "for the new physics the method of materialistic dialectics has become a necessity" ("Physics," Great Soviet Encyclopedia, 1st edition, vol. 57), Vavilov himself creatively applies this method to the solution of a number of the urgent problems of modern physics. He deserves the credit for working out the dialectical-materialistic representation of a field as a special, qualitatively distinctive form of matter, a representation that has become generally recognized. This was not the case, however, when Vavilov first began to investigate the problem. Numerous incorrect concepts of a field existed in physics—it was "radiant energy," "a physical space," "an auxiliary mathematical concept," etc., and these erroneous viewpoints, which hindered the evolution of physics, had to be overcome. Identification of the field with energy closed the way to a correct understanding of many phenomena, for example the transformation of an electron and a positron into photons or particles of light; it led to the idealistic conclusion that matter "is transformed" into motion, which allegedly exists without matter. To say that a field is "a physical space" means to identify matter with one of the forms of its reality and to tolerate the absurd idea that matter is transformed into its own form of being. To assert that a field is an "auxiliary mathematical concept" means to directly reject the principle of conservation of matter and by the same token radically undermine the bases of science altogether.

The creative solution to this problem given by Vavilov removed all difficulties and became an important conquest of materialistic ideology. Furthermore, the bankruptcy of the recurrent idealistic cry, "Matter has disappeared!" (based on references to the "annihilation" of electron-positron pairs) became completely obvious. This remarkable phenomenon discovered by modern physics was revealed as a process for transforming material objects of one type (electrons and positrons) into material objects of another, qualitatively different type (electromagnetic field particles or photons).

Vavilov investigated deeply the question of the existence of conservation laws and their role in an epistemology of nature. He showed that all the most complex and delicate problems of physics are invariably governed by the conservation laws, which function as the principal and resolving criterion expressing the fact that matter can neither be created nor destroyed. "More than ever," wrote Vavilov, "the principle of the conservation of matter serves as a reliable guide to the discovery of the secrets of nature" ("Lomonosov's Law," Collected Works, Vol. III, p. 103). He pointed out the internal connections between the individual conservation laws, which express various aspects of the conservation of a single, moving matter. His works aided greatly the development of a correct understanding of one of the most important laws of modern physics—the relation between mass and energy expressed by the formula $E = Mc^2$. He decisively emphasized that the often-encountered assertion that this law signifies the convertibility of mass into energy is erroneous.

A similarly distorted interpretation of the relation between mass and energy has been adopted by "physical" idealists to substantiate the "newest" energetics. Mass is incorrectly identified with matter, and the conclusion is drawn that matter is transformed into energy which exists without matter. The development of a correct understanding of the law $E = Mc^2$ as a law of the interrelation of mass and energy undermined the basis of contemporary idealistic energeticism.

Vavilov's investigation of the essence of the so-called particle-wave dualism (the discovery by modern physics that microobjects possess both particle and wave properties) achieved results of fundamental importance. There was no question of the presence in microobjects of both kinds of properties, since this had been demonstrated by direct experiments. The problem was to establish the relation between these properties. Were these attributes externally contiguous and separable or were they interpenetrating and indivisible? This problem was important from both purely physical and philosophical points of view. A number of eminent scientists construed the corpuscular and wave properties to be "complementary," i.e., as two properties of which the first is found under certain conditions, the second under other, incompatible conditions. In other words, instead of a formula expressing the interpenetration of the contradictory aspects of the microbject—"both corpuscle and wave"—the dilemma "either corpuscle or wave" arose, expressing the idea of their mutual exclusiveness.

Such an opinion took into account in its own way the inevitability of a dialectic splitting up of the one into contradictory parts or aspects, but it did not take the decisive leap to a unification of these aspects, to their organic synthesis.

Vavilov understood the necessity of correcting such a viewpoint. He was conscious of the urgency of establishing the unity and interpenetration of the opposites. And he did establish it. He took a "typical wave" phenomenon, interference, where according to the complementarity dilemma only the wave properties should exist. Using for the first time in the study of interference light rays of the lowest possible intensity, Vavilov discovered that the usual interference picture took on completely new lines: the brightness of the light bands varied irregularly instead of remaining constant. As analysis of the phenomenon showed, the random variations or fluctuations in intensity were without a doubt a sign of the corpuscular nature of light, while of itself the presence of light and dark interference fringes indisputedly confirmed, in the very same experiment and under the very same conditions, the wave properties of light. It inescapably follows that the contradictory corpuscular and wave properties come in an indivisible unity, an organic union. "Nature," wrote Vavilov, "unrolls before our eyes in an interference pattern the dialectical antithesis and synthesis of its contradictory parts..." ("The Dialectics of Light Phenomena," Collected Works, Vol. III, p. 20). He emphasized that this is "a picture of the unity of opposites—regular waves and disorderly corpuscles—in the same event..." (ibid., p. 19). Vavilov's conclusion, of course, relates not only to light but also to other forms of matter.

The establishment of the unity and interpenetration of the contradictory aspects of microobjects was a considerable scientific victory.

Vavilov's works disclose many features not only of the dialectics of nature but also of the dialectics of the development of knowledge.

His "The Dialectics of Light Phenomena" is a sparkling essay on the dialectics of knowledge of light phenomena, which covers the long development of optics, yet is expressed in a short and extremely elegant form. Here a picture is given of the gradual penetration of human thought into the essence of light—a penetration which, in the words of Lenin, proceeds along the path of the splitting of the unity and knowledge of its contradictory parts to culminate in their synthesis. Lenin saw in the thesis of the splitting of the unity and the knowledge of its contradictory parts the essence of dialectics. He posed the task of verifying the correctness of this aspect of dialectics from the history of science (see "Philosophical Notebooks," Moscow, 1947, p. 327). Vavilov carried out the verification as applied to the history of knowledge about light, which is an important part of the history of natural science in general.

He analyzed philosophically such methods of research, long applied to physics, as the "method of principles" and the "method of hypotheses." He succeeded in showing that, in spite of these being opposites, they cannot exist without each other and are interpenetrating. He rendered indisputable the conclusion that "along with principles, hypotheses have had and have enormous moving value in the development of science" ("Newton and the Present," Collected Works, Vol. III, p. 285).

Newton's maxim "hypotheses non fingo!" is well known. The picture of Newton as a fiery opponent of hypotheses, not allowing them at all in his own works and steadfastly adhering to his own method or principles, is a familiar one. This gave many scientists fundamental justification for neglecting to seek hypotheses about the inherent nature and hidden essence of phenomena. Vavilov showed that not only did Newton not avoid hypotheses, but he actually used them widely when applying the method of principles. For the first time, thanks to Vavilov's profound analysis, Newton appeared as the "shining master of the hypothesis, undoubtedly surpassing the majority of his contemporaries in this art" ("Isaac Newton," Collected Works, Vol. III, p. 365).

The evolution of modern physics has brought much that is new not only into the perfecting of experimental research instruments but also into theoretical methods. Drawing inferences from research practice, Vavilov developed an understanding of the method of mathematical hypothesis or extrapolation. This method is actually used widely and successfully in modern physics, but before Vavilov it had not undergone a philosophical analysis, nor had an attempt been made to define it as a special method. Vavilov revealed the essence of this new method, its power and possibilities, and described those regions of natural phenomena in which it is inescapable.

Vavilov notes that when applying the mathematical hypothesis method "the simplicity and orderliness of the expressions obtained is also an important consideration" ("Lenin and Contemporary Physics," Collected Works, Vol. III, p. 79). This consideration is quite widely resorted to in the works of theoretical physicists. It is not ordinarily mentioned by philosophers because of its certain external resemblance to the positivistic "principle of the economy of thought" or the "principle of convenience." But in essence it is not at all the same as the Machist requirement of "economy of thought" or "convenience". The viciousness of the positivistic "principle of the economy of thought" lies in the fact that thought is considered as the demiurge of reality, as the author of natural laws foisted on nature by a cognizant subject and constructed by him according to the "law" of the economy of thought.

The consideration of simplicity and orderliness applied by working scientists when creating physics theories is not a requirement they impose on nature and its laws. It does not refer to the external world but to its reflection which they have constructed in thought. This conceptual reflection must be so composed that the relations between all its parts are presented in the simplest and clearest form, that the different concepts are not a disorderly heap of categories but form if possible an orderly system in which the less essential and derivative is subordinate to the more essential and basic. But no orderliness and simplicity force the scientist to cling to his theory if it contradicts objective facts. The consideration of simplicity and order is thus always subordinate in science to the criterion of objective truth, and is always used in connection with this criterion. When the theoretical physicist conforms to the consideration of simplicity and orderliness, he arranges the internal structure of his theory in such a way as to place the elements according to their relative value; he brings out the most important and separates it from the less important, and traces the logical connections between various concepts as intelligibly as possible. By this orderly work the scientist gropes for that objective subordination of essences and phenomena which is to be found in nature itself.

The ever-increasing application of mathematics to physics research is in itself a sufficiently obvious and well-known fact, behind which, however, Vavilov revealed a fundamental change of mathematics' role in theoretical physics. He showed that formerly mathematics played a purely technical and auxiliary role in the creation of scientific theory, which amounted to performing quantitative calculations within the framework of already-formulated theory. In modern physics it has acquired enormous heuristic and directive value, and become a primary tool for changing theory and developing its initial principles.

Vavilov had many valuable ideas on the subject of experiment, the fountainhead of scientific knowledge. Here, being able to see the profound contradictions in the very heart of the subject, he brilliantly demonstrated his mastery of dialectics. Following Lenin, Vavilov shows that experiment is a relative criterion of truth with a historically limited framework in which it reveals the essence of phenomena to human thought. In the history of science a dispute between conflicting, contradictory views and theories is usually resolved by so-called experimenta crucis—"decisive experiments." The sentence they pass is considered forever final and irrevocable. Vavilov showed by a number of convincing examples the relative importance of decisive experiments, the incompleteness of the truth they convey. For example, Foucault's experiment showed that the velocity of light in an optically denser medium is less than its velocity in a vacuum. This experiment dealt a deathblow to Newton's then supreme corpuscular theory of light; the latter had been verified by other experiments which, however, did not reveal the whole truth. It was concluded on the basis of Foucault's experiment that no corpuscular theory of light could exist. However, contemporary light theory has robbed this conclusion of its absolute value. The importance of Foucault's experiment has been reduced.

Vavilov analyzed such characteristics of the experiment as its inevitable, historically conditioned inaccuracy. This limitation would seem to be a very regrettable circumstance which can only hinder the progress of science. Vavilov revealed the actually positive side of this fact, which facilitates rather than impedes the forward motion of science. He brought forward as evidence a number of convincing facts from the history of science. Thus, Newton used a not very perfect monochromator in his optical research, thanks to which his experiments went in such a way that the phenomenon of fluorescence, which might have been observed, escaped his attention. In making a spectral analysis, certain deficiencies in his apparatus prevented him from observing dark lines in the solar spectrum—the so-called Fraunhofer lines, discovered only long after Newton with apparatus of almost the same accuracy as his. Not having observed these phenomena, Newton formulated a series of simple principles of optics which form the basis of the science of light. A discovery by Newton of both fluorescence and the dark lines, Vavilov emphasizes, would have made it incredibly difficult to arrive at the basic optical principles and proceed to the whole normal development of optical theory.

"Before us," concludes Vavilov, "is the not infrequent example of how the imperfection of an experiment aids the development of science. It is hard to imagine the confusion in optical concepts which would have arisen had the Stokes shift (i.e., the change in wavelength in fluorescence—Author) been discovered in the seventeeth century" ("Principles and Hypotheses of Newton's Optics," Collected Works, Vol. III, pp. 111—112).

Thus the historically transient imperfection and limitedness of experiment is transformed into a condition for the progress of scientific thought, which moreover invariably removes the imperfection and the limitedness. This is one more feature of the complex and contradictory dialectics of knowledge revealed by Vavilov.

An incomparable master of modern physics as well as a fine philosophical thinker, Vavilov was also a very great specialist in the history of science. To his pen is due a fundamental scientific biography of Newton which is unique in all of world literature in its unusual wealth of ideas, as well as a number of profound writings on special aspects of the work of this brilliant scientist. Vavilov also contributed in a valuable way to the investigation of the life and activity of Galileo. He wrote studies on Lucretius, Faraday, Michelson, and other foreign scientists.

Vavilov saw that one of the most important tasks of Soviet science historians was to reveal fully the great role of Russian scientists in the evolution of world science. Thousands and thousands of readers are familiar with his brilliant papers on V. V. Petrov, P. N. Lebedev, A. N. Krylov, P. P. Lazarev, and other Russian scientists.

Vavilov's studies on the life and scientific work of M. V. Lomonosov, the founder of Russian science, are a tremendous contribution to the history of our native science. At his initiative and under his direction, intensive searches for new materials describing this genius son of the Russian people were conducted, and many studies of Lomonosov were prepared and published. Under Vavilov's editorship the complete, authentically scientific edition of Lomonosov's works began to appear. Vavilov was, essentially, the initiator of Soviet Lomonosov study.

He was a very great historian of Soviet science; he outlined its development and described its fundamental features.

Vavilov also revealed in the area of the history of natural science his characteristic profundity of thought and his ability to approach the problem before him thoroughly, indeed dialectically. He came out against a "one-dimensional," as he put it, picture of the evolution of science in which the living connection between science and social life, science and the historical situation, was missing. He underlined the enormous role of practice and technology in the development of science, and traced the connection between scientific theories and the struggle between materialism and idealism. He indicated that "the basic task in studying the development of knowledge must be the restoration of the vital dialectical process, which in the face of complex, unforeseen circumstances, struggle and change approaches mankind to the truth" ("Foreword," Collected Works, Vol. III, p. 795).

We are far from having considered everything touched on by Vavilov's inquiring intellect, about which he had his own novel opinions. Only a part of his accomplishment in philosophy and the history of natural science has been illuminated. But from what we have said the fascinating picture emerges of a remarkable scientist, whose thinking bequeathed to both philosophy and the history of science truly invaluable gifts, such as delight anyone seeking the way to scientific truth.

Translated by Mrs. J. D. Ullman