V. Gott

THIS AMAZING, AMAZING, AMAZING BUT KNOWABLE UNIVERSE

In **This Amazing, Amazing, Amazing but Knowable Universe,** V. S. Gott examines some of the philosophical issues of modern physics—matter and motion, the uncreatedness and indestructibility of matter, the heuristic role of the laws of physics, the dialectic of the absolute and the relative in cognition. The principal design of this book is to demonstrate that modern science develops along the line of increasingly profound reflection, in scientific laws and categories, of the infinite diversity of the material world.

V. S. Gott, professor of philosophy, head of chair and editor-in-chief of the magazine *Filosofskiye nauki,* has greatly contributed to the elaboration of many problems of dialectical materialism and the philosophy of science. He is the author of a number of scientific papers and articles. In a radically new way he approached the problem of discreteness and continuity, the principles of symmetry, etc.

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Progress Publishers
Moscow

Translated from the Russian
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УДИВИТЕЛЬНЫЙ, НЕИСЧЕРПАЕМЫЙ,
ПОЗНАВАЕМЫЙ МИР

На английском языке

First printing 1977

Г $\frac{10502\text{-}816}{014(01)\text{-}77}$ 62—77

CONTENTS

INTRODUCTION

An enormous, fascinating and to a large extent unknown world surrounds man from the first moments of his existence down to the moment when he draws his last breath. Resting on preceding generations' advances in science and culture, each new generation makes its own contribution to our knowledge of the unknown.

The more man knows, the more clearly he understands that there is still something unknown to be sought, for example, in atomic nuclei, in the structure of "elementary" particles, in the deeps of space, in the depths of the Earth; that we need to uncover the secret of the origin of life from non-life, to grapple with many unsolved problems.

The presence of the unknown gives rise to two contradictory feelings: pessimism in some, optimism in others, and this makes the question of the world's cognizability most relevant. However, this question passes beyond the limits of natural sciences into the realm of philosophy.

We should immediately make clear the sort of philosophy we are referring to. In the history of philosophy, millennia passed before the pre-scientific philosophy of Babylon, Egypt, Ancient Greece, Mediaeval Europe, of the 18th and the first half of the

19th centuries, was supplanted by the scientific philosophy of Marxism-Leninism. There is nothing in this assertion to belittle what was done by the great philosophers of the past—Democritus, Plato, Aristotle, Descartes, Spinoza, the French materialists of the 18th century, Kant, Hegel, Feuerbach and many others. We have something else in mind. Even the most brilliant pre-Marxist philosophers were limited in their work by the historical framework within which they lived; they could not create a scientific philosophy. Only after capitalism had become the dominant economic system in a number of European countries and the proletariat had emerged into the historical arena as a class able not only to free itself from exploitation but also, by means of revolutionary upheaval, to eliminate the exploitation of man by man, only when the natural sciences began to advance rapidly, were the necessary conditions present for the emergence of a scientific philosophy that could serve as the theoretical basis for the world outlook of the most progressive class in human history—the working class.

Karl Marx and Frederick Engels, generalizing from the experience of the workers' movement and the achievements of natural science, and making use of—and critically reworking—the best of earlier philosophy, worked a major revolution in philosophy, creating the philosophy of dialectical materialism, which is a creative, developing doctrine on the most general laws of nature, human society and thinking. After Marx and Engels, scientific philosophy was further developed in the works of V. I. Lenin, his followers and disciples and in the documents of Communist and Workers' parties throughout the world.

In order to explain to the reader the idea of this book, I shall permit myself a short digression of a personal nature. While still quite young, my attention

was caught by many phenomena in nature and social life, and I sought for explanations in books on physics, astronomy, chemistry, biology and the history of the workers' movement; I also became interested in archaeology, the history of art, philosophy and world history. I read unsystematically Orest Khvolson, Élisée Reclus, Camille Flammarion, Francis W. Aston, and Plato, but only when I read Engels' *The Development of Socialism from Utopia to Science* at age 15, and somewhat later Lenin's *Materialism and Empirio-Criticism*, did I realize that it was necessary to select a clearly delimited range of questions to the study of which one should dedicate one's life. I understood, too, and subsequent years confirmed it, that intense study of finite scientific problems is most effective given a broad approach, on the basis of the general methodology of Marxism-Leninism. Since that time the study of the natural sciences and philosophy have for me been a single process.

Many years later, I came across a remark by the well-known French physicist, Paul Langevin, which beautifully expresses the naturalist's relationship to Marxism-Leninism. Speaking in December 1938 at a conference of the French Communist Party, Langevin said:

"To your Party has fallen the honor of closely uniting thought and action.

"A Communist, it is said, must constantly learn. I want to say that the more I learn, the more I feel myself a Communist.

"In the great communist doctrine developed by Marx, Engels and Lenin I found the answer to questions relating to my own science, and I would never have found it without this doctrine."[1]

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[1] **World Marxist Review**, No. 2, February 1972, p. 45.

At first independent study of some of the Marxist-Leninist classics, especially on philosophy, and then systematic study of them at the university level, helped me, as it did many of my colleagues, to carry out research in the physics of the atomic nucleus, a problem with which I was concerned for more than ten years, and then in other research.

The son of a worker and myself a worker, in 1930, after completing the workers' courses I entered the first year of the newly established department of physics and mechanics at the Kharkov Mechanical and Engineering Institute, simultaneously beginning work at the Ukrainian Institute of Physics and Technology (IPT), which had opened in the same year.

Young physicists from Leningrad formed the nucleus of the Ukrainian IPT. Under their benevolent influence, theoretical and experimental physics began to make rapid strides in the Ukraine. The personnel constituted a harmonious, international research group. The Leningrad physicists L. Landau, I. Obreimov, A. Leipunsky, K. Sinelnikov, A. Valter, V. Gorsky, L. Shubnikov, among others, in addition to carrying out an immense amount of research, began to train physicists for the research institutes and industry of the USSR, the Soviet Ukraine included.

There was only a slight difference in age between ourselves—students and laboratory assistants—and our professors and academic advisors. In 1933, when Landau taught our course on theoretical physics, he was only 25; Leipunsky was 30, Valter 28; the students in my group—Evgeni Lifshits and Aleksandr Kompaneyets among others—and I were between 18 and 20. We were together during lectures and lab assignments in the department, during research work in the Ukrainian IPT, and took part in sports and excursions together. We often discussed current issues in physics and philosophy, literature and art, and problems in domestic and international life.

The situation in the Institute in those years was conveyed well by a newspaper article "High-Voltage Komsomol Lab", published September 1, 1933. The article deals with the atomic ("high-voltage") laboratory where pioneering work was being done in breaking down the nuclei of a number of chemical elements and in the search for peaceful ways of using the enormous reserves of intra-nuclear energy.

"The high-voltage Komsomol team bombards the atomic nucleus in order, like the Soviet Union, having destroyed the old to create the new, magnificent, enormous and fine.... This young cluster of Soviet scientists is marked by its multiplicity of qualities: Russian revolutionary sweep, American practicality, the concentrated focus of the German scientist and the buoyancy of the very young man who sees his goal and has the opportunity to reach it." Reporting the research being conducted in the laboratory, the newspaper wrote: "The work would go badly without the activity of the students Taranov, Vodolazhsky, Gott and Marushak, who have put together all of the high-voltage circuitry. At 19 to 20 years of age, these Komsomol members have joined the ranks of the leading scientitic pathfinders.... Komsomol scientists, people with enormous concentration, purposefulness and organization, they are blazing the trail into the unknown on the basis of harmonious collective work."

We presented surveys of current literature and reported on the results of our own research at seminars. This was an arduous and difficult test, we had to be prepared to answer the searching and pointed questions of "Dau" (L. D. Landau) and I. V. Obreimov. At these seminars we put to test the scientific data obtained, and acquired the ability to carry on a scientific dispute. All this made for a special atmosphere of joint involvement in the solution of the current problems of modern physics, demanded an enormous expenditure of energy, the mobilization of willpower, and developed our ability to value and use time properly, combining intense study with research and civic activity.

It was extremely interesting to listen to lectures by Landau, a man who not only made an important contribution to modern science but also did much to shape a Soviet school of theoretical physicists. Though something has already been written about Landau, we still have no true monograph on this outstanding scholar. In my possession are photographs from the 1930s, and memory supplies the living features of those captured in them. In one, Landau is enthusiastically and passionately engaged in a scientific argument, in another he is out skiing. Before us is "Dau", spare, militant, with a great shock of hair. Young himself, he is surrounded by even younger students.

For all of us post-graduate students in experimental physics, passing the Candidate qualifying exams in theoretical physics was of special significance for all our subsequent work. Landau examined us in theoretical mechanics, statistical physics, electrodynamics, quantum mechanics and the theory of relativity; the theoretical physicists took the "theoretical qualifying" exams, which later became famous.

Young scientists who aspired to study under Landau came to the Institute every year. A Kharkov school of theoretical physicists took shape. Among them, in addition to E. Lifshits (now a Corresponding Member of the Academy of Sciences of the USSR) and A. Kompaneyets, should be mentioned I. Pomeranchuk (Member of the USSR Academy of Sciences), I. Lifshits (Member of the USSR Academy of Sciences) and A. Akhiyezer (Member of the Ukrainian Academy of Sciences). This list alone (and it is far from complete), containing a number of

outstanding physicists, speaks of the high level of training received under the direction of Landau.

The Institute was dominated by an atmosphere of intolerance for opportunistic, dogmatic and ignorant work and those who carried it out, be they theorists or experimenters. It is not surprising that the prewar members of the Institute continue today to be at the cutting edge of modern physics. One may recall, beyond those already mentioned, the names of L. Vereshchagin, Hero of Socialist Labor and Member of the USSR Academy of Sciences; N. Alekseyevsky, Corresponding Member of the USSR Academy of Sciences; B. Lazarev, A. Prikhodko, A. Usikov and S. Braude, all Members of the Ukrainian Academy of Sciences.

The years pass, and with them, to our great regret, so do people. Landau, Pomeranchuk, Leipunsky and far too many others are no longer among us. These were scholars whose talent is embodied in the advances of Soviet and world science and technology, whose talent served the development of the productive forces of socialism. They were true sons of their native land. In this regard, the life of Aleksandr Leipunsky, Member of the Ukrainian Academy of Sciences, is characteristic. He was a worker at a chemical plant in Rybinsk, then a student at the Leningrad Polytechnical Institute, and then one of the organizers and later Director of the Ukrainian Institute of Physics and Technology. Later, Leipunsky worked for many years in the Institute of Physics and Energetics, where he created a new field in atomic energetics. He was a tireless scholar, the breadth of whose knowledge and whose ability to penetrate into the unknown allowed him to enrich atomic science and technology with new discoveries.

The intellectual and moral climate in our research institute, in which an atmosphere of scientific creativity reigned, helped to shape a broad general outlook in the field of physics and the materialist view of the world. We studied Marxist-Leninist philosophy in immediate connection with science and public service. I would like to emphasize that the questions of our world outlook, of Marxist-Leninist philosophy, were always in the center of our attention.

I remember the passionate speeches, filled with polemical heat but scientifically backed, delivered by Pomeranchuk, a talented scientist and a man of exemplary honesty, against all attempts to use the difficulties of developing physics for crudely speculative purposes. He demonstrated the groundlessness of attempts to interpret outstanding, epoch-making theories of physics—the theories of relativity and quantum mechanics—in an idealistic spirit, and at the same time opposed those who attempted to present their superficial ideas on these theories as the last word in Marxist philosophy. And though he did not specially concern himself with the methodological problems of physics, all of his innovative and original research, which has left an important imprint in science, was imbued with dialectics.

Our work in the realm of the methodological problems of physics attracted the interest not only of Soviet physicists and philosophers, but also of those outside the country. I recall discussions on these questions with the renowned physicist P. Ehrenfest during his stay in Kharkov, as well as with Frédéric Joliot-Curie, who at the behest of Paul Langevin familiarized himself with the work of the Institute's methodological seminars.

Many decades have passed since then, but even today many of those who have worked and are working in the Institute of Physics and Technology show great interest in the philosophical aspects of physics.

I. M. Lifshits, A. K. Valter, A. I. Akhiyezer and others have taken an active part in recent scientific conferences on these questions.

The difficult international situation of the 1930s and 1940s—the threat of a world war, that increased sharply with Hitler's advent to power—demanded that the efforts of all Soviet citizens, those working in science included, be redoubled. The group at the Ukrainian Institute of Physics and Technology became even more actively involved with a number of problems of great importance for the economy and for defense.

The Great Patriotic War of the Soviet Union against nazi Germany (1941-1945) brought new and irrefutable confirmation of the loyalty of the scientists at the Ukrainian Institute of Physics and Technology, as of all Soviet scientists, to the Soviet Union. Many of the Institute's personnel were in the army. Most unfortunately, not all returned from the war. Among those who died were D. Shepelev, K. Shabaldas, P. Borisov and A. Ivanov. Their memory is treasured in the scientific community at the Institute and at its branches.

Soviet physics even before the war had come to the verge of practical utilization of nuclear chain reactions. Much had already been written on the extensive research in the physics of the atomic nucleus in the USSR in the prewar years, so I shall cite but one further example.

The fifth issue of *Priroda* (Nature) in 1940 contained an interesting review by G. Kh. Frank-Kamenetsky "Some Problems in the Physics of the Atomic Nucleus". The article dealt with the conference on the physics of the atomic nucleus held in Kharkov in November 1939 by the Academy of Sciences of the USSR. The author emphasized that the field was developing with exceptional rapidity. Discoveries and theoretical studies of great importance were coming along in rapid succession, and earlier data were constantly changing or being supplemented.

In the year since the previous conference on the physics of the atomic nucleus, a remarkable new phenomenon had been discovered—the fission of the nucleus of heavy elements (Otto Hahn and Fritz Strassmann, Germany), and this attracted the attention of physicists not only because of the theoretical import of the phenomenon but also because it opened up the possibility of practical utilization of intranuclear energy.

Frank-Kamenetsky called attention to the fact that while in 1938 it had been possible to write of nuclear transmutations as a potential source of enormous energy that at the time could not be tapped in any known way, by 1939 the way to obtain it had already been outlined.

I was fortunate enough to have been one of the speakers at the 1939 conference. The atmosphere of elation and confidence in the rapid solution of this task of supreme practical importance that ruled at the conference impressed itself upon me. We viewed the new source of energy as active participants in socialist construction, and we were interested above all in the ways to meet the needs of the economy. At the same time, we were clearly aware that this outstanding achievement of human reason could be used for other purposes if it fell into the hands of those who were stirring up war, the threat of which was continually growing, primarily because of the actions of the German nazis.

It was far from mere coincidence that Kharkov was chosen as the site for the conference on the physics of the atomic nucleus. The world's leading physicists—Niels Bohr, Werner Heisenberg, Paul Dirac, Frédéric and Irène Joliot-Curie, P. Ehrenfest, P. Kapitsa, A. Ioffe, I. Kurchatov and others—came

to Kharkov. The Ukrainian Institute of Physics and Technology was at the time one of the country's leading centers of research on the physics of the atomic nucleus. This was indicated by the fact that of the 42 reports delivered at this quite representative forum, 14 were prepared by the Ukrainian IPT. Since many reports had two or more authors, the number of reporters from our institute exceeded 30 persons.

Frank-Kamenetsky chose only a few of the many reports presented at the conference for review—principally those dealing with the decay of uranium nuclei. These reports dealt with the products obtained upon decay and with giving a clearer picture of the nature of decay. The review stressed that the central problem for all nuclear physics was the problem of practical utilization of the enormous energy contained in atomic nuclei. The decay of uranium nuclei is triggered by the capture of neutrons by the nuclei of the atoms and is attended by the emission of neutrons which, in turn, may be captured by other nuclei and again trigger decay. The interaction of heavy nuclei and neutrons was dealt with in the reports by I. Kurchatov, A. Leipunsky, K. Petrzhak, G. Flerov and L. Rusinov.

The report by Ya. Zeldovich and Yu. Khariton drew much attention. Frank-Kamenetsky wrote: "Ya. B. Zeldovich and Yu. B. Khariton (Institute of Chemical Physics, Leningrad) calculated the possibility of bringing about the chain decay of uranium.... It is enough to increase the concentration of U^{235} in the uranium to make a reaction possible. On the other hand, if deuterium is used as a delaying agent instead of hydrogen, there will be almost no absorption in the delaying agent, and the reaction will, obviously, also be realizable.... In principle, the possibility of utilizing intra-nuclear energy has been discovered." Thus, the results of research in physics showing that scientists in the USSR were on the verge of solving the problem of carrying out a chain nuclear reaction were made public as early as 1939.

Participation in research on the cutting edge of physics—to be precise, in the field of the physics of the atomic nucleus—gave rise to the desire to substantiate philosophically what physicists had already done in investigating the unknown, to trace not only the impact of philosophy on physics, but also the influence of physics and other natural sciences on the development of Marxist-Leninist philosophy. Working for a number of years in the laboratory for the physics of the atomic nucleus, and being in scientific contact with physicists working in other laboratories of the Ukrainian IPT (low-temperature physics, solid-state physics, radio-physics, etc.), I became increasingly interested in the principle of the inexhaustibility of the material world as one of the methodological principles of modern science, as well as in the dialectic of absolute and relative truth, which found its reflection in the principle of harmony, and in a number of other philosophical aspects of physical science.

In the last half century, mankind has advanced far in the knowledge of the micro-, macro- and mega-worlds, in the exploitation of the hidden forces of nature, but as before has not yet obtained answers to many questions. And one does not have to look far for an example. For instance, in our everyday life we come up against, literally at every step, the action of the force of gravity, we live in a gravitational field. We know a number of the laws governing this phenomenon, beginning with Newton's law and ending with Einstein's general theory of relativity. But what gravity is, why the inert and gravitational masses are equal, what mass is, do gravitational waves exist or not—modern science cannot yet provide satisfactory answers to these questions.

It is difficult to imagine human existence without the application of electricity, but though it has long served mankind even today we do not know what an electrical charge is, or why charges can only be multiples of the electron, or whether the electron has a structure or is a point.

Richard Feynman, one of the leading contemporary theoretical physicists, wrote on this score: "If an electron is all made of one kind of substance, each part should repel the other parts. Why, then, doesn't it fly apart? But does the electron have 'parts'? Perhaps we should say that the electron is just a point and that electrical forces only act between *different* point charges, so that the electron does not act upon itself. Perhaps. All we can say is that the question of what holds the electron together has produced many difficulties in the attempts to form a complete theory of electromagnetism. The question has never been answered."[1]

The situation with the vehicle of the positive charge, a multiple of the charge of an electron—the positron—or with the nucleus of a hydrogen atom—the proton—is no better. The proton, the mass of which exceeds the mass of the electron 1836 times, forms together with neutrons the nucleus of all the chemical elements, and since this is a stable particle (experimental study of the stability of the proton yields as the lower limit for the life of the proton the value $\sim 10^{27}$ years), it conditions the stability of more complex systems. Science has obtained much interesting information on protons, but here, too, a number of questions remains unanswered. For instance, how is the charge of the proton distributed; is it a point or is it "spread out"?

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[1] **The Feynman Lectures on Physics**, Vol. II, New York, 1965, pp. 1-2.

Feynman writes: "We do not know how to make a consistent theory — including the quantum mechanics — which does not produce an infinity for the self-energy of an electron, or any point charge. And at the same time, there is no satisfactory theory that describes a non-point charge. It's an unsolved problem."[1]

Everyone knows that time is irreversible, that we can move only from the present to the future and cannot in a real sense return to the past. However, the fundamental equations of modern physics are indifferent to a change in the sign for time (to the substitution of $-t$ for $+t$). How can we explain that time is uni-directional in the real world and ignore this fact in the mathematical apparatus of modern science? We have no answer.

The number of questions to which science cannot yet provide an answer is quite large, and in a certain social order and intellectual climate this can engender distrust of science or pessimism.

I have cited the *Feynman Lectures on Physics* because in the opinion of many authoritative physicists this is one of the best modern series of lectures on the subject. Their author, a Nobel laureate, concludes his lectures on electricity and magnetism with the following remark: "So you see, this physics of ours is a lot of fakery—we start out with the phenomena of lodestone and amber, and we end up not understanding either of them very well. But we *have* learned a tremendous amount of very exciting and very practical information in the process!"[2] Alongside the recognition of the enormous practical benefit of what physicists have already learned, there is in Feynman's words a note of pessimism, masked by irony.

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[1] **The Feynman Lectures on Physics**, Vol. II, p. 28.
[2] **Ibid.**, p. 37.

Fred Hoyle, a well-known English cosmologist and Professor of Astronomy at Cambridge University, recognized with regret in lectures delivered in 1965 at Columbia University, and published in book form as *Man in the Universe*, that the idealist philosophy with which he is familiar is not now of benefit to science: "We are prisoners of our own mold of thought, of the mold of thought of our present society, and it is excessively difficult to break loose from the strait jacket in which we are clamped."[1]

The number of newly discovered and remarkable phenomena of nature exceeds the number of reliable answers to questions raised earlier many times over. However, both the answers and the new questions indicate one thing: that we live in an inexhaustible but knowable world. The road travelled by science shows the might of human reason and, in principle, the unlimited potential for knowledge.

The curious human mind strives to penetrate the secrets of nature and society, to know itself, the structure and activity of the brain, so that the knowledge obtained can be utilized more extensively for the good of mankind.

To a large degree, this is furthered by the process of détente now under way, a process that promotes the collaboration of scholars from different countries in the solution of the complex fundamental problems that mankind as a whole now faces. The search for new sources of energy, protection of the environment, the problem of mineral resources, of food and population—these are all problems that can be dealt with successfully only in an atmosphere of increasing trust and cooperation. Scientific research must be freed of narrow, selfish political and military

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[1] Fred Hoyle, **Man in the Universe**, New York and London, 1966, p. 20.

calculations and put fully at the service of exalted humanist ideals. Such a course of development of science is organically inherent in a society where the exploitation of man by man has been eliminated.

The essence of the social function of science is that it services society with theoretical knowledge to the extent that social production, technological progress, the demands of industry and, above all, man himself, require. Science is a special realm of the activity of society, a special social phenomenon the function of which is to generalize man's practical activity, to disclose the laws of nature and society and to develop ways and means of using these laws in all areas of human activity, above all in social production. The revolution in science and science's transformation into an immediate productive force are the basis of technological progress—a prime element in the scientific and technological revolution.

Penetrating into the inexhaustible but knowable world with the help of the vast arsenal of modern science began for me more than forty years ago and continues to this day. We invite the reader to take a short journey, principally into that corner of the material world that modern physics studies. Marxist-Leninist philosophy will be our trusty compass on the journey.

CONCEPTS, CATEGORIES, COGNITION

Work in the laboratory investigating the atomic nucleus forced me to think deeply about the tools of scientific research. They include, after all, not only technology, instruments and various pieces of research apparatus but above all the arsenal of our tools for thought: concepts, categories, judgements, deductions, laws, principles, and so on.

Both in scientific research and in practical affairs, every person—often without thinking about it—uses these tools of cognition. But the more intricate the object of cognition, the more perfect operation of the investigator's apparatus of thinking is required, and this means that he is forced to turn for assistance to formal logic and dialectical materialism.

Science's growing role in the life of society makes it increasingly important continually to develop scientific concepts, which summarize man's knowledge of the surrounding world.

Marx, Engels and Lenin showed that without concepts and categories that fix the results of cognition, that serve as an "instrument" for penetrating further and deeper into the essence and pattern of development of nature and society, cognition and human thinking are inconceivable.

"...The simplest *generalization*, the first and simplest formation of *notions* (judgements, syllogisms, etc.) already denotes man's ever deeper cognition of the *objective* connection of the world."[1]

The movement of cognition to the general, to the essential is impossible without categories and concepts, without the creation of a scientific picture of the world. Concepts are the result of generalizing experimental data, of practical mastery of the world, they are the result of the prolonged development of human cognition.

Among the concepts and categories of science, a special place is held by the categories of Marxist-Leninist philosophy, categories that perform methodological and logical functions and serve as underpinnings for all cognition.

All individuals—some consciously, others unconsciously—think with the aid of such philosophical categories as matter, consciousness, movement, space, time, form and content, phenomenon and essence, necessity and chance, cause and effect, actuality and potentiality, general and singular, and so on. The categories of philosophy are concepts reflecting the most general properties and interconnections of the phenomena of the material world. They permit thought to subdivide the material world and the phenomena that go to make it up, to isolate in these phenomena that which is essential and to perceive reality around us in all the variety of the interconnections that are inherent in it. Categories, like other concepts, lack substantiality, their material envelope is provided by words.

Lenin described philosophical categories as the supports on which cognition rests, as "nodes" in the network of the objective world and practical activity, nodes that allow us to see the world in its inherent state of movement and development.

[1] V. I. Lenin, "Conspectus of Hegel's Book **The Science of Logic**", **Collected Works**, Vol. 38, p. 179.

Human cognition is based not only on the accumulation of practical and experimental data, but also on the generalization of these data; for the latter, theoretical thinking is required, thinking that relies on philosophical categories and laws, on specific and general scientific concepts.

Every science has its basic, fundamental concepts that may be either specific or general. Such physical concepts as mass, substance, field, and electrical charge emerged in the course of the study of physical objects. All the laws of physics known at present have been formulated with the aid of these concepts, therefore they are specific concepts. There are in addition general concepts, for example, algorithm, probability, invariance, information, element, system and many others that are used in virtually all the sciences.

Take, for example, the concept of quantity (totality) or the concept of magnitude, both being mathematical concepts. It is impossible to find a science in which they are not used. Mathematical concepts are general, too, because the process of mathematization in principle encompasses all the individual sciences. This means that mathematical concepts function as general scientific concepts for all the individual sciences (or can so function in principle). We should note that among the concepts we have mentioned that claim the status of general scientific concepts some are rooted in mathematics and are by their nature mathematical (algorithm and probability, among others).

The categories of Marxist-Leninist philosophy provide a method of cognition for all the sciences and in this sense are also general. But not all general scientific concepts are philosophical concepts and categories.

There is nothing unexpected in the fact that the basic concepts of mathematics have become general scientific concepts. If this were not the case not all fields of science would have undergone progressive mathematization. At the same time, it is clear that mathematical and philosophical categories are general scientific concepts in different senses. This refers not only to the fact that philosophical concepts are general in the full sense of the word (for they are applied both in scientific philosophy itself as well as in all the individual sciences, while mathematical concepts are applied only in the individual sciences). Philosophical concepts carry a universal methodological load in all the individual sciences precisely because they disclose the most essential, substantive relations of the objects of being and thinking. Mathematical concepts, on the other hand, encompass the external aspect of the investigated objects, most often their formal, quantitative characteristics; therefore, they do not have a methodological function when applied in other sciences. This explains why the use of mathematics in, for example, sociological research does not of itself make this research more valid if it disregards concrete social conditions, classes and their interrelations. Moreover, this leads to mistakes and errors, to pseudo-scientific juggling of fashionable mathematical concepts and methods. Mathematics by itself, consequently, scarcely ensures validity when used in other sciences. It ensures precision only when mathematical tools are applied on the basis of the methodology of dialectical materialism, taking into account the specific nature of the objects under study. Therefore, the increasing penetration of the ideas of scientific philosophy into the other sciences is simultaneously a condition favoring their further mathematization, an increase in their general efficacy in producing new scientific knowledge.

But not only philosophy and mathematics are sources of general scientific concepts. Some of the

latter come from individual, natural, technical or humanist fields of science, are then assimilated by other sciences and gradually acquire a general scientific character. The concept of information is a good example. The term "information" originally designated the transfer of some data from one person to another or to a group of persons. This understanding was typical for the social sciences and humanities, though it underwent no noticeable development until it became the concern of the theory of information transfer, which is one of the most highly developed areas of cybernetics. Within the framework of cybernetics, the concept of the quantity of information was developed and specific approaches to making more precise such attributes of information as content (meaning), value and so on were sketched out. Through the application of the methods of information theory, the concept of information entered other sciences, and one cannot now find any science where it cannot in principle be employed, where it cannot further the acquisition of new knowledge.

The system of special scientific, general scientific and philosophical categories forms the structure of theoretical thinking which is not only one of the sources of scientific cognition, but also a product of the development of such cognition. "In every epoch ... theoretical thought," wrote Engels, "is a historical product, which at different times assumes very different forms and, therewith, very different contents."[1]

The achievements of theoretical thinking are inseparable from the development of philosophical categories. It would be wrong to suppose that philosophical categories exist outside the general process of scientific cognition, that given any content

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[1] Frederick Engels, **Dialectics of Nature**, Moscow, 1974, p. 43.

and any interconnections they can serve as a base for theoretical thinking. Quite to the contrary, only through their development can philosophical categories be one of the bases of theoretical thinking. If particular philosophical categories are turned into dogmas they drop from theoretical thinking and cease to serve the process of cognition.

The development of philosophical categories is based on data relating to the properties of the objective world, properties expressed in new scientific concepts arising in individual sciences. While the original development of new concepts in sciences is based on the existing philosophical categories and the existing links between them, the development of scientific concepts requires enriching the substance of philosophical categories and the links between them with new aspects, and forming new philosophical categories.

Materialist philosophy has always functioned as a science synthesizing or promoting the synthesis of categories in the individual sciences and participating in the formation of a scientific picture of the world. The object of cognition in all modern sciences, scientific Marxist-Leninist philosophy included, is one and the same—nature, society and thought. The general and the particular in the object of cognition are linked, which means that the sciences studying this general (including the most general, philosophy) and particular must be linked. The objective link of the general and particular requires the reproduction of this in knowledge, too, which makes necessary an alliance between philosophy and the individual sciences.

The object of cognition common to all sciences is divided by the individual sciences into separate parts, aspects, relations and so on. But in order to form an integral scientific picture of the world, to reconstruct in

knowledge the object of cognition, it is necessary to connect those fragments of scientific knowledge that are provided by the individual sciences. The synthesis of a scientific picture of the world, of the subjects of the different branches of science, into something integral occurs through the interaction of the individual sciences themselves, but it will not be fruitful without scientific philosophy.

Natural science of the 19th century did not, with few exceptions, make use of the dialectical method. It was no coincidence that at the beginning of our century Lenin had to carry out an immense amount of work in substantiating philosophically the revolution in natural science, noting that total unfamiliarity with dialectics was felt in the work of the leading theorists of natural science of the time, that the essence of the methodological crisis in physics was ignorance of dialectics.

Lenin showed that this crisis could be overcome only in the event that scientists renounced the metaphysical style of thinking and adopted a dialectical method. However, effort must be made by professional philosophers, if dealectics is to enter the thinking of scholars. At the beginning of our century, this work was done by Lenin; now, a large band of professional Marxist philosophers are developing Lenin's ideas, the philosophical aspects of physics and other natural and special sciences.

The most important scientists of the 19th century represented natural historical materialism which reflected "instinctive, unwitting, unformed, philosophically unconscious conviction shared by the overwhelming majority of scientists regarding the objective reality of the external world reflected by our consciousness".[1] Physicists became materialists under

[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 346.

the influence of the data of their own science, data that confirmed experimentally the fundamental thesis of materialism. However, the materialism thus developed among physicists was not stable precisely because it was still firmly tied to metaphysical thinking. Physicists who held to the position of natural historical materialism, not knowing dialectics, often fell prey to the influence of idealism. Lenin demonstrated the limitations of natural historical materialism and emphasized that "no natural science and no materialism can hold its own in the struggle against the onslaught of bourgeois ideas and the restoration of the bourgeois world outlook unless it stands on solid philosophical ground. In order to hold his own in this struggle and carry it to a victorious finish, the natural scientist must be a modern materialist, a conscious adherent of the materialism represented by Marx, i.e., he must be a dialectical materialist".[1]

These words can be applied equally to other disciplines as well, for example to the humanities, where naive materialism proves, given ignorance of dialectics, even more subject to the influence of idealist views. Not coincidentally, even the most important materialist philosophers of the past (before Marx) held idealist views on social questions.

Of course, dialectics can enter the sciences through direct study of the object. As Engels stressed, one can arrive at a dialectical understanding of nature under the compulsion of the facts of natural science. However, without knowledge of materialist dialectics, without an understanding of the laws of dialectical thinking, the road by which dialectics enters the sciences is long and difficult, it is travelled "not directly, but by zigzags, not consciously, but

[1] V. I. Lenin, "On the Significance of Militant Materialism", **Collected Works**, Vol. 33, p. 233.

instinctively, not clearly perceiving its 'final goal', but drawing closer to it gropingly, unsteadily, and sometimes even with its back turned to it".[1]

The highroad of the development of modern science passes through conscious and extensive use of dialectical materialist philosophy.

In any given natural science, dialectics does not show itself to its full extent, only a small proportion of its categories play a role (overt or covert) in increasing knowledge. No single theory in natural science, even if it contains certain elements of dialectics and develops in a dialectical manner, embodies so substantial an apparatus of categories as philosophy. And this is the case because philosophy draws information not only from the study of nature, as is basically the case with the natural sciences, but also from other realms of being, cognition and practice.

The philosophical categories and laws that scientists have integrated into their views contribute substantially to scientific cognition. The laws and categories of materialist dialectics are a methodological base ensuring the selection of the most correct general course of scientific endeavor, selection of reliable guideposts for the development of scientific theories. The entire course of development of modern science, natural science in particular, confirms this truth. Consciously using the categories of Marxist philosophy, the natural scientist is able more fully to evaluate the directions of development of scientific knowledge in his field, to explain and anticipate the emergence of new fields and results of research. Materialist dialectics functions above all as the logic and methodology of scientific cognition, as a system of primary theoretical, cognitive principles.

[1] V. I. Lenin, "Materialism and Empirio-Criticism", Collected **Works**, Vol. 14, p. 313.

The basic task of materialist dialectics, i.e., assisting the individual sciences in generating new knowledge in an optimal manner, cannot be dealt with effectively without elaborating the logical aspect of particular scientific knowledge. After all, new knowledge emerges not only in the process of empirical cognition, but also as a result of theoretical thinking, of the logical processing of empirical information. The methods of formal logic are applicable basically to knowledge already at hand; they are especially important where man is preparing to hand over some of his functions to computers. Here, the methods of formal logic do not aid in the generation of new knowledge so much as they help to make knowledge more precise. The principal logical tool for generating new knowledge is dialectical logic.

The development of physics and other sciences sets philosophy methodological questions, and if philosophers do not answer them successfully then specialists in the field of physics attempt to solve them independently, which sometimes leads to confusion, mistakes and mutual recriminations.

Analysis of the works of Einstein, Bohr, Born and many other outstanding 20th-century physicists shows how much attention they devoted to philosophy. They saw the historical background and the limitations of the then known pre-Marxist philosophical systems (mechanistic materialism and various schools of idealist philosophy), but at the same time found rational elements in these transitional doctrines. Max Born wrote: "Every scientific period is in interaction with the philosophical systems of its time...."[1] Born (and many other leading physicists) criticized positivism, which indicates that he did not consider it—or other varieties of idealism—to be a modern-day

[1] Max Born, **Physics in My Generation,** New York, 1956, p. 38.

philosophy. Unfortunately, however, he did not rise to the recognition that the only scientific philosophy for the present day is the philosophy of dialectical materialism.

Einstein, too, gave much attention to philosophical questions and held that "philosophical generalizations must be founded on scientific results. Once formed and widely accepted, however, they very often influence the further development of scientific thought by indicating one of the many possible lines of procedure."[1]

Like Born dissatisfied with the idealistic theory of cognition, Einstein tried to create his own theory, in which elements of dialectics can be clearly traced.

Dialectic-logical analysis focuses primarily upon the pressing problems of modern science, it does not confine itself to recreating the dialectic of the thinking of scientific theories of the past (though this, too, is indispensable). Retrospective dialectic-logical analysis is, of course, better than the "illustrative" approach, but the scientist is, after all, interested in dealing with contemporary problems, not in learning that problems in the past were also resolved dialectically. Indeed, the productive participation of the philosopher in the synthesis of new particular scientific knowledge consists in methodological assistance in resolving important problems that have at present come to the fore in a given science.

Using the dialectic-logical method, the philosopher can take note of the one-sidedness and limitations of the approach used in an individual science and suggest ways to improve it. This is possible if the development of knowledge in a given field is analyzed, if this knowledge is not taken in statics, as is

[1] Albert Einstein and Leopold Infeld, **The Evolution of Physics,** New York, 1954, p. 55.

basically the approach of formal logic, but in dynamics. Moreover, the philosopher is able, using the great methodological "capacity" of dialectical categories, to isolate to a certain extent the possible general directions of the development of the scientific concepts and theories in a particular field.

The influence of philosophy and physics is mutual. This, it seems, became clear from the moment when mechanics broke away from natural philosophy, became an independent science and made its first major advances, above all as a result of Newton's discoveries (i.e., with the publication of *Principia Mathematicae* in 1687). From that point on, mechanics had an important influence on the philosophical predecessors of Marx and Engels, particularly the materialists. This first period of the influence of mechanics and mathematics on philosophy may be called the mechanistic period.

In the 19th century, three fundamental discoveries in natural science had an impact on the formation and development of Marxist philosophy: the law of the conservation and conversion of energy, cellular structure of organisms and Darwin's theory of evolution. It was this impact of natural science on philosophy that permitted Engels, and then Lenin (though on the basis of other discoveries in physics) to say that with each epoch-making discovery in natural science (not to mention the history of mankind) materialism must inevitably change its form.

Marxist philosophy was developed by its founders principally on the basis of an analysis of social development, on social science. It was in *Capital* that the dialectical-materialistic teaching on development found its highest expression. At the same time, the founders of Marxism also took into account data from natural science.

Physics and biology have continued in our century to influence the development of Marxist-Leninist

philosophy, and since mid-century they have been joined by cybernetics. Now that the development of the modern scientific and technological revolution sharply accelerated, we cannot speak of the influence of any major discovery, but of the overall, systematic impact of all of modern science on philosophy — and not just the natural sciences, but the social, technical and other applied and special sciences as well. In this connection, the complex of sciences dealing with man and the environment takes on great significance.

This impact on philosophy leads to the development, enrichment and a certain modernization of the set of categories of materialist dialectics. Drawing on and generalizing from the knowledge recently acquired by the natural and social sciences, philosophy enriches the content of its traditional categories and is supplemented by new categories. We are referring to the generalization and deepening of content, to the distinguishing of the most essential aspects of scientific knowledge in a particular field, and to the investigation of the logical and gnoseological tendencies in the development of the corresponding concepts.

Viewing cognition as an historical process that ever more profoundly and actively reflects the world in our thinking, we must also view the categories of cognition in their historical development. The historical essence of the categories of cognition is manifest in many respects, for instance in the possibility for general scientific categories to transform into philosophical categories and in the restriction of the significance of certain philosophical categories to specific states of the world, to specific aspects of the processes of the world's change. For example, in the past the categories "substance" and "mass" were viewed as philosophical categories and it was held that these categories coincided in content with the category "matter". We now know that the category "substance" refers only to a specific state of matter in motion. In physics, the category "field" now exists side by side with the category "substance".

Philosophical analysis of the problems of modern physics is no substitute for specifically scientific investigation. The philosopher is called upon to assist in explaining only those questions that go beyond the limits of scientific theories in a given field, beyond the limits of problems resolved by the given science with its own resources. The philosophical investigation corresponding to a given science functions as a meta-theoretical investigation. Philosophical investigation is analysis of the real life of any given science as though "from the side", from the philosophical "side"; it is analysis of which the specialist going beyond his own immediate field is in the greatest need.

The few aspects of the interconnection between philosophy and physics that we have examined far from exhaust the multiplicity of forms in which this interconnection manifests itself. It is absolutely clear that the study of this problem and the results obtained are of immediate relevance to the development of scientific cognition and to the present stage of the struggle against idealistic philosophy. As in Lenin's time, our ideological opponents come out against Marxism, using for this purpose the advances and discoveries of modern science.

At the turn of the 20th century, a number of idealist philosophers and some physicists sharing their views maintained that materialism was refuted by the development of science. At the time they made use of the "revolution in physics" that had come about as a result of certain scientific discoveries (X-rays, the radioactive decay of atoms, etc.) that put in doubt the universality of a number of the theories of physics.

Under these circumstances, genuinely scientific analysis and philosophical generalization of the discoveries in physics from the standpoint of dialectical materialism acquired overriding importance both for theory and for revolutionary practice.

In *Materialism and Empirio-Criticism*, Lenin creatively applied Marxist dialectics and drew scientifically based gnoseological conclusions from the advances of the physics of his day; he showed that the idealists' attempts to prove the "collapse of materialism" were scientifically unfounded, traced the profound contradictions characteristic of this stage of the development of idealism and enriched the philosophy of Marxism with new tenets. He demonstrated that the new discoveries in physics did not contradict the philosophy of dialectical materialism, in fact, they confirmed it.

Interestingly, many physicists who stood firmly on the position of naive materialism were critical of the fashionable idealistic views. For instance, when it had been established that the atom has a complex structure, as indicated by radioactive decay, the well-known Russian physicist, N. A. Umov, wrote: "The life of the inner world of the atom will reveal to us properties and laws that are, perhaps, different from those that constitute old, already ancient, physics. Does not a note of disappointment sound over us? We were right on top of truth, we had seized it, and suddenly it moved so far away from us that we cannot even estimate the distance! Yes, but we have discovered that the tasks of physics consist not only in the description of phenomena and the search for the links between them, i. e., laws. On the strength of its experimental and theoretical methods, physics brings us close to the unitary reality that lies beyond the limits of the senses. We have once more become aware of the grandeur and inaccessible height of truth, and this awareness is a pledge of the uninterrupted development and unfading life of scientific thought."[1]

A passage from M. Y. Goldstein's *Foundations of the Philosophy of Chemistry* spells out a contrary point of view. In the first chapter, the author writes: "Modern philosophy (Machist philosophy —*Author*) tells us with good reason that we cannot study the external world as such, since any study consists first of all in obtaining impressions, and an impression is a psychic process which is then processed in our self, so we do not know the external world, but our perceptions, which we project onto the external world. What, then, are we studying? We are studying our own perceptions. And what in fact the causes, the external phenomena that create these impressions are —this we neither know nor can know." After this assertion, the author continues: "We shall not contest this, because, first, we personally share this opinion and, second, because even if we were personally against this view the argument all the same would not produce any results."

Before us, then, are two different points of view. Time has proven N. A. Umov correct; it has also supplanted the naturalists' naive materialism with dialectical materialism.

One of the most important tendencies in modern science is the application of dialectics in the theoretical and experimental work exploring our intricate and contradictory world. Something happens which is absolutely unbelievable from the standpoint of metaphysics, which is comprehensible and permissible only within the framework of materialist dialectics. For instance, "empty nothing", Newton's absolute space, this "box" with moving masses, has been discarded by science—in its stead has emerged the unitary world of

[1] N. A. Umov, **Works**, Vol. III, Moscow, 1916, p. 284 (in Russian).

Einstein; the previous discontinuity between mass and space has been eliminated, the two have proved to be linked in an indivisible whole where the geometrical properties of space are determined by masses.

The metaphysical juxtaposition in the old physics between the discontinuous and continuous, between corpuscles and waves, has been overcome in quantum mechanics, where they stand before physicists in contradictory, dialectical unity.

Broad synthesis of scientific knowledge requires that scientists have a profound grasp of the processes by which new theories emerge and of the reasons why old theories are limited. The scholar cannot but be a philosopher, whether he wishes to be or not, as Lenin pointed out when he wrote that natural science progresses so rapidly, is experiencing such a profound, revolutionary break in all fields that it cannot in any case do without philosophical inferences.

In analyzing the results of his work, a scientist in any field sets himself the question, often without realizing it, of the relationship between the concepts and theories in his field of knowledge and objective reality. And though he may sincerely believe that he is not concerned with philosophy, this question is in fact profoundly philosophical in nature, and development in any field of knowledge requires that it be answered.

Some physicists hold that in answering this fundamental question of philosophy they rise above materialism and idealism, that they are above this "limitedness", that they stand aside from parties in philosophy.

The eminent physicist Wolfgang Pauli remarked at an international symposium in Zurich: "To orient the philosophers, I could note that I belong to no particular philosophical current whose name ends with an 'ism' .... My general tendency is to hold to a certain middle way between extreme currents."[1]

But he did not realize his intent, for it is unrealizable. In fact, Pauli, contrary to his statement, moved constantly back and forth between materialism and idealism.

As we know, there are in principle only two answers to the fundamental question of philosophy: the materialist, according to which objective reality, its properties and regularities are reflected in the theories and concepts of all sciences; and the idealist, according to which theories and concepts are not connected with reality and are the free creations of the intellect, not reflecting objective reality, its properties or processes. There is no third answer. This was argued especially persuasively and scientifically by Lenin in *Materialism and Empirio-Criticism.*

The special and general theories of relativity, quantum mechanics, the theory of elementary particles and other achievements of modern physics are associated with the names of Einstein, Bohr, Born, Heisenberg, Dirac, Pauli, Schrödinger, de Broglie, and many other outstanding scientists. These physical theories reflecting reality with a certain degree of precision are in essence materialist and to a certain extent dialectical. In this sense, recognition of the reality of the external world is the principal condition for scientific activity. Einstein put it well: "The belief in an external world independent of the perceiving subject is the basis of all natural science."[2] And this consideration cannot but influence the philosophical stance of leading modern physicists.

One can agree wholeheartedly with Academician V. A. Fok, who wrote that "the general impression one

[1] **Dialectica**, Vol. 11, No. 1-2, 1957, p. 36.

[2] Albert Einstein, **Ideas and Opinions**, London, 1956, p. 266.

gets from all of Bohr's works, beginning with the very earliest, is of their profound dialecticism. Bohr is not baffled by the contradictions that arise when he approaches new phenomena of nature from the standpoint of old concepts and old views, he rather seeks to resolve the contradictions in new ideas. This dialecticism is completely conscious: Bohr told me that he studied dialectics as a youth and always valued it highly."[1]

Unfortunately, however, Bohr was not a dialectical materialist, and he sometimes expressed views that were taken up by idealists. This was the case, for instance, when he attempted to apply the principle of complementariness to phenomena in public life.

In effect, only the creator of wave mechanics, Louis de Broglie, stated his materialist views openly; all the other physicists mentioned above proclaimed that they were above the extremes of materialism and idealism. Nevertheless, dealing with objective reality in their practical scientific activity they had in the final reckoning to proceed from materialist premises that were often recognized indirectly as methodological principles guiding cognition in the search for truth.

[1] V. A. Fok, "Niels Bohr in My Life", **Science and Humanity**, Moscow, 1963, p. 519 (in Russian).

MATTER AND MOTION

Years ago, when we had just begun to study the structure of the atomic nucleus, all scientific and especially popularized literature was liberally sprinkled with statements such as: "atoms are the ultimate building blocks of matter", the "indivisible building blocks of matter", the smallest units, constituting the essence of matter", and so on and so forth.

What is matter, and what is the concept of matter? Physics studies not concepts, but atoms and their structural elements. What role in this cognition do concepts, including the philosophical concept of matter, play? These questions remain important to this day, which is why we shall be speaking of matter and the fundamental forms of its existence. In his practical activity, interacting with the objects around himself, observing the enormous variety of existing things, man even in antiquity asked himself: is there something that is basic in this infinite variety of things and phenomena?

Centuries and millennia passed before men concluded that there exist objects, things and bodies external to and independent of us. This conclusion was one of the most important steps in the development of man's consciousness.

Much later, ancient Greek thinkers in their attempts to explain the phenomena of nature posited a unitary principle. For Thales it was water, for Anaximander apeiron (the infinite), for Anaximenes air, for Heraclitus fire.

"Here, therefore," Engels wrote, "is already the whole original naive materialism which at its beginning quite naturally regards the unity of the infinite diversity of natural phenomena as a matter of course, and seeks it in something definitely corporeal, a particular thing, as Thales does in water."[1]

While for Thales the primary basis was sensibly concrete (water), for his student Anaximander this basis—apeiron—lacked sensible concreteness. For him, it was indefinite and infinite matter. This was a major step in the development of the idea of matter, but it required two thousand-odd years more before a truly scientific definition of the category of matter was arrived at.

The history of philosophy and natural science provides an abundance of material on the struggle between the materialist and idealist views of the world, between the metaphysical and dialectical approaches to the phenomena of the world. This struggle was connected above all with different ideas on the nature of matter.

Many propositions on the nature of matter that have not lost their importance even for modern science have come down to us from the past (on the uncreatedness and indestructibility of moving matter and on its independence of consciousness, among others), but on the whole ideas on matter in pre-Marxist philosophy were of a limited, metaphysical character.

The atomistic ideas of Democritus held sway over pre-Marxist materialist philosophers and the most

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[1] Frederick Engels, **Dialectics of Nature**, p. 186.

important naturalists down to the end of the 19th century. The thinkers of the past, following Leucippus and Democritus, considered atoms to be indivisible, structureless and unchanging particles, the ultimate "building blocks" out of which all material objects are fashioned. In Newton's mechanics, a special role was played by a constant magnitude, mass, which Newton viewed as a measure of the quantity of matter. Later philosophers and physicists equated it with matter.

Most pre-Marxist materialists did not link the concept of matter with a materialist treatment of the basic question of philosophy, i.e., the question of which is primary: matter or consciousness. The category "matter" was often related not to the category "consciousness", but to the categories "form", "property" and "motion". The development of the natural sciences in the 17th and 18th centuries (mechanics, physics, biology, chemistry, etc.) prompted development in ideas on matter, a development based on a notion of the primary basis (substance), the atomic structure of substance and the crucial significance of mass, which began to be viewed as the fundamental attribute of matter.

This idea was expressed succinctly in the 19th century by the well-known Russian scientist D.I. Mendeleyev, who wrote: "Substance or matter is that which, filling space, has weight, i.e., is a mass... —that which makes up the *bodies* of nature and with which the movement and *phenomena* of nature are performed."[1] The materialists of the 18th century, and Feuerbach in the 19th century, made important progress toward shaping a concept of matter, opposing matter to spirit, but only Engels gave a consistent materialist answer to the fundamental question of

[1] D. I. Mendeleyev, **The Foundations of Chemistry**, 5th edition, St. Petersburg, 1889, p. 1 (in Russian).

philosophy. The doctrine on matter was further developed in Lenin's writings.

In its most general form, as Lenin showed, matter can be defined only by explicating its relationship to men's consciousness. In fact, in their variegated activity men come up against two incontestable facts: first, that they exist in a specific milieu, in specific conditions —in nature, in society; and second, that they think, that they have their own spiritual world. Hence the question, basic for every philosophical doctrine, of the relationship of thinking to being, of spirit to nature. Materialist philosophy answers this question as follows: there is an objective reality that exists independent of man and humanity—matter, which is primary, human consciousness being secondary.

The consciousness of men and the embryonic consciousness of animals is a property of highly organized matter; therefore, consciousness cannot exist without matter, while matter existed before the emergence of man and his consciousness. Consciousness is in effect the reflection of the material world in the human brain.

On the basis of the materialist treatment of the fundamental question of philosophy, Lenin formulated the following most general definition of the concept of matter: "Matter is a philosophical category denoting the objective reality which is given to man by his sensations, and which is copied, photographed and reflected by our sensations, while existing independently of them."[1]

Lenin's definition of matter focuses attention on the universal, absolute property of matter, a property that belongs to matter in all its guises, both the known and

[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 130.

those yet unknown: its property of being objective reality, of existing external to and independent of consciousness of whatever sort. Not only the objects that exist in nature independently of man's activity (the Sun, the Earth, etc.) are material; so, too, are objects created by human labor (machines, buildings, roads, etc.), because they, too, exist external to the consciousness of men and consequently do not disappear when a particular individual ceases to sense or think about them.

In his philosophical writings, Lenin devoted great attention to the concept of matter, for it is against this fundamental category of materialist philosophy that Machists, neo-Thomists and representatives of other schools and currents of idealist philosophy have directed their fire, both then and now. Distorting the substance of new discoveries in physics, taking advantage of the difficulties that arose as a result of the collapse of old ideas, as a result of the further expansion of our knowledge about nature, they have asserted that "matter has disappeared", and with it materialism. Unfortunately, some physicists have joined in this chorus.

One cannot, for example, agree with the numerous statements by the well-known German theoretical physicist, Werner Heisenberg, who, ignoring dialectical materialism, equates materialism with mechanistic materialism and holds that all elementary particles are made of a single substance, "energy", that these particles are in a certain sense the form that energy must assume for its transformation into matter, and that "modern atomic physics has turned natural science from the materialist path on which it travelled in the 19th century".[1]

[1] Werner Heisenberg, **Physik und Philosophie**, Berlin, 1961, S. 41.

The Austrian physicist Arthur March has gone even further, proclaiming the "dematerialization" of the elementary particles and asserting that "there is nothing material about the electron", that the "desubstantialization" of the elementary particles "is one of the most striking traits of modern physics that will undoubtedly have a decisive influence on the spiritual position of the precise sciences, since it is clear that a physics that no longer believes in matter but only in form is incompatible with the materialist spirit that has reigned in the sciences for centuries."[1]

However, examination of March's entire article leads us to the conclusion that he is, in fact, opposing metaphysical materialism, rather than dialectical materialism; but since he illegitimately equates the two, he provides grounds for interpreting his words as a denial of materialism in general. Yet in the same article we read: "The electron ... cannot be the empty product of our imagination, it must be something real manifesting itself in our observations..."[2] One can agree with March that metaphysical materialism is bankrupt, but March does not know dialectical materialism, and he inflates his denial of metaphysical materialism into a denial of "the materialist mode of thinking", into a denial of materialism as a whole.

Idealism has always used the unjustified substitution of concepts, philosophical inconsistency and the philosophical impotence of naturalists in its own interests. Drawing upon statements such as those cited above, idealists maintain that "materialism has been refuted" by the advances of modern physics.

Contemporary neo-Thomists are waging an especially determined struggle against the dialectical

[1] A. March, "Mécanique ondulatoire et concept de substance", **Louis de Broglie, physicien et penseur**, Paris, 1953, pp. 111-12.

[2] **Ibid.** p. 111.

materialist definition and understanding of matter. For instance, the neo-Thomist Paul Grenet, Professor at the Catholic Institute in Paris, maintains that "matter, which 'can be everything', is in and of itself nothing; it becomes something real only when given form.... It is only by giving it form that the Creator gives matter existence".[1]

"If, *on the one hand,*" writes Paul Grenet "one believes that form is the determinant of being and action, it follows then that God conceives the Universe and creates it, realizing in matter his ideas which give it shape; *...on the other hand,* it follows that any body bears in itself the divine idea, which comes from the divine thought to our thought."[2]

Postulating the primacy of the idea, of God, interpreting the advances of physics in a speculative manner, taking advantage of some scientists' retreat from a consistently materialist approach to the fundamental question of philosophy, neo-Thomists and other idealists "demonstrate" what they have already taken without any proof as the starting point for their constructs—the existence of spirit, of idea, before the existence of nature and man.

The Marxist-Leninist understanding of matter, of its primacy with respect to consciousness, is also attacked by present-day revisionists. The French Marxist Lucien Sève justifiably and to good effect criticizes the revisionist Henri Lefebvre, who in attacking the philosophy of dialectical materialism has asserted that the primacy of matter is unprovable. In *La Différence. Introduction au léninisme.* Sève writes: "...philosophy must *of necessity* begin with the recognition of something anterior to philosophy: real human experience, which *of necessity* leads to the recognition of the anteriority of the thing with respect to the sensation, of

[1] P. B. Grenet, **Les 24 thèses thomistes**, Paris, 1962, pp. 147, 153.

[2] Paul Grenet, **Le thomisme**, Paris, 1964, p. 22.

nature with respect to consciousness, of matter with respect to spirit.... Thus, according to Lenin, and in truth, proof of the fundamental premise of materialism is given to each of us millions of times, while according to Lefebvre it is impossible to provide it even once: such are the beauties of creative anti-dogmatism."[1]

Much anti-scientific speculation has arisen from the use in the literature, and in our view not entirely satisfactorily, of the term "anti-world". In the dialectical materialist understanding, all of moving matter is a single material world. We know that in principle anti-particles (positrons, anti-protons, anti-neutrons, etc.) can form atoms (anti-atoms), molecules (anti-molecules), matter (anti-matter), macro- and mega-objects, and in totality they may conditionally be designated by the concept "anti-world". This "anti-world", the existence of which is entirely possible, will also be material, will be one of the constituent elements of the world, the Universe, i.e., objective reality, existing independently of the cognizing subject. There can in principle be no non-material "anti-world".

The facts of modern physics, astrophysics and other sciences confirm that the properties of material objects are not something given for eternity, that they are not unchangeable, absolute, preset in the metaphysical sense. Lenin analyzed philosophically the new discoveries in physics and demonstrated the baselessness of the Machists' allegations—also made by "physical" and other idealists—that "matter had disappeared", that the new physics had discarded the "outmoded" concept of matter, that there is nothing in the world except the sensual experiences of the subject, that the world consists of "sense elements", and that it is a "complex of sensations".

[1] Lucien Sève, **La Différence. Introduction au léninisme**, Paris, 1960, p. 149.

In pre-Marxist materialist philosophy, matter was from the time of Democritus viewed as qualitatively unchangeable, consisting of eternally existing, identical atoms. Marx and Engels disclosed the limited, metaphysical nature of such a view of matter. They showed that matter is in constant motion, development and change.

Engels demonstrated that we abstract ourselves from the qualitative differences of things when we unite them as materially existent in the concept of matter. He wrote that matter in general, as distinct from the definite, existing matter, is not something perceptibly existent. One can recognize matter and motion only "by investigation of the separate material things and forms of motion, and by knowing these, we also *pro tanto* know matter and motion *as such*".[1]

Developing Marxist theory, Lenin in *Materialism and Empirio-Criticism* gave his profound and full definition of the category of matter, already cited. In Lenin's definition, as distinct from the ideas of pre-Marxist materialism, matter is not identified with the concrete, historically limited forms of matter known at a given time, "...sole 'property of matter with whose recognition philosophical materialism is bound up is the property of *being an objective reality*, of existing outside the mind".[2]

Recognizing the primacy of matter and the unlimited potential for knowing objective reality, dialectical materialism resolutely opposes agnosticism and scepticism and turns investigators to the cognition and use of the laws of nature for the development of productive forces, and consequently for the good of all mankind.

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[1] Frederick Engels, **Dialectics of Nature**, p. 236.

[2] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, pp. 260-61.

One expression of the profound crisis in present-day bourgeois ideology, a reflection of the crisis in the capitalist social order, is the spread of agnosticism and scepticism among intellectuals. Scepticism and irrationalism have always been characteristic of the ideology of classes that history has doomed to extinction, of classes incapable of creating a new, life-affirming view of the world. As in the past, when Lenin wrote *Materialism and Empirio-Criticism* and other works, so today agnostics and other idealists deny not only the primacy of matter and put consciousness in first place, they also hold the world around us to be unknowable.

The development of physics has provided much new data that indicate the limitations of previous ideas on matter. We can count here the discovery of radioactivity, the transformation of one chemical element into another through radioactive decay (e. g., the transformation of the metal radium into the gas radon), the discovery of the electron, and thereafter many other elementary particles, the establishment of the fact that the mass of these particles is a function of their velocity at speeds comparable to the speed of light in a vacuum, and a number of other later discoveries. These developments have shown the limited application of Newton's mechanics and of ideas on the immutable atom and the unchanging mass.

There is nothing in the world other than moving matter, and only the existence of this objective reality external to and independent of human consciousness is immutable. "No other 'immutability', no other 'essence', no other 'absolute substance', in the sense in which these concepts were depicted by the empty professorial philosophy," Lenin wrote, "exist for Marx and Engels. The 'essence' of things, or 'substance', is *also* relative; it expresses only the degree of profundity of man's knowledge of objects; and while yesterday the profundity of this knowledge did not go beyond the atom, and today does not go beyond the electron and ether, dialectical materialism insists on the temporary, relative, approximate character of all these *milestones* in the knowledge of nature gained by the progressing science of man."[1]

There exists an objective reality, for the designation of which the concept matter has been used for several millennia. The content of this concept has changed in the course of history, but only in Lenin's definition did it attain to maximum completeness and universality.

The definition of matter as the initial category of dialectical materialism cannot be refuted by any, not even the most improbable, most unusual, discoveries in natural science. They will all enrich our knowledge of the concrete forms of matter and motion, but they will not affect the essence of the definition of matter. This definition is directed both against metaphysics and against relativism, against all shades of idealism and religion, especially against subjectivism, agnosticism and scepticism. Lenin's definition of matter is today and forever our foundation in the cognition and transformation of the world.

The concept of motion, too, is important for all of modern science, including physics and Marxist-Leninist philosophy. As a result of scientific generalization from the history of cognition, from the achievements of social and natural sciences by Marxist philosophers, it has been proved that matter and motion are inseparably linked, that motion is the form of matter's being. Engels wrote: "Matter without motion is just as inconceivable as motion without matter."[2] Matter has never existed without motion and cannot so exist.

[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 262.
[2] F. Engels, **Anti-Dühring**, Moscow, 1975, p. 76.

Even in antiquity, the philosophers of India, China and Greece made a number of brilliant guesses to the effect that the objective world is in motion, undergoes change and development, that motion is an inalienable property of everything that exists, an attribute of matter. Heraclitus' dicta on motion (everything flows, everything changes, there is nothing immovable), on opposites and their role in nature's changes, make an exceptionally strong impression even today. Marx, Engels and Lenin considered Heraclitus a brilliant spokesman of the spontaneous dialectic of the ancient Greeks. Engels, for example, stressed that, according to Heraclitus, everything is in a continual process of emergence and disappearance.

The materialists of the 17th and 18th centuries, especially La Mettri, Diderot and Helvetius, made a major contribution to the doctrine of motion, repeatedly asserting that matter is unthinkable without motion, that motion is matter's mode of existence.

Hegel has a special place in the elaboration of the doctrine of motion. Though on an idealist basis he overcame the metaphysical and mechanistic limitations of his predecessors' ideas on motion and showed that contradictions are the source of all motion; he discovered and gave philosophical generalization to the most general laws of motion.

Marx and Engels, in creating dialectical materialism, showed that "motion, as applied to matter, is *change in general*".[1] Motion is the unity of opposites: of the absolute and the relative, of stability and changeability, of discontinuity and continuity. Motion is the unity of opposites—change and rest.

All these and many other aspects of the dialectical materialist doctrine of motion are a generalization, a deduction from the theoretical and practical results of

[1] Frederick Engels, **Dialectics of Nature**, p. 247.

human activity; as truly scientific data, they allow us not only to explain phenomena already discovered, to foresee the discovery of new phenomena, they also promote dialectical materialist thinking among scholars in all fields.

The history of science provides many examples of the need for such thinking. Take one of them, which has to do with the relationship between motion and rest. At the beginning of the 19th century, the French scientist Gay-Lussac discovered one of the basic laws covering gasses (a law that has since then borne his name):

$$V_t = V_0 (1 + \alpha_p t),$$

where V_t is the volume of gas at temperature t° C; V_0 is the volume of the same mass of gas at temperature 0°; and α_p is the coefficient of the volumetric expansion of gas under constant pressure. Only so-called ideal gasses are completely covered by this law. The concepts of absolute temperature and absolute zero—minus 273.16°—were derived from this law. Absolute zero was taken as the state of a body at absolute rest, that is, for which all motion has ceased.

Subsequent research, discoveries in the micro-world and the foundation of quantum mechanics, however, showed that motion at temperatures close to absolute zero does not cease, but is of a special nature that is manifested in the super-conductivity effect, in the superfluidity of helium-II and in other quantum effects. All this indicates the variety of forms of motion and the absence of absolute rest, as well as the non-scientific character of assertions that it can exist.

The dialectical materialist doctrine on motion does not deny rest, rather viewing it as a specific case of motion, as relative rest. We can speak of rest only when we mentally sever a body's links with other bodies and view it in isolation. However, one cannot find a single body in state of rest that is not at the same time a

part of some moving system. Standing, for example, between huge modern buildings of a large city, at rest with respect to the Earth's surface, it is hard to believe that this is a state of relative rest, that in fact all of these bulks are in motion, since the given sector of the surface is in motion with respect to the axis of the globe, rotates with it around the Sun, together with the Solar system moves in our Galaxy and with the Galaxy moves with enormous speed with respect to other star-clusters. Rest is only one moment of motion, a moment that is a function of the relative constancy of a given phenomenon.

But relative rest is of importance for matter in motion, without such relative rest it would be impossible to cognize motion. Relative rest is the necessary condition for the differentiation of matter and, by the same token, an essential condition for life. Rest and motion form a dialectical unity of opposites, but rest is only a relative moment of motion, while motion (as change in general) is absolute and eternal.

The absoluteness of motion is realized through transitional forms of real motion, which are in this sense relative. Hence it follows that it is impossible to identify motion as an absolute property of matter with any relative, concrete form of the manifestation of absolute motion, for this would lead to a denial of the universality of motion.

The idea that motion is an attribute of matter is directed against the metaphysical understanding of matter as an inert mass, the normal state of which is rest, from which it is jolted only by the action of external forces. This metaphysical idea of matter deprived of the activity inherent in it leads to the positing of the existence of a first action, of God, as an external source of motion.

Let us examine, though briefly, some of the physical theories on which modern physics is based and the features of matter in motion that these theories reflect.

The first scientific theory of the motion of physical objects was Newton's classical mechanics. This theory did not concern itself with the structure of an object and dealt with impenetrable, structureless formations—physical bodies, which were studied in their motion in three-dimensional space. Space under this theory was viewed as a receptacle for bodies, which existed absolutely independently of the latter (absolute space). Time, too, was taken to be an external form of matter, independent both of matter and space (absolute time).

The principal propositions of Newton's mechanics boil down to the following:

1) the state of a system (a totality of physical bodies) is described by the assignment of coordinates and velocities for all physical bodies within the system at a given moment in time (in the general case, by the assignment of generalized coordinates and impulses);

2) a change in the state of the system in time is given in Newton's equations (more elegant forms of the equations of motion are those of Lagrange and Hamilton);

3) the assignment of a state at a given moment in time (the initial conditions) fully and unambiguously defines all motion in the system, that is, its state at any moment in time (both in the past and in the future). This formulation of causality is called mechanistic determinism (Laplacean determinism);

4) physical bodies have a single property not reducible to more simple properties—mass. The nature of mass within classical mechanics remained completely unexplainable, and was in fact formulated simply as a measure of the resistance of physical bodies to external action. The total mass of a system was constant.

Energy is an important concept describing motion. Newtonian mechanics in effect explains only the nature of kinetic energy (a measure of the mechanical motion of bodies). Potential energy is introduced in a rather formal manner and, like various non-mechanical forms of energy, is described within the Newtonian system merely as "the capacity of bodies to perform work".

Newton's mechanics, despite the fact that it does not take account of the connection that exists in reality between space and time, and of the two with matter in motion, was and remains a good scientific theory of the motion of bodies at speeds that are small as compared with the speed of light in a vacuum. This mechanics is a relative truth containing a particle of absolute truth, and is therefore of tremendous import for science.

Einstein's special theory of relativity is a theory of the motion of bodies at speeds close to the speed of light in a vacuum ($3{\cdot}10^{10}$ cm/sec); it showed the inalienable link between space, time and moving matter; it showed that the mass of physical objects and their dimensions (in the direction of motion) depend on the speed of motion, that the flow of time likewise depends on speed, and that energy and mass are interrelated. Einstein's famous formula $\Delta E = \Delta mc^2$ is now familiar even to secondary school pupils. It is extremely simple, but how enormous is its importance, or rather, the importance of those processes that it describes. All of modern atomic energetics is based on it, with its help we explain the sources of the energy of the Sun and other astrophysical objects.

When physics began its assault on the atomic nucleus in the 1930s, the theoretical basis of the endeavor was Einstein's aforementioned formula. It was clear that if we succeeded in extracting the energy from, for instance, the atomic nuclei of one cubic centimeter of matter, then despite the fact that the emission of energy from each nucleus would be small because of the enormous number of atoms in the given volume ($2.69 \cdot 10^{19}$) the total amount of energy would be shatteringly great.

The work of several generations of scientists, engineers, technicians and workers has been crowned with success, and atomic energy now makes its contribution to the energy resources of the Soviet Union.

In addition to its purely physical significance, the interconnection of mass and energy is of a major philosophical import, and it is no coincidence that even today the struggle of materialism against different idealist trends continues to center around this formula.

The law of the interconnection of mass and energy has been frequently interpreted as a law of the equivalence of mass and energy and even as the transformation of matter into motion. This mistaken understanding of the law, when developed consistently, leads to a recrudescence of energeticism. Energeticism is an idealist trend that emerged at the end of the 19th century. Its spokesmen equated the concepts matter and energy and called for a renunciation of the concept matter for the sake of "an economy of thought". The founder of this trend was the eminent physical chemist Wilhelm Ostwald, who held that "*energy* is the most general substance, for it is the *precedent* in time and space, and it is the most general *Accidenz*, for it is *discernible* in time and space".[1]

Lenin sharply criticized Ostwald's philosophical views. He wrote: "Energetist physics is a source of new idealist attempts to conceive motion without

[1] Wilhelm Ostwald, **Vorlesungen über Naturphilosophie,** Leipzig, 1902, S. 146-47.

matter—because of the disintegration of particles of matter which hitherto had been accounted non-disintegrable and because of the discovery of hitherto unknown forms of material motion."[1]

Energy is merely one of the physical characteristics of matter, a characteristic reflecting some features of motion. Mass, which likewise describes aspects of matter studied by physics, has a specific quantitative relationship to energy and reflects qualitatively different and unique aspects of matter in motion. In the future, science will certainly discover many more important and universal properties of matter that will, possibly, play a larger role in science than does energy.

It should be especially stressed that the physical concept "energy" is not identical to the concept "motion" (since the physical forms of motion are described not only by energy, but also by impulse, momentum of impulse, spin, and so on), while the concept "mass" is not identical to the philosophical concept "matter". Any attempt to present motion as the basis of everything existing means to cut it off from matter.

Lenin repeatedly turned attention to the inseparability of matter and motion, to the connection between this proposition and the treatment of the fundamental question of philosophy. He wrote: "... To divorce motion from matter is equivalent to divorcing thought from objective reality, or to divorcing my sensations from the external world—in a word, it is to go over to idealism".[2]

Philosophical delusions left their mark on Ostwald the scholar: for instance, for many years he was an

[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 273.

[2] **Ibid.**, p. 267.

opponent of atomism, denying the reality of atoms at a time when science already had persuasive proof of the atomic structure of matter. Even after recognizing in 1908 the reality of the existence of atoms and molecules, Ostwald did not renounce the doctrine of "energeticism".

Examining the question of motion and its forms in detail in *Materialism and Empirio-Criticism* and in a number of other works, Lenin came to the conclusion that the development of natural science would lead to the discovery of new aspects of matter and new forms of motion, would demonstrate their uncreatedness and indestructibility, would provide new confirmation of dialectical materialism and would promote the further development of the latter.

Penetration into the micro-world made it necessary to create a theory of motion and of the behavior of micro-objects that are qualitatively different from the unchanging and structureless objects of classical mechanics and the special theory of relativity.

The great English physicist Ernest Rutherford demonstrated that there is, in the center of the atom, a massive, positively charged nucleus, around which move, under the action of electrical forces, light negatively charged particles—electrons. We know that these forces are covered by Coulomb's law, which is analogous to Newton's law of universal gravitation. Under both laws, they are inversely proportional to the square of the distance between particles, so the planetary model of the atom suggested itself quite naturally: the movement of electrons in the atom seemed just like the movement of planets in the Solar system.

This model attracted Lenin's attention: "...atom can be explained as resembling an infinitely small solar system, within which negative electrons move around a positive electron (the atom nucleus, according to

modern terminology — *Author*) with a definite (and, as we have seen, enormously large) velocity."[1]

However, the planetary model of the atom ran into difficulty. In Newtonian mechanics, motion is defined by the initial conditions, but they may be arbitrary; hence the various dynamic characteristics of the atom—its dimensions, energy, moment of revolution—can have an arbitrary value. This means that there should be an infinity of atoms, quite different from each other, for any given chemical element. But in fact this is not the case. Atoms of a single chemical element are identical.

Further, part of the atom are electrons, which must of necessity be in motion—otherwise they would collapse into the nucleus. But if they are in motion, then the atom can be compared to a radio transmitter emanating electromagnetic waves. Since the waves carry away energy, the energy of the electron should be continuously reduced, and the electron should fall onto the nucleus. Yet we know that atoms are quite stable formations. Hence classical mechanics and classical electrodynamics are unable to explain the existence of the stable atom.

These difficulties made it necessary to revise the classical ideas on the nature of motion. Here we must return to 1900, when Max Planck proposed his famous formula for the energy of the spectrum of radiation of a black body. Previously, two experimental functions had been known: for low frequencies—the Rayleigh-Jeans distribution, for high frequencies—the Wien distribution. Planck was able to derive an interpolated expression for the entire spectrum, an expression that covers both of the extreme relationships at the corresponding frequencies. It turned out that the energy function cannot be continuous, and the

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[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 260.

magnitude of the energy jump is proportional to the frequency. The universal constant h, introduced by Planck, played the role of the coefficient of proportionality. Since its dimensionality corresponded to the dimensionality of the energy multiplied by time, Planck called it the quantum of action (action has just this dimensionality).

Planck continued for a long time to ponder the meaning of the result he had obtained, for much remained unclear. Only after Einstein had explained the laws of the photoeffect (1905) did the true meaning of Planck's truly great discovery become clear; this was the first impetus for the creation of quantum mechanics.

Einstein asserted that any monochromatic wave of a given frequency ν carries a quant of energy, equal to $h\nu$, and an impulse $\frac{h\nu}{c}$ (where c designates the speed of light in a vacuum). Using only this statement and the law of the conservation of energy, he created the theory of the photoeffect. This was the origin of the idea of the discrete structure of light, which is expressed in the fact that specific portions of energy correspond to each wavelength. This corpuscular structure of radiation is reflected in the concept of the photon—the elementary particle of light corresponding to radiation of a specific wavelength. Quantum theory provided just as natural an explanation for phosphorescence and fluorescence, light-absorbing photochemical reactions, heat absorption by solid bodies (the Einstein-Debye theory) and the behavior of diatomic gasses at temperatures close to absolute zero.

The next stage in the development of the quantum hypothesis was Niels Bohr's explanation, in 1913, of the empirical laws of linear spectra. He postulated the presence of stationary electron orbits in the atom; each state of the electron matches a specific energy E_1, E_2, E_3... and so on. An electron in a specific orbit cannot radiate, as classical electrodynamics requires. On the other hand, upon passage from one orbit (level) to another, the electron emits (or absorbs) a light quant, the frequency of which is defined by the equation $h\nu = E_2 - E_1$. The selection of stationary orbits is based on the following quantum condition: the moment of the quantity of the electron's motion during its motion in orbit must be an integral, that is a multiple of the value $\frac{h}{2\pi} = \hbar$.

The quantum hypothesis did not, however, mean that classical mechanics was invalid. It only limited the applicability of classical mechanics. Classical mechanics turned out to be an extreme case of a more general physical theory—quantum and wave mechanics, one of the cornerstones of which is the Heisenberg uncertainty principle. This mechanics was the result of the work of Bohr, Schrödinger, Heisenberg, Dirac, Born, Louis de Broglie and others.

Quantum mechanics is the science of the motion of electrons in the atom, of all elementary particles with speeds rather small in relation to the speed of light in a vacuum. This mechanics is known in two forms: Heisenberg's matrix mechanics and Schrödinger's and de Broglie's wave mechanics.

De Broglie hypothesized that all bodies in nature must (like light) simultaneously possess both wave and corpuscular properties, and he derived a formula for the length of the wave of a particle. For example, the wavelength of an electron is $\lambda = \frac{h}{mv}$, where h is the Planck constant, m is the mass of the electron and v is the velocity of its motion. Electron diffraction experiments have confirmed the equation. This equation was formulated by de Broglie two years before Heisenberg's work.

Erwin Schrödinger generalized de Broglie's hypothesis into the wave equation that now bears his name: $\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}[E - U(x)]\psi = 0$.

Here m is the mass of the electron; $\hbar$ is the Planck constant, divided by 2π; E is the total energy of the electron in the atom; $U(x)$ is its potential energy; x is the distance from the electron to the nucleus; and Ψ is the wave function describing the motion of the electron in the atom. It should be mentioned that even today the meaning of this function is debated, but despite this Schrödinger's equation makes it possible to solve complex problems of the movement of micro-objects.

We have reviewed some of the forms of the motion of matter. We have not considered the motion of the structural elements of atomic nuclei and elementary particles themselves, or other forms of motion in non-living and living nature and society. But even if we have considered all the forms of motion known to science today, we would still have every reason to assert that in reality—in the micro-, macro- and mega-worlds—there exist other forms of motion that are as yet unknown to inquisitive human reason. This is evidenced by the entire history of science, which brilliantly confirms the proposition that the world is eternally moving, uncreated and indestructible matter.

THE UNCREATEDNESS AND INDESTRUCTIBILITY OF MATTER

The idea of the uncreatedness and indestructibility of the objective world has a long history, the roots of which go back to deep antiquity. The most reliable evidence seems to be associated with one of the greatest thinkers of antiquity, Aristotle. He maintained that the material world has always existed and will always exist, that this material world does not require the existence of a special spiritual world to explain its existence. However, the inconsistency and vacillation between materialism and idealism characteristic of Aristotle were reflected in his views on the material world. According to Aristotle, matter contains only potential, which becomes reality only under the action of form. The form of all forms, in his doctrine, is God, who has the function of "prime mover". Itself immobile, the "prime mover", according to Aristotle, sets the entire world in motion.

One of the ancient world's outstanding materialists, Epicurus, emphasized with especial force that nothing comes from the nonexistent and nothing becomes nonexistent. Here we meet again a conjecture as to the eternity and indestructibility of matter as the substratum of all natural objects, an attempt to explain the phenomena of nature within the framework of nature itself, without the assistance of supernatural, divine forces.

The idea of the uncreatedness and indestructibility of moving matter, an idea that is the antipode of the idea of the creation of world by an immaterial force, can be traced through the works of many thinkers of the past. But limitations of space force us to confine ourselves to what has already been said.

Recognition of uncreatedness and indestructibility of matter and the forms of its existence deprives the question of the creation of the world by some higher, extra-worldly force, i.e., God, of any meaning. The uncreatedness and indestructibility of matter means that there is no means by which its existence can be ended or by which it can be created from "nothing", that there has never been and will never be a time when matter will not exist.

All forms and states of matter in motion are finite, emerge and disappear, pass from one into another, but moving matter itself is eternal, infinite and inexhaustible in its properties. Denial of the inexhaustibility, uncreatedness and indestructibility of matter, whatever form that denial may assume, always leads to an idealist, and in many cases a religious, view of the world.

In effect, in the religious view of the world the indestructibility and uncreatedness inherent in matter and its attributes are transferred to a being created by human imagination—God. From the religious point of view, God exists eternally, he is uncreated and indestructible, while matter and its attributes are merely products of God's activity, i.e., created and destructible. It is worth noting that in comparatively early forms of religion, such as the ancient Greek, a succession of gods was recognized, the replacement of one generation of gods by another; no generation of gods was endowed with eternity, which was given only to chaos, to primordial matter, from which emerged and to which returned everything existing in the world,

including the gods. But this view of the gods was, even in Ancient Greece, ultimately taken to be in fundamental opposition to religion. Not in vain did Plato in his project for an ideal organization of the state demand that the works of Homer and Hesiod, who presented this view of the gods, be forbidden. In the Christian religion, any doubts as to the eternal existence of God were declared a criminal heresy. In short, in every form of developed religion—where religious tenets are put into some logical system—recognition of the eternal existence of God is a fundamental dogma.

The question here arises as to how we can explain the fact that both science and religion make identical use of the concepts of uncreatedness and indestructibility, the first with respect to matter and its attributes, the second with respect to God. Marx noted that any fantasy, even the most absurd, has a rational core. People not only create fantastic images, arbitrarily combining differing but quite valid ideas (e.g., the image of the mermaid is an arbitrary combination of realistic ideas of maids and fish), they also allot them the known properties of nature, society and their own thinking.

People transfer the features of nature that have been generalized from practical experience and cognition to the imaginary beings that they have invented—gods. The idea of the uncreatedness and indestructibility of the material world took shape gradually in the course of practical experience and cognition, and this same idea was used in religion to describe God as the basis and original source of the material world.

However, there is a profound difference between the scientific idea of the uncreatedness and indestructibility of matter and its attributes and the religious idea of the uncreatedness and indestructibility of God. In religion, this idea has acquired the character of a dogma, a proposition in which one must simply believe, which one cannot in any way demonstrate; it is attributed to a non-existent object, the study of which is absolutely impossible, so one cannot in religion express this idea in any concrete forms that would express its substance more profoundly. This idea is frozen in religion at the level of an abstract, trivial assertion. It is both reactionary and not conducive to the development of science and thinking.

In science, on the other hand, the idea of uncreatedness and indestructibility is attributed to the objective world, which is open to ever deeper knowledge and is therefore expressed in increasingly concrete, substantive forms, verifiable by the further development of science and practical activity.

The idea of the uncreatedness and indestructibility of matter is continually confirmed by science and functions as a guiding principle in the development of the scientific cognition of the world. Religion, borrowing some concepts from science, always turns them into lifeless, trivial dogmas, and on the strength of this they lose completely their real content. The idea of the uncreatedness and indestructibility of the world when attributed not to the material world but to God is an idea that has no concrete meaning, it is an empty idea.

One of the expressions of the scientific idea of the uncreatedness and indestructibility of the material world is the principle that it is impossible for "something" to come from "nothing" and for "something" to turn into "nothing". In short, this principle is formulated as follows: "Of nothing comes nothing." This principle emerged first as a generalization from work experience, even in its most elementary forms. In practice, it was clear even to primitive man that it was impossible to create a

tool, to construct a dwelling, or to prepare food from "nothing". This principle entered science from daily life, becoming one of the cornerstones of science. We can say with complete justification that this principle is the basis both of science and the materialist view of the world. There is nothing surprising in the fact that this principle, which excludes the possibility of creating any material object from "nothing", has been subjected to every possible attack by religion and idealist philosophy.

At the end of the 18th century, the German philosopher Immanuel Kant, though he did not reject the principle outright, limited its application to the world perceived by the senses, to the world of our sense experience, the phenomenal world. In the world that exists independently of men, of their experience, the world, in Kant's terminology, of "things in themselves" (which is from Kant's point of view absolutely unknowable for us) we cannot apply this principle. With respect to the world of "things in themselves", we can with identical lack of knowledge maintain both that nothing comes of nothing and that "something" can come of "nothing" and return to "nothing".

According to Kant, then, this principle is of significance only with respect to our experience, but in no case with respect to the world itself. With the principle so limited in import, it became completely harmless for religion and in no way refuted the religious dogma of the omnipotent will of the deity, which is allegedly capable of creating not only specific objects, but in fact the entire world, from "nothing".

The Kantian treatment of the principle under consideration is an example of his handling of the general task of philosophy, which was, in his words, to limit knowledge so as to leave room for faith, and to limit faith so as to leave room for knowledge. Briefly stated, Kant's treatment of this principle is an attempt to reconcile science and religion, assigning each a special sphere: for science, the world of experience, for religion, the world that exists independently of man's experience, the world of "things in themselves".

Hegel also attacked this principle. He strove to provide an idealist foundation for science itself, holding that materialism with its principle of "nothing comes of nothing" limited science, made it incapable of understanding the true regularity of the world. The concepts "something" and "nothing", maintained Hegel, are of equal standing. Each can emerge from the other: the concept "something" from the concept "nothing", and vice versa. Moreover, in their most general content these concepts are identical. Science cannot be full or complete, said Hegel, if it relies solely on the concept "something" and rejects the concept "nothing". Only on the basis of the unity of these concepts, in his opinion, is it possible to bring into science the concept of emergence, development, and destruction. Without these concepts there cannot be a genuine science.

In the idealist philosophy of Hegel, the existence of the absolute spirit is anterior to the existence of the material world, of nature, while the connections between concepts, the transition of one concept into another, are anterior to the connections and transformations of the things and objects of nature.

Therefore, from Hegel's point of view, demonstration of the connection and transition of the concepts "something" and "nothing" is demonstration of the connection and transition of the being and non-being of the objects of nature. If we admit the connection between being and non-being, "something" and "nothing", and the movement, as Hegel said, of one into the other, it is obviously impossible to admit the truth of the principle that "nothing comes of nothing". But it is also obvious that Hegel refuted this principle only in the realm of pure ideas, and his proof can be accepted only if we accept the foundations of his philosophy—in other words, if we recognize his "absolute spirit" as the source of the existence of nature, and therefore the connection between concepts as the source of the connection between things.

Hegel's refutation of the principle at issue revolves in a closed circle. According to Hegel, "absolute spirit" creates itself from nothing, by pure logical development, and then manifests itself in nature, which functions as its other, external being. Therefore, nature simply repeats what has already been created by the "absolute spirit", and if there is no place for the principle "nothing comes of nothing" in its own internal development, then this principle cannot have a place in nature. Hegel's refutation is, therefore, a direct consequence of the idealist bases of his philosophy. Hegel proved, in effect, what he had accepted without proof.

Opposing the principle under discussion, Hegel understandably opposed all its concrete expressions, too, in particular the laws of conservation known to physics at the time. At this level, Hegel's philosophy was in sharp opposition to the level of development that science had then achieved.

We should note here that Hegel was wrong to hold that the recognition of this principle eliminates from scientific usage the concepts "nothing" and "non-being" in their connection with the concepts "something" and "being". Quite to the contrary, the concepts "nothing" and "non-being" in their connection with the concepts "something" and "being" play an important role in science, and this role is constantly expanding. Before examining this, however, we must take a more detailed look at the substance of the principle we are considering.

Its content, even when viewed in the most general form, includes the following basic aspects (and does not come down simply to the assertion "nothing comes of nothing"):

first, a material object can come into being only from other material objects;

second, the disappearance or destruction of a material object always means the conception of one or more other material objects;

third—and this follows from the first and second points—no material object can be created or destroyed by the process of thinking alone. In other words, no material object can be created from concepts, ideas or sensations. The latter can reflect material objects as precisely as one may wish, but they do not under any circumstances create material objects. One may have extremely precise ideas of all the parts of the works of a clock, but one cannot create a clock from these ideas, one must materialize them in the form of parts from which one may then put a clock together. In the process of conscious labor, men have in their heads a system of concepts and ideas that express more or less precisely the construction and properties of the thing being manufactured, but this thing, in accordance with this construction, will not be manufactured from concepts and ideas, but from other material objects;

fourth, the conception and destruction of material objects is nothing other than moments of their change, of their transformation. A material object transformed into another material object ceases to exist in its previous guise. It is a new object. In the process of change or transformation, a material object possesses both being and non-being. Any process of transformation, change or development of material

objects includes both destruction and conception. Here it is worth noting the inaccuracy of the use of the term "the annihilation of matter" in some works on physics, a term used with especial frequency in popularized literature. The literal meaning of this term (nihil—nothing) is transformation into nothing, the destruction of matter. This term is applied in physics to the process in which particles and anti-particles are transformed into radiation. One form of matter—substance turns into another—field. Here, however, there is no destruction of matter. This not very apt term has been picked up by the present-day enemies of materialism who use it in the attempt to "refute" dialectical materialism.

It is easy to understand that the destruction of a given concrete thing can be viewed as its transition to "non-being", to "nothing", while its emergence can be viewed as the transition to "being", to "something". Thus, contrary to Hegel, the principle that we are examining does not exclude the use of the concepts "nothing" and "non-being", and with them the concept of development, but on the contrary lends these concepts the necessary precision and eliminates the tinge of mysticism.

We have already indicated that the concepts "nothing" and "non-being" play an important role in science. Hegel was correct in holding that without these concepts it is impossible logically to define the concepts "development", "change", "becoming", and without the latter, of course, no scientific theory is possible. But this is only one side of the role of the concepts "nothing" and "non-being" in science. The other side is that they directly describe the historicity and uniqueness of many properties and states of material objects, their limitation in time, their transitional nature. The state our Earth was in, say, in the Paleozoic era, no longer exists, no longer possesses being, is now nothing. The concepts "nothing" and "non-being" refer to the past—not in the sense that some states did not exist, but in the sense that they do not exist in the present. The transition from being to non-being is an objective process, an aspect of the change, the development of material objects.

We can reflect in our thought the processes of the development, change and transformation of material objects only by means of the transition from the concepts "being" and "something" to the concepts "non-being" and "nothing", and vice versa.

But there is a third side to the role of the concepts "non-being" and "nothing" in the development of science. It consists in the fact that these concepts can be considered, in a number of their limited expressions, designations for states of moving matter that are unknown to us. For instance, we often take emptiness in nature to be a limited "non-being", a limited "nothing". Emptiness, some think, is space in which there is no moving matter. That is to say, it is not an absolute "nothing", but a "something" (space) in which there is no matter. But this assertion contradicts both the philosophy of dialectical materialism and the facts of modern science. It has turned out that "empty" space does not and cannot exist in nature. Space without matter is impossible, for it is one of the basic forms of being. Every area of space is always connected with some aspect of matter, and space itself is not a receptacle for bodies.

The concept of emptiness is unscientific, and it cannot be used in an absolute sense, that is, in the sense of denying the being of all forms of moving matter; it is permissible only in a relative sense—in the sense of the non-being of some specific aspects of matter, of specific fragments of objective reality. If there is no substance, there is a field, and if there is no field then there is its physical vacuum.

As a rule, then, the concepts "non-being" and "nothing" are used in modern science in a relative rather than absolute sense. And when some contemporary physicists and astrophysicists maintain that in some unit of time some quantity of matter arises in the Universe from "nothing", this must (if it were to be confirmed) be understood as the conception of a substance through the transformation (transition from one state to another) of some other form of matter. The concept "nothing" clearly functions here as a designation for forms of matter as yet unknown to us, as a designation allowing us to apply the idea of development to realms of nature as yet hidden from us. True, one might, in such cases, speak directly of forms of matter as yet unknown to us, but in what way would this be better than the expression "from nothing"? We are dealing in both cases with our lack of knowledge. Speaking of forms of matter as yet unknown to us, we speak of a "something" about which we can as yet say nothing. But this "something" differs little from "nothing".

It is clear from all of this that the concepts "non-being" and "nothing" have a number of different applications in science. And none of these applications contradicts the principle "nothing comes of nothing". However, we must keep in mind that replacing the concept "something" with the concept "nothing" when we cannot as yet say anything about that "something" may, unless we explain that in the given case the concept "nothing" is simply substituting for the concept "something", lead to the incorrect inference that we are violating the principle "nothing comes of nothing". This sort of explanation is absolutely mandatory, especially in the popular literature.

As with any principle in science, the principle "nothing comes of nothing" must be viewed in its development, in the concrete forms in which it is expressed. We must here recall again that the principle itself is one of the aspects or forms of the expression of the more general principle of the uncreatedness and indestructibility of matter and its attributes.

In the development of modern physics, situations have repeatedly arisen when it has seemed to many researchers (and even more so to popular-science writers) that given just a little bit more the physical picture of the world would be complete and the development of physical science would end. The aspiration to finiteness, completion, closure, perfection, simplicity has some basis in thinking and in everyday activity, e.g., in the fact that people ordinarily have to do with finite phenomena and things. But scientific cognition does not stop at the study of phenomena, but penetrates into their essence. It is in the cognition of the essence and in practical experience that one answers the question as to whether the object of cognition is finite or infinite, limited or inexhaustible.

The principle of finiteness is at the base of many religious beliefs, so spokesmen for such beliefs have always sought confirmation of their assumptions in the conceptions of finiteness defended by some scientists. For instance, we sometimes meet in the scientific, popular scientific and mass literature theories on the "beginning" of the Universe—and it is not made clear that what is being referred to is not the world as a whole, but that part of the world that is studied by the astrophysical sciences. The concept of finiteness is also the basis for arguments to the effect that physical science has exhausted or will soon exhaust its objects of cognition, and so on.

Analysis of various finite hypotheses and theories leads to the general conclusion that their "finitism" is often the result of an insufficiently rigorous use of the

logical and conceptual apparatus, of a loose use of scientific facts, of a lack of the necessary training and of deep understanding of the fundamental propositions of dialectical materialism. In this regard, we should direct special attention to the heuristic role of the principle of the inexhaustibility of moving matter, an enormous role in the development of which belongs to Lenin.

In the course of their research, genuine scientists are consciously—or, for many, unconsciously—guided by this principle, they understand its heuristic role in the creation of scientific theories. The objective content of a principle as yet unknown to scientists often appears spontaneously in the process of their thinking. For instance, Albert Einstein, who did not make conscious use of the principle of inexhaustibility, wrote: "The belief in an external world independent of the perceiving subject is the basis of all natural science. Since, however, sense perception only gives information of this external world or of 'physical reality' indirectly, we can only grasp the latter by speculative means. It follows from this that our notions of physical reality can never be final. We must always be ready to change these notions...."[1] Norbert Wiener expressed himself in the same sense: "To me, logic and learning and all mental activity have always been incomprehensible as a complete and closed picture and have been understandable only as a process by which man puts himself *en rapport* with his environment."[2]

Belief in the power of human intellect, the conviction that we have an unlimited potential for knowledge of what is as yet unknown, plays a leading role in the development of science. But if one adopts the position

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[1] Albert Einstein, **Ideas and Opinion**, London, 1956, p. 266.
[2] Norbert Wiener, **I Am a Mathematician**, New York, 1956, p. 324.

that it is possible to obtain complete knowledge by means of the reflection of all the properties and interrelations of the world around, if one admits of the finiteness and exhaustibility of the object of cognition, one not only deprives science of its prospects for the future, but leads in the final analysis to the admission of the conception, and hence disappearance, of the material world.

The infinite potential for cognition is inseparable from the inexhaustible properties of moving matter, which exists eternally, which has no beginning and no end to its existence. Any assertion as to the finiteness, the exhaustibility of the properties either of the material world or of its constituent objects is in substance anti-scientific.

Attentive study of the facts of modern physics and astrophysics, study of scientific hypotheses and theories on the micro- and mega-worlds, permits us to assert that there is not a single experimental or observed fact, not a single reliable theory, that provides any basis for the assertion that matter can be created and can disappear, that the world is finite or that knowledge of the world or of the objects and phenomena that go to make it up is exhaustible.

Lenin, drawing on the achievements of science and on socio-historical practice, showed that the object of human cognition—matter in motion—is uncreated, indestructible and inexhaustible in its properties.

The uncreatedness and indestructibility of matter and of its forms means that no process that occurs in the world can ever involve the creation or destruction of moving matter, can ever create it from absolute nothing or transform it into absolute nothing, or can destroy or create its being in space and time. The only scientific meaning of the concept "conception" is the

transformation, restructuring or modification of pre-existing states of moving matter into new states—and without exception in specific, though perhaps quite different, spacio-temporal forms. The scientific meaning of the concept "destruction" is the transition of one state or form of moving matter into another state or form. The concepts "conception" and "destruction" are interrelated in their meaning, and in effect they coincide. Thus, they cannot be separated one from the other and must be viewed as moments of a single concept of qualitative change. These concepts are applicable only to concrete objects that emerge and disappear as such. But they originate as the result of the transformation of other material objects, and they are destroyed only by turning into other material objects.

The great principle of science and practical experience—"nothing comes of nothing"—will never lose its importance. True, one occassionally comes across in the popular literature the following assertion: modern physics admits of the possibility of the conception of substance from a vacuum, understood as emptiness, as absolute "nothing". In fact, a vacuum is understood in modern physics as a special state of matter. For instance, the vacuum of an electromagnetic field is the state of this field in which there are no photons.

Recognition of the indestructibility and uncreatedness of matter and of its forms leads to recognition of the principle of infinity. The infinity of the existence of moving matter means that it cannot cease existing by any means, that there has never been or will be a time when it has not existed or will not exist. If the forms and states of moving matter are finite, i.e., originate and disappear, moving matter itself is infinite, and its infinity consists in the fact that it never ceases to pass from one finite state to another.

Correspondingly, the infinity of space and time consists in the fact that the infinite transitions of moving matter from one state to another will not lead to its exit from spacio-temporal forms of being, though they may be attended by transition from one spacio-temporal region to another, with a different dimensionality and topology. The infinity of space and time is the continuously existing potential for the transition of matter from one spacio-temporal region to another, both of which are of themselves finite. The infinity of moving matter and of its spacio-temporal forms, then, is disclosed through the transition of one finite state of matter to another finite state and by its exit from one finite spacio-temporal region to another, likewise finite, region.

In the philosophical and natural-science literature we sometimes come across assertions according to which recognition of the finiteness of the world does not contradict natural science and dialectical materialism, in particular, the latter's proposition to the effect that there is nothing in the world besides matter in motion. This view comes from the difficulty of understanding infinity. Our ordinary ideas of infinity are involuntarily linked with its counterposing to the finite, the transitional, so we consider the infinite to be something beyond the finite. And since we have to do with the finite, the concept of the infinite functions as a supplement as to the real meaning of which we may have doubts. Here, however, we must note that the difficulty in understanding infinity begins with its opposing to the finite. If we take the infinite in its connection with the finite, as we have done above, then the mystery of the concept disappears and it becomes apparent that through finite objects that pass from one state to another we have to do, too, with the infinite.

As to the proposition that admission of the finiteness of the world does not contradict dialectical materialism, we must say that this is at the least inconsistent. One cannot accept dialectical materialism without accepting the uncreatedness and indestructibility of matter, and acceptance of the latter is in fact acceptance of the eternity and infinity of the existence of matter.

ON THE INEXHAUSTIBILITY OF MOVING MATTER

There follows immediately from the infinite existence of moving matter and its attributes the inference, confirmed by practical experience, that the properties, states and connections of the matter in motion are inexhaustible. Since infinity exists only through finite objects and their passage into other finite objects, through the changes that they undergo, inexhaustibility is inherent not only in the world as a whole, but in each of its objects. Lenin's proposition speaks to this point: "The electron is as *inexhaustible* as the atom, nature is infinite, but it infinitely *exists* ... outside the mind and perception of man...."[1]

In our time, physics concerns itself with two forms of matter, substance and field, which are linked closely to each other. We now include among the special states (or forms) of matter the physical vacuum as well, though the latter is as yet not studied well enough by physics. Science has even less reliable information on new forms (with respect to the terrestrial) of matter in the astronomical Universe, though there is every reason (both physical and philosophical) to anticipate such new forms from considerations of the qualitative and quantitative differences between the mega-world, on the one hand, and the macro- and micro-worlds, on

[1] V. I. Lenin. "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 262.

the other. These considerations pertain, too, to our treatment of the micro-world, especially at distances of less than 10^{-14} cm.

In principle, we retreat not one step from dialectical materialism in admitting the infinity of the forms of matter. In their turn, the forms of matter that we know already—substance and field—also possess an inexhaustible diversity of properties.

The world is the totality of interacting real objects, and since the properties of things are manifested in their interrelationships, the number of properties of each object and of the material world as a whole is infinite and each object is itself inexhaustible for cognition.

The principle of inexhaustibility that Lenin formulated applies to the basic forms of matter's existence: motion, space and time. Since motion is an infinite totality of diverse changes, transitions and transformations of matter, it is as inexhaustible as matter itself. Even now, we know a multitude of differing changes that occur in the world, beginning with the interconvertibility of elementary particles and ending with changes in the material and spiritual life of society. The intrinsic task of science is to study and discover new changes, transformations and transitions occurring in the material world.

Space and time, too, possess an inexhaustibility of properties, structures and interactions between themselves and moving matter. Before Lobachevsky's discovery of the possibility of non-Euclidean geometries, there was a widely held view in science that our knowledge of the properties and structure of space was complete. After the discovery of non-Euclidean geometries, it was clear that the properties of space depend on the structure of matter, on its forms of motion, and are inexhaustible.

The general theory of relativity (in which the idea of non-Euclidean geometries found application), which established that the properties of the space-time continuum are a function of the presence of large objects possessing gravitation mass, provided new confirmation for dialectical materialism's proposition that space and time are attributes of matter. It turned out that, near massive bodies, space is warped and the flow of time is slowed.

And what of the space of living objects? Science now faces the task of building up a picture of the properties of the space of living objects (of which Academician Vernadsky wrote in his day), as well as of the space of the inner regions of elementary particles and unusual astrophysical objects with the aid of new geometries and topologies and, perhaps, other new fields of mathematics.

At present, we have good reason to suppose that even so fundamental a property of space and time as uniformity is only an approximation of reality. When there are large gravitational masses in a space-time region, we can speak of uniformity only with respect to local regions. The general theory of relativity is evidence of this.

The question of the uniformity of the space-time continuum is of importance in principle, since some of the laws of conservation in physics, laws to which we shall return, are linked to this uniformity. We have to stress here that the facts of modern physics reveal the contradictory unity of the uniformity and non-uniformity of the space-time continuum. If the concept of the uniformity of space and time expresses aspects of stability, conservation and symmetry inherent in moving matter, the concept of non-uniformity expresses its changeability, historicity and asymmetry. The unity of uniformity and non-uniformity is one of the aspects of inexhaustibility.

One can speak of the uniformity of space and time only having completely isolated them from moving

matter, and one can speak of their non-uniformity only having equated space and time with moving matter. Both extremes destroy the unity of space-time and moving matter and contradict the facts of science and experience. Recognition of the unity of the attributes of matter, on the other hand, leads necessarily to recognition of the unity of the properties of the uniformity and non-uniformity of space and time, or more generally, recognition of the unity of symmetry and asymmetry inherent in moving matter and its spacio-temporal forms of existence. Truth consists not in the separation of the attributes of matter, but in their unity, not in the opposing of uniformity to non-uniformity, of symmetry to asymmetry, but in their contradictory, dialectical unity, in which uniformity and non-uniformity operate as aspects of each other. Uniformity exists in non-uniformity, and vice versa. In general, as we shall show subsequently, in every symmetry there are elements of asymmetry, and in every asymmetry elements of symmetry.

The principle of the inexhaustibility of the states, properties and connections of matter and its forms has one further aspect. Can we assert that the attributes and basic forms of matter's existence are exhausted by such known forms as motion, space and time, or are there in reality other forms of its existence? In conformity with the principle of inexhaustibility, we must answer this question in the affirmative. It is quite possible that in the world there exist other forms of the being of matter, such, for instance, as reflection. The hypothesis that reflection is a fundamental, universal property of matter was advanced by Lenin in *Materialism and Empirio-Criticism*. This hypothesis now finds increasing support in physics and biology as well as in cybernetics.

But we must keep in mind that discovery of new forms of matter's being will not lead to a limitation of the universality of motion, space and time. The same processes of reflection change and have spacio-temporal being. In other words, no discovery of new forms of matter's being will lead to the inference that matter can exist without motion or outside space and time.

When Lenin wrote of the inexhaustibility of the electron, the concept of "elementary particles" did not yet exist, since only two particles—the electron and the proton—were then known. The family of particles and anti-particles now has more than two hundred members. Among them are the electron, a stable particle with a negative charge and a mass equal to $9 \cdot 108 \cdot 10^{-28}$ grams; the proton, the positively charged nucleus of hydrogen with a mass 1836 times greater than the mass of the electron; the neutron, a particle that has no electrical charge and has a mass equal to the mass of 1838 electrons; the neutrino, a particle also lacking an electrical charge, with a mass at rest either equal to zero or small to the vanishing point (the neutrino is known in two forms, the electron neutrino and the muon neutrino); the photon, a quant of the electromagnetic field, with a rest mass exactly equal to zero. This particle is always in motion with a constant velocity of $3 \cdot 10^{10}$ cm/sec (the speed of light in a vacuum).

There is a large group of particles, the masses of which are intermediate between the masses of the proton and the electron. These particles are called mesons: the μ-meson (muon), π-meson (pion), K-meson and others; in addition, we know of hyperons, the mass of which exceeds the mass of a proton. A large group of short-lived particles, called resonons (unstable particles decaying in 10^{-24} sec), has also been discovered in recent years. In November 1974 came the first reports of the discovery of a new particle, called ψ-particle. Its mass is quite large

(more than three times the mass of a proton), and it has a relatively long lifetime. Soon thereafter, an analogous particle with a mass exceeding that of the ψ-particle was discovered, and in January 1975 two similar particles with large masses were discovered. The discovery of these particles raises new questions whose solution will obviously present mankind with something that is new in principle. All these particles have their antipodes—anti-particles (with the exception of the photon, which is itself an anti-particle). Theorists engaged in systematizing particles contend that there are a number of undiscovered particles, among them quarks, dions, partons, vector mesons and others.

Recent study of the structure of nucleons (intra-nuclear particles—protons and neutrons) on the two-mile Stanford linear accelerator has led to the conclusion that nuclear particles have "a complex internal structure consisting of point-like entities now called partons".[1] What is most striking is that the data obtained thus far indicate that some of the properties of partons are similar to the properties of the hypothetical quarks. Murray Gell-Mann and, independently, George Zweig proposed in 1964 that there should be particles bearing (as distinct from all known particles) a fractional electrical charge: either $+\frac{2}{3}$ or $-\frac{1}{3}$. However, neither quarks nor partons have as yet been discovered experimentally in their free state.

There are many different processes in which elementary particles take part; we know of a large number of scatter and generation reactions, transformations and formation of particles out of other

[1] Henry W. Kendall and Wolfgang K. H. Panofsky, "The Structure of the Proton and the Neutron", **Scientific American**, June 1971, p. 61.

particles. These experimental data permit us to assert that the particles have an internal structure, for a point-like, structureless particle could not yield such a variety of phenomena.

Every micro-object not only conditions particular phenomena in nature, it is itself conditioned and has, consequently, a structure. It is the changeability, the dynamism of the structure of micro-objects that gives rise to the multiplicity of their states under different interactions, and this in turn determines their inexhaustibility.

Modern physics has shown that the micro-world is complex in its structure, in its interconnections and interactions.

Scientists strive to systematize the existing data so as to predict, by means of a table of elementary particles similar to Mendeleyev's Periodic Table, the existence of new particles, to discover new connections and interdependencies.

It is now firmly establisted that there are four types of interactions—strong, electromagnetic, weak and gravitational. All elementary particles subject to these interactions can be divided into three clearly distinguished groups: adrons, leptons and photons.

Adrons include the various baryons (the general name for nucleons and hyperons), mesons, the corresponding anti-particles, and the various resonons—baryon and meson—that represent very short-lived adron states.

Leptons include electrons, positrons (anti-electrons), muons of both positive and negative charge and electron and muon neutrinos.

The majority of particles, or more precisely, of adrons, including all the anti-adrons and resonons, have been "created" artificially by the acceleration of charged particles—the principal experimental tool in the physics of elementary particles. The emergence of

new particles in collisions between known "old" particles provides experimental proof of the possibility of the existence of new material objects unknown in present conditions on Earth. The discovery of these material objects (known in physics by the general name "sub-nuclear matter"), as well as of different processes of the interconvertibility of various forms of matter—the electromagnetic field, electrons and positrons, nuclear and sub-nuclear matter—is one of the greatest achievements of science.

Let us consider briefly the types of interaction known in modern physics. We shall begin with strong interaction, to which only adrons are subject. This interaction includes, in particular, nuclear forces acting between nucleons (i.e., between protons and neutrons) and conditioning the structure of nuclei. Strong interaction is non-homogeneous and can be subdivided into two interactions: especially strong (or strong) and moderately strong (or semi-strong). They differ somewhat in intensity, but the primary difference is in their internal symmetry.

Electromagnetic interaction is determined by the electrical charge, identical for all charged particles and equal in magnitude to the charge of an electron. Though electromagnetic interaction is the most thoroughly studied of all types of interaction, modern theory cannot give a persuasive answer why this is so.

Electromagnetic interaction conditions the structure of atoms and molecules. The intensity of electromagnetic interaction is approximately 100 times less than the intensity of strong interaction.

The radii of action of electromagnetic and strong interaction differ sharply: while electromagnetic forces act over any distance, strong interaction is of brief duration, with a radius of action on the order of 10^{-13} cm (i.e., on the order of the dimensions of the atomic nucleus).

All elementary particles, except the photon, are subject to weak interaction. The intensity of this interaction is approximately five orders less than the intensity of strong interaction. Weak interaction is responsible for various decay processes of adrons. For example, the free neutron decays (into a proton, electron and anti-neutrino, with a decay time approximately 17 minutes) because of weak interaction, as do charged pions (with a decay time of approximately 10^{-8} sec). Weak interaction is responsible for the β-decay of nuclei.

All physical objects are subject to gravitational interaction, which determines the movement of planets, stars and, in general, the structure of the astronomical Universe. In the world of particles, gravitational interaction is not immediately manifest because of the small mass of the particles, but it is possible that gravitational interaction plays a substantial, though as yet unknown, role here, too.

The fundamental interactions are characterized by specific forms of symmetry. This means that interaction remains invariant, i.e., does not change upon certain transformations. Such transformations (they always make up a certain group) may be the transformation of coordinates and time, the replacement of some particles by others, and other more intricate and subtle transformations. It is extremely important that a law of conservation is connected with each type of symmetry.

Even this brief excursion into the micro-world gives us grounds to assert that, as a whole and in each of its constituent objects, it possesses inexhaustible properties.

What Lenin said with respect to the electron has proved applicable not only to the electron, but to all objects in the micro-world, and the principle of inexhaustibility formulated by Lenin is being

increasingly taken over as a principle of cognition by naturalists throughout the world.

Cecil Frank Powell, an eminent English physicist and professor at Bristol University, has remarked: "Nuclear and particle physics, and the associated subjects which have been reviewed at this symposium, are among the main growing points of science and are concerned with our deepest penetration into the structure of the material universe. From the time of classical antiquity it has commonly been assumed that there would one day be an end to the process of delving deeper into the nature of matter. But such a position can no longer be asserted.... I recently recalled the astonishing remark made by Lenin in *Empirio-Criticism* in 1912 (in fact, this study was published in 1909—*Author*), when the electron was the only elementary particle. At a time when the whole scientific world tended to think of fixed unchanging particles he said: 'The electron is inexhaustible.' "[1]

Shoichi Sakata, a major Japanese theoretical physicist, has expressed himself in the same spirit. By his own admission, dialectical materialism has led him to conclude that "as experimental technique develops, the models of elementary particles will change their form. A view fixing a certain form and holding to it firmly is metaphysical.... Lenin, as a great philosopher, noted: 'The electron is also inexhaustible.' "[2]

We could cite a number of other such statements by physicists who recognize the importance of the principle of inexhaustibility; they all maintain that this philosophical principle has become a heuristic and methodological principle for modern physics.

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[1] Concluding Address at the Warsaw Symposium on "Perspectives of Nuclear Physics, Elementary Particle Physics, Radio-Chemistry and Nuclear Chemistry".

[2] **Lenin and Modern Natural Science**, Moscow, 1969, p. 169 (in Russian).

The situation with elementary particles and the atomic nucleus in physics is at present somewhat paradoxical: on the one hand, an abundance of information on the structure of matter, while on the other hand we are as yet unable to systematize more or less reliably the elementary particles already discovered (and their number is continually increasing); the role of some of them in nature is incomprehensible; for instance, μ-mesons do not "work" in physics, and their very existence seems excessive. These particles are 206 times heavier than the electron, but so far as we know today that is the only difference between them.

What function do muons have in nature, what is the meaning of their inseparable connection with neutrinos (at present no muon decay has been found without the participation of neutrinos)—modern physics still cannot answer these questions.

A no less mysterious particle is the neutrino. The neutrino (according to present data), like the photon, has no rest mass, but it is "opposed" to an anti-particle that the photon lacks. There are four neutrinos (including the anti-particles): one type of neutrinos always accompanies the electron during the decay of negative pions, while the other type accompanies a negative muon. Why this is so no one can say. It is now accepted in astrophysics that neutrinos play a substantial role in the energy balance of stars. Theory has predicted that the number of anti-neutrinos emitted by the Sun should be sufficient for experimental detection on Earth. Careful experiments in recent years have shown that the stream of anti-neutrinos from the Sun is considerably less intense than predicted on the basis of the accepted model of intersolar processes, and this stream has yet to be detected on Earth. The question remains open and requires further research.

It is also curious that the neutrinos generated in different processes always have left helicity. That is, their helicity does not depend on the conditions of their emergence, and science still cannot say why this is so, what the reason for this particular spacial asymmetry is.

We have already noted that the number of questions left unanswered not only is not reduced as physics develops, but in fact increases. Why should this be? We can find a general answer only by turning to the principle of the inexhaustibility of moving matter.

Ever deeper penetration in objects and processes studied yields not only new information, but also raises new questions, and this orients us to the further cognition of the inexhaustible multiplicity of properties, interactions and forms of moving matter and its attributes. There is also continual improvement of the conceptual apparatus of science. Initial concepts, such as whole and part and elementariness, among many others, lose their significance. Assertions to the effect that cognition leads to an increasingly simple picture of the world, to the discovery of a "primordial matter", of the "building blocks" of matter from which everything is fashioned, meet with objection.

Quite to the contrary, the development of our knowledge includes the formation of increasingly complex ideas and concepts. For instance, the concept of the wave function in quantum mechanics is considerably more complex than that of the material point in classical mechanics. The Bohr-Sommerfeld model of the atom is more complex than Rutherford's model, and the contemporary model is even more complex. The idea that the development of science leads to simplicity and that what is simple is true is, in our opinion, not borne out by modern science. The true and the simple are not synonyms. The basic mark of the truth of our models and concepts is their correspondence to objective reality, a correspondence verified in the course of the socio-historical productive activity of mankind, rather than their simplicity.

The legitimate striving for simplicity in scientific inferences is not the path to truth, but the path to its more effective presentation. The demand for simplicity does not refer to the methods of knowing nature, but to the methods of presenting the results of cognition. Newton's well-known proposition that nature is simple and does not permit the luxury of redundant causes has no meaning with respect to nature, since there are objective cause-effect functions in natural phenomena; it is true only with respect to our hypotheses on the causes of a given phenomenon; the rational meaning of this proposition is that in our hypotheses we must reflect the most essential causes, of the phenomenon in the given conditions. In view of the impossibility of exhausting all of a given phenomenon's connections with other phenomena, we must of course be able to isolate the aspects of their most important connections. Proclaiming the simplicity of nature a law contradicts nature's inexhaustibility, its infinity both in breadth and depth.

In and of itself, nature is neither simple nor complex. Simplicity and complexity are categories of our cognition, intertwined one with another and based one on the other, incompletely reflecting the multifariousness, the inexhaustibility of objective reality. There is truth in both simple and complex models, and there is no serious scientific basis for asserting that truth is always simple, that all phenomena can in the final analysis be explained by a single cause.

Complexity is the multisidedness, the historicity, the concreteness, the multiformity of connections, while

simplicity is discreteness, unilateralness, stationariness. Simplicity is a moment of complexity. Many outstanding scientists (Einstein, Wiener and others) write of the great importance of the principle of simplicity in their work, but if we study their writings carefully we are persuaded that what they call simple is in fact very complex, but seems to them to be simple because they command this knowledge to perfection. When one knows or is able to do something well, it seems simple. We would not deny the importance of the principle of simplicity in cognition, but we would warn against overstating its significance.

Since the world around us is complex and multiform, the reflection of this objective world in the system of concepts and laws of the science of nature is complex and multiform. But often, to clarify what is important, essential, determining in a given concrete situation, in a given phenomenon, we abstract from the particular, discard the unessential, the secondary, and attempt to build a simple model of a complex process. We should always remember, however, that such models are not eternal and that they will be replaced by models that more adequately reflect the inexhaustible wealth of properties and structures of material objects and phenomena.

A graphic example of this is the situation that has arisen in recent decades in the study of the astronomical Universe, where the relatively stationary and simple model of the mega-world has yielded to a dynamic, evolutionary model. With new technology at its disposal—large optical telescopes and radio telescopes—and using the methods of infrared and X-ray astronomy, astronomers and astrophysicists have obtained new information on the Universe that indicates its evolution, the existence of non-stationary processes. Einstein's general theory of relativity (the modern theory of gravitation) was of enormous significance for the development of our ideas on the Universe.

As far back as 1922, the Soviet scientist A. Fridman, studying the equations of the general theory of relativity, showed that the Universe must be in a state of evolution, that it is expanding (though other processes—pulsation and contraction—are possible), i.e., that the galaxies must be moving away from each other. Observation confirmed Fridman's deductions.

Calculations showed that approximately 10-15 thousand million years ago a substance making up all the astrophysical objects was concentrated in a single super-dense and super-massive object (the primary atom), which exploded; since then, the astronomical Universe has been expanding. Science can say nothing definite about the reasons for the explosion or the processes that preceded it, or what this super-dense object that "gave birth" to our Universe was like.

More than 25 years ago, the theoretical physicist George Gamow proposed what is popularly known as the "big bang" theory of the expanding Universe; a significant contribution to the development of this model was made by a group of Soviet theoretical cosmologists led by Academician Ya. Zeldovich. If the hypothesis is true, there should be residual radiation with a temperature of around 3° K (three degrees above absolute zero). This radiation was discovered some ten years ago—one further confirmation of the explosion that set off the recession of the galaxies.

Study of the Universe as a whole (cosmology) and of individual astronomical objects (astrophysics) has yielded an immense amount of information about the mega-world. New members have been added to the family of stars and galaxies. Quasars (superstars), pulsars, radio galaxies, X-ray stars and other objects have been discovered. Astronomers now see novas and supernovas as evidence of the evolution of the star

"population" and advance the proposition that there are such exotic objects as "black holes".

Black holes are objects that do not radiate, only absorb. Hence their name. The origin of black holes is explained as follows. If the mass of a star exceeds the mass of the Sun by more than two or three times, after it exhausts its supply of nuclear fuel it will cool, thermal pressure will disappear (it was in a state of equilibrium) and gravitational forces will begin to contract the star. When the star has contracted to a radius smaller than its gravitational radius $\left(R_{gr} = \frac{2\gamma M}{c^2}\right)$, gravitational collapse sets in: the gravitational field on the surface of the star increases without limit and the star becomes unobservable. With every passing year, the number of facts that can be interpreted as evidence for the existence of black holes increases. There is, however, no scientific basis for treating the lack of signals from these objects as the "disappearance of matter".

Academician Ya. B. Zeldovich and I. D. Novikov have quite justifiably criticized these anti-scientific assertions, which are in substance idealist. The disappearance of the signals of particles buried in the collapse is not, in fact, equivalent to the death of the particles; we do not, after all, presume that a person has died just because he has hidden behind the corner of a building.[1]

Novas (when the luminosity of stars increases 10^4-10^6 times) occur in our galaxy almost annually. Supernovas (when luminosity during the eruption increases 10^8-10^{10} times) are observed extremely rarely. Only four supernovas are known for the last thousand years.

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[1] See **The Theory of Gravitation and the Evolution of Stars**, Moscow, 1971 (in Russian).

It has been established that the substance of the Universe consists basically of hydrogen (approximately 70 percent by mass) and helium (approximately 30 percent). It is generally accepted that when a star condenses out of interstellar matter it begins to radiate energy powerfully, the energy being obtained through the conversion of hydrogen into helium—a thermonuclear reaction is at work. After the hydrogen has been consumed, a chain reaction transformation of elements occurs, leading to the formation of iron. The emergence of an iron nucleus in the center of the star results in the source of energy at this stage being gravitational contraction, with the temperature mounting in the center of the star. The increase in temperature leads to the decay of the iron into neutrons, protons, helium nuclei. Energy is absorbed in this process. All this leads to the loss of stability, as a result of which rapid contraction begins, attended by an expansion of the outer envelope of the star and an enormous increase in luminosity. This picture of the evolution of a star down to the supernova stage was formulated by the English astrophysicist Fred Hoyle and the American physicist William Fowler.

A supernova (with a mass 20 times greater than the mass of the Sun) shines for approximately 100 days, and its luminosity is equal to the luminosity of several billion suns—comparable to the luminosity of our entire Galaxy.

There are other hypotheses as to the occurrence of supernovas. All of them involve a number of unanswered questions.

Pulsars (or neutron stars), discovered in 1968, are now taken to be the remains of supernovas. However, pulsars have been detected in the remains of only two supernovas, and have not been found in others. All that can be detected in the latter are nebulae that are sources of powerful radio-emissions.

There was a time when many generations of astronomers observed the same movements of the stars, noting only fluctuations over the centuries and rare supernovas. Much has changed now. Along with the classical objects of astronomy, observations are now carried out on objects whose behavior is described, for instance, by times on the order of 0.033 sec—the period of revolution of the most rapid of the known pulsars.

At present, there are two opposing views on the history of the material objects that make up the astronomical Universe. The so-called classical point of view is that the conception and evolution of these objects is a process of condensation out of a primordial gaseous nebula; the other view is that held by Academician V. A. Ambartsumyan and his followers. According to their theory, the principal direction of evolution is from dense (or rather, super-dense) objects to diffusion.

Ambartsumyan has advanced the idea of the activity of galactic nuclei, the notion that galaxies are formed as a whole from super-dense bodies, the remains of which are the nuclei observable at present. It is quite possible that these super-dense bodies will prove to be nothing other than matter in a special, singular state that was impeded in its development as compared with the other (larger) part of matter. Such impeded nuclei have been called "white holes".

The existence of two (basic) opposing approaches to the evolution of the Universe indicates that there is a lack of evidence to validate conclusively either one. The search for such evidence is the task of natural science, not philosophy. What is important for us is the philosophical approach to the problem as a whole, and that approach is obvious: new astrophysical objects are being discovered and new properties of known objects are being detected, which again confirms the truth of the proposition that the world as an object of cognition is inexhaustible.

The work of a great number of Soviet and foreign physicists and astrophysicists has yielded valuable scientific information on the origin of stars and other cosmic objects, on the sources of the energy that they discharge, on the synthesis of chemical elements inside cosmic objects. On the scale of the part of the Universe under study, the decay and synthesis of chemical elements are aspects of a dialectical contradiction describing the eternity, infinity and inexhaustibility of moving matter.

Moving, infinite, inexhaustible matter in its changing totality is what makes up the Universe studied by various natural sciences, the astrophysical sciences included.

The Universe presents itself in the multiplicity of its finite forms, each of which is a dialectical unity of the finite and the infinite.

The interconvertibility of elementary particles and fields, the evolution of stellar systems, residual radiation, the radioactive decay and synthesis of chemical elements, as well as many other facts, evidence the processes of interaction, change, motion and development in the micro-, macro- and mega-worlds.

The different models of the structure of matter and field, space and time, galaxies, different types of stars and the (astronomical) Universe are historical, they reflect certain moments in the eternal existence of moving matter.

The outstanding French scientist Léon Brillouin has written: "It is splendid to discuss the creation of our world, but never forget that you are dreaming, and do not expect the reader to believe in any model, whether with a sudden atomic explosion or with expanding back and forth from $-\infty$ to $+\infty$. All this is

too wonderful to be true, too incredible to be believable."[1]

In fact, all considerations of the origin, the emergence of the Universe taken as the material world as a whole, as matter in general, lack all scientific meaning. At the same time, with respect to the "big bang" theory Brillouin's criticism appears to be unfounded. This particular cosmological model is at present well buttressed by observations; it should be noted that arguments put forth against any given cosmological model on the grounds that the model is improbable or exotic cannot be accepted as persuasive in light of the lessons taught by the development of physics in the 20th century. Modern astrophysics has various models with which it attempts to explain the processes and phenomena in the part of the Universe now accessible to study. But to make these models, hypotheses and theories absolute contradicts the essence of science as an eternally developing system of knowledge.

Individual models, hypotheses and theories contain, as a rule, elements of absolute truth, but they are as a whole but relative truths. Even so fundamental a physical theory as the general theory of relativity is only one stage in the cognition of the material world. A. Z. Petrov, an eminent Soviet specialist on the theory of relativity, has remarked very aptly on this point: "The period of respectful rapture over Einstein's brilliant hypothesis has closed. We now hear the heavy tread of the master in physics—his majesty experiment is on the move, and it is given only to him to say what in this hypothesis finds confirmation in nature, and what must be rejected."

Metaphysical philosophy and mechanicism with their fixed categories no longer meet the needs of the

[1] Léon Brillouin. **Relativity Reexamined**, New York and London, 1970, pp. 2-3.

present-day perfervid, contradictory development of science. Rejection once and for all of a given scheme or model and the synthesis of mutually exclusive theories, rejection of the idea that material objects are unchanging, recognition of connections, transitions, of the unity of contradictory tendencies, leads scientists, as Lenin foresaw, to dialectical thinking in fluid, unstable categories. The only scientific theory of cognition that meets the needs of modern science, as science itself has shown, is the theory of cognition offered by dialectical materialism.

The evidence we have presented shows persuasively, in our view, the enormous methodological role of dialectical materialism, the significance, in particular, of Lenin's principle of the inexhaustibility of the material world and its objects, a principle that promotes the choice of the proper directions for scientific endeavor and plays an important role in modern physics.

THE LAWS OF CONSERVATION IN MODERN PHYSICS

The expanding family of laws of conservation is among the theoretical and cognitive principles and laws that play an important role in the generation of knowledge about the physical world. We should note first that these laws are connected with general philosophical principles such as the uncreatedness and indestructibility of matter and its attributes and the principle of causality. We know that moving matter is eternal and the infinite number of forms of its motion have the potential for interconvertibility. These fundamental propositions can be expressed in the form of a *universal law of the conservation of moving matter and of the transformation of forms of matter and forms of motion.*

Conservation is not equivalent to the metaphysical immutability of matter. Matter is in a state of motion and change, the source of which are the internal contradictions inherent in it; but through all its changes, it remains objective reality existing external to and independent of our consciousness.

Conservation and change are the contradictory aspects of natural phenomena and objects that are reflected in thought in the form of the laws of science. The dialectical contradiction of conservation and change is manifested in the laws of motion. The development of natural science—of physics above all—continually yields new information confirming the immutability of the universal law of the conservation and transformation of the forms of matter and motion in the shape of specific laws of conservation and transformation, the number of which in physics is continually expanding.

Of all the laws of physics, the laws of conservation and transformation have a special role as one of the tools, as a method for knowing the hidden forces of nature. Marx, Engels and Lenin attributed fundamental significance for materialism to the laws of conservation known at the time, e.g., the law of the conservation and transformation of energy. In *Materialism and Empirio-Criticism* Lenin wrote that all materialists hold the law of the conservation and transformation of energy to have established "the basic principles of *materialism*".[1]

As distinct from other laws, the cognition of each law of conservation is inseparable from the appearance of a new and fundamental concept in physics, a concept to which the law in question applies. This isolation of the invariant (conserved) characteristic of motion is an essential and necessary step in its cognition.

One of the characteristic features of the laws of conservation is that they may appear in the form of limitations or even categorical inhibitions, expressing the fact that a certain process cannot occur under specific conditions. Knowledge of the process in question often begins at this point. When man comes up against the impossibility of a process in principle, he arrives in the final analysis at the discovery of a new conserved value. An important feature of the laws of conservation is that in their general form they define

[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 332.

the possibility or impossibility of particular processes independent of their concrete nature. This is one of the manifestations of their absolute character, their universality, which is different in principle from the universality of other laws of science. While the law of the conservation and transformation of energy covers all forms of motion possible, all types of interaction, and is observed with absolute precision (in isolated systems), Newton's universal law of gravitation, for example, applies only to a specific sphere of material interactions (gravitational) and even in this sphere cannot be considered absolutely precise—the laws of gravitation are expressed more precisely in Einstein's general theory of relativity.

Let us take a look at some of the laws of conservation that have been established during the lengthy advance of human knowledge about nature; we shall attempt to trace how the discovery of new laws of conservation has furthered the development of physical science and the advance of dialectical materialism's theory of cognition.

The Law of the Conservation of Mass

The conjecture that there is some universal law of the conservation of matter can be traced back to prehistoric times and is known in the earliest period of civilization. There was very early a practical need to compare objects to each other, to select standards against which they could be compared, and for this purpose to choose bodies consisting of the most constant, stable, durable substances. To compare bodies and objects, weights were invented and used in daily life, commerce and later in scientific research. All further development of chemical knowledge was linked with the use of weights, and the use of weights is based on the supposition that the weight (mass) of the standard is conserved.

By the beginning of the modern era, a large body of experimental data had led to certain conclusions as to the existence of a certain value that is conserved during chemical transformations.

The prerequisites for the development of the concept of mass and the discovery of the law of its conservation were prepared over the course of centuries. The concept of mass became necessary not only because of direct study of the properties of matter, but also as a result of general philosophical considerations as to the indestructibility of everything existent; these considerations were the result of generalization from the totality of positive knowledge confirmed by social practice.

The great Russian scientist M. V. Lomonosov was the first to show experimentally, in 1756, that weight is conserved during chemical reactions. The work of Lomonosov, and then Lavoisier, laid the foundation for a conscious application of the law of the conservation of weight (with which mass was equated) in all chemical and physical experiments as well as in theoretical work. This law of conservation became the foundation of classical mechanics and the basic law of chemistry.

At the beginning of the 17th century, generalizing from the enormous number of observations carried out by Tycho Brahe, Kepler discovered the laws of planetary motion: planets move in ellipses, with the Sun at the focus; a line connecting a planet with the Sun, or the radius vector, describes equal areas in equal times; the squares of the period of planet rotation are proportional to the cubes of their distance from the Sun. It is worth noting that as early as 1660 Robert Hooke, engaged in experimental study of the laws of gravitation mentioned specifically in a letter to

Newton that attraction is inversely proportional to the square of the distance between the centers of the attracting bodies.

However, the law of gravitation did not follow from this; it could not be formulated until the concept of a body's mass was introduced by Newton. He emphasized that both experiments and astronomical observations had established that all bodies in the neighborhood of the Earth are drawn to the Earth, in proportion to the quantity of matter in each of them. Newton's predecessors could not, therefore, deduce the law of universal gravitation because they could not connect the fact, already clear to them, that the force of gravitation is a function of the distance, with any specific characteristic of the attracting bodies. Newton was able to do so, formulating the concept of mass and giving a mathematical description of the law of universal gravitation:

$$F = k\frac{m_1 \cdot m_2}{r^2},$$

where k is a constant value; m_1 and m_2 are the masses of the interacting bodies; and r is the distance between them. It should be stressed that Newton did not equate the concepts matter and mass. For him, the concept "matter" was without question more universal, while mass was only one of the features of matter. Only later did a number of scientists begin erroneously to equate mass and matter.

Newton's law of universal gravitation led in the final analysis to the emergence of the concept of gravitational mass. This concept includes both a qualitative and quantitative characteristics of bodies located in a field of gravity.

Studying the motion of bodies under the influence of a force applied to them, Newton gave a quantitative expression for the mass of moving bodies when the magnitude of the moving force and the acceleration obtained therefrom by the body are known. The operation of this law of Newton's mechanics ($F=am$) rests on the fact that force is connected with inert properties inherent in any body, and mass here functions as a measure of inertia.

One more mass, then, entered Newton's mechanics—inertial mass; the gravitational and inertial masses of any body proved to be equal.

The relationship $F=am$, where a is acceleration and m is the inertial mass, is often interpreted by physicists as an example of the fact that mass is only a coefficient of proportionality between force and acceleration. Of course, the value of the mass can be thus derived, but behind the mathematical relationships we must see real physical properties of material objects and real physical forces reflected in the concept mass.

The Austrian physicist Ernst Mach criticized Newton's definition of mass by eliminating the materialist content from it.[1] In Mach's interpretation, science is no more than an economical record of experience. The concept of mass, in his view, contains no theory, only experience. He denied the connection between mass and the concepts of matter and inertia. According to Mach, inertia is a verbal expression of an experimental fact, of the proportionality of force and acceleration. Having equated inertia with a certain connection between force and acceleration, a connection derived from experience, Mach eliminated the possibility of disclosing the physical content of the concept of mass and reduced mass to the status of a coefficient of proportionality. Mach's program, however, was not met by physicists with a great deal of sympathy.

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[1] The views of Mach, who attempted to create a philosophical system allegedly standing above materialism and idealism, were subjected to soundly based, scientific criticism in Lenin's **Materialism and Empirio-Criticism.**

Investigating the phenomenon of inertia, physicists concluded that every physical body has the property of changing, in a definite manner, its velocity under the influence of a specific action; this is expressed in a physical magnitude called the inertial mass. Careful study has shown that the inertial and gravitational masses are numerically equal. But why the inertial and gravitational masses of any physical object are expressed by one and the same number, why, despite their different natures, they are equal, is a mystery, the solution of which remains unknown to science. The equality of the inertial and gravitational masses plays an enormous role in science, it is one of the initial postulates of the general theory of relativity.

In classical mechanics, a body's mass is a constant. However, by the end of the 19th century a number of physicists, on the basis of experimental data, began to develop the notion that the mass of a body in motion is not constant, but changes as a function of the object's velocity. The English physicist Thompson was in 1881 the first to propose, and attempt to give a theoretical basis for, the idea that an electron's entire mass is of electromagnetic origin.

This proposition was, it would have seemed, confirmed by the fact that the formula for the dependence of mass on velocity

$$m_v=\frac{m_0}{\sqrt{1-\beta^2}}; \quad \beta=\frac{v}{c},$$

(where m_0 is the object's mass at rest, v is the object's velocity and c is the speed of light in a vacuum), derived by Lorentz from a hypothesis as to the purely electromagnetic nature of mass, is in good agreement with experiments. But it turned out not to be the case.

The special theory of relativity showed that a mass of any origin, not just electromagnetic, is a function of velocity. Physics acquired new concepts—"stationary (or rest) mass" and "motion mass".

As physics developed, new structural elements of the physical forms of matter were discovered—the elementary particles. The mass of the elementary particles has been determined experimentally through study of the processes in the micro-world. The value of their mass cannot yet be derived from a general theory.

Modern physics holds that the mass of an elementary particle is determined by the nature of its interaction with a physical vacuum. Since the electron and positron interact only electromagnetically, they have practically identical masses; $\pi^{\pm}$-mesons show both electromagnetic and nuclear interaction, and they also have practically identical masses, equal to 275 m_e (m_e is the mass of an electron), while the π^0-meson (neutral), which shows only nuclear interaction, has a mass of only 264 m_e. Here, then, it would seem that we have an explanation for the difference between the masses of charged and neutral pions. However, it is a mystery for modern physics why the masses of the electron and μ-meson are markedly different even though both interact only electromagnetically.

It should also be noted that if the quants in a field, the exchange of which ensures corresponding interaction, have a stationary mass, the force radius is finite; in the case of an exchange of particles with zero mass the force radius is equal to infinity.

This indicates one further qualitative difference between particles possessing a stationary mass (m_0) and particles (photons and neutrinos) whose stationary mass is equal to zero and which have the satisfactory property of being able to move with the maximum velocity possible in nature, c (the speed of light in a vacuum).

Mass, then, is not a random, unimportant indicator of material bodies, but one of the fundamental properties of physical objects; it is connected with the

features of their motion and with their relative stability. In modern physics, mass is one of the crucial criteria of the stability of atomic nuclei: they are stable if the difference between the mass number and the charge of the nucleus (between the number of protons and neutrons in the nucleus) does not exceed narrow limits. The stability of the nucleus is described by the binding energy of the nucleons in the nucleus, that is, by the work that must be expended to tear a nucleon from the nucleus. Binding energy is determined by the difference between the mass of the nucleus and the sum of the masses of the isolated nucleons before they are joined in the nucleus. Modern physics gives us grounds to conclude that the masses both of different physical objects and of the different states of one and the same object are qualitatively different; we must seek an understanding of this remarkable phenomenon, an understanding of the physical nature of mass, possibly through discovery of a connection between material objects and the fields that surround them.

In the literature on physics and philosophy one sometimes finds statements to the effect that mass is the quantity of matter. In our view, such assertions are imprecise at best. They reveal an unconscious aspiration to equate one of the properties of matter (as objective reality) with matter as a philosophical category. Matter as a philosophical category and the concrete forms of matter —objective reality existing external to and independent of the cognizing subject—are not one and the same thing. Mass is only one of the properties of matter inherent in only some of its states.

There are many definitions of mass, but none of them can be considered satisfactory, relatively complete, or encompassing all the manifestations of this property common to the different states of moving matter studied by physics. Physics textbooks give the following definitions of mass: the mass of a body is understood as the quantity of matter in the body (K. Putilov); the basic property of matter is the fact that it occupies a certain volume of space, and that it has weight. Indeed, weight is ordinarily made the basis of the definition of matter. The masses of bodies are compared by their weight: it follows from the second law that mass is at the same time the measure of inertia (N. Papaleksi); in physics, the concept of mass designates two properties of every body: that of having weight, and that of being inert. "Inert" means that the body does not change its velocity by itself, that the action of a force is required if its velocity is to change. The masses of bodies are compared by their weights (R. Pol); for any body acceleration is proportional to force. This coefficient of proportionality is what determines the value of a body's mass, which characterizes the degree of the body's inertness (A. Khaikin); mass is a certain property of a given physical object, a property that describes it from the point of view of resistance to a change in its velocity (E. Shtrauf); the measure of a body's inertness is the physical value called the mass of the body (P. Strelkov); different bodies under the action of identical forces are accelerated in a different manner, the magnitude of acceleration being determined by some property peculiar to the body. This property of bodies is described by a special value, called the mass of the body (S. Frish); it is accepted in mechanics to take the mass of the body to be the measure of its inertness (E. Shpolsky).

It is not at all surprising that it has proved difficult to give a general definition of mass suitable for all physical processes, for mass is a category of a higher degree of generality than other categories in physics; in order to formulate a satisfactory definition, we need a

deeper understanding of the nature of moving material objects. Definition of mass as a *property* inherent in different forms of matter is sufficiently general, but there is no reason to consider it exhaustive. We know that a *property* of a thing is manifested in relationships, but the latter are inherent in the given object and are the characteristic of that object and pertain precisely to that object, so that the property is distinct from the relationship, though it is manifested only in the latter.

We know, then, the law of the conservation of mass, we use it in cognizing nature, but thus far we cannot say precisely what mass is, why there are different types of mass, or what the essence of the difference between them is. It is a surprising but not hopeless situation.

The Law of the Conservation and Transformation of Energy

The law of the conservation and transformation of energy is extremely important for theory and practice, for the materialist view of the world. It has a special place among the laws of conservation because it is connected with the absoluteness, uncreatedness and indestructibility of motion.

Down to the second half of the 19th century, when physicists spoke of motion they used concepts such as "force" or "vital force", and if the terms "energy" and "work" were used they did not have an autonomous role but were derivatives of the concept "force".

The concept "energy" has a long history. It was at first associated with the mechanical form of motion.

Then Hamilton introduced a potential force function into dynamics (in modern terms this force designates the total energy of a system for the case of stationary conserved forces).

The next stage was connected with the elucidation of the nature of heat, this ultimately leading to the establishment of the equivalence of thermal and mechanical forms of motion.

There were two distinct tendencies in the theoretical interpretation of experimental data on heat. Some viewed heat as a fluid, while others viewed it as a type of motion. In 18th-century Russia, Lomonosov supported the notion that heat is a type of motion. According to Lomonosov, heat consists of "the internal motion of matter".[1]

Yet the level of knowledge in Lomonosov's day imposed certain limits on his theory of heat. In particular, because of his ignorance of non-mechanical forms of motion, Lomonosov had considerable difficulty in dealing with phenomena associated with chemical conversions.

After many years of struggle against the phlogiston theory, the mechanical equivalent of heat was discovered, and this was in turn of great importance for the establishment of the principle of the transformation of one form of motion into another, for the law of the conservation and transformation of energy. Thanks to the work of Benjamin Rumford, Humphry Davy, Nicholas Sadi Carnot, Alessandro Volta, Antoine Lavoisier, Robert Mayer, James Joule, Hermann Helmholtz, Heinrich Lenz and Rudolf Clausius, various conceptions of "weightless" fluids were conclusively dethroned and the data necessary for the development of the modern concept of energy were obtained.

By the middle of the 19th century, science had accumulated much data confirming the existence of diverse forms of matter's motion and of links among them. Researchers had discovered numerous mechanical, thermal and chemical phenomena as well as phenomena associated with magnetism and

[1] M. V. Lomonosov, **Collected Works**, Vol. 2, Moscow, 1951, pp. 11, 13 (in Russian).

electricity. A law of the conservation of "vital forces" for mechanical processes was formulated. However, these were as yet isolated facts, though the idea that the different forms of motion were somehow connected had lodged itself firmly in natural science.

"In addition to the 54 known elements," wrote the German chemist Mohr in 1837, "there is in the nature of things only one other agency, and it is *force:* under suitable conditions, it can manifest itself as motion, chemical affinity, cohesion, electricity, light, heat and magnetism, and from each of these types of phenomena all the others can be obtained. The same force that raises a hammer can, if it is applied in another manner, bring about any other phenomenon."[1]

Max Planck, describing the situation in this field, aptly observed that "it was only one step to the question of a common measure of all these admittedly homogeneous forces of nature".[2] Through analysis of sense impressions, through generalization from the empirical data on motion, a unitary characteristic of the basic properties of motion was isolated—energy. This process represented a mental passage from the particular to the general, to a concept with a deeper content.

Motion is the point of departure in the development of the concept of energy. However, as a mode of existence of matter, as a concrete whole, it exists outside the process by which it is known, outside the process of the emergence, establishment and development of the concept of energy.

The concept of energy, reflecting a specific property of motion, could be isolated only by bringing to light and studying the interconvertibility of the different

[1] Cited in M. Planck, **Das Prinzip der Erhaltung der Energie**, Berlin, 1921, S. 24.
[2] **Ibid.**

forms of matter's motion; this was a revolutionary leap in which the culminating point was the discovery of the law of the conservation and transformation of energy. The establishment of this law signified the development of a notion of different forms of energy, of their material essence, of their change in accordance with a specific general law.

The concept of energy as an abstraction, the basic content of which is highlighted in the law of the conservation and transformation of energy, includes the interconnection and unity of qualitatively different forms of energy. This has become a central concept in physics, one that is constantly developing and acquiring new meaning through the addition of new information and ideas.

Mayer and Helmholtz hold a special place in the historical and logical development of the concept of energy. In effect, they expanded the traditional concept of "force" in a way that was new in principle, treating it as a value that describes qualitatively and quantitatively any form of material motion and its transformation into another form.

Before Mayer and Helmholtz (and even during their lifetime), "force" was given various meaning and was often applied far too broadly. Engels remarked quite pointedly on this score: "In mechanics the causes of motion are taken as given and their origin is disregarded, only their effects being taken into account. Hence if a cause of motion is termed a force, this does no damage to mechanics as such; but it becomes the custom to transfer this term also to physics, chemistry, and biology, and then confusion is inevitable."[1]

In an article "Observations on the Forces of Non-Living Nature", published in 1842, Mayer formulated

[1] F. Engels, **Anti-Dühring**, p. 86.

his task as elucidating the concept "force" and the interrelations of different forces.[1] It is evident from this article that Mayer, proceeding from the proposition "cause is equal to effect" and using the term "force", in fact had in mind energy that has the property of being conserved and transformed. He was even able to see the connection between the phenomena of inorganic and organic nature. "There is no process," he wrote, "without an alteration in the form of force!"[2] Stressing the qualitative aspect of forces, he did not reduce them to each other, but viewed them in the forms in which they appear in nature.

Mayer stressed the substantive character of the forms of motion, which testifies to his materialist views. "There is no immaterial matter," he wrote.[3] He resolutely opposed the anti-scientific concept of the action of "vital forces" in the world of plants and animals, viewing the vital activity of the latter as a manifestation of change in the forms of energy, though he noted the qualitative uniqueness of processes occurring in living organisms.

Yet Mayer could not entirely free himself of the metaphysical conception of "weightless" forces, which he opposed to material matter. "*Forces are changeable, indestructible and* — as distinct from matter — *weightless objects,*" he maintained in one of his last works, written in 1850.[4]

Hermann Helmholtz, one of the co-discoverers of the law of the conservation and transformation of energy, proceeded in his work from the impossibility of *perpetuum mobile.* As distinct from Mayer, who

[1] Robert Mayer, **Die Mechanik der Wärme in Gesammelten Schriften**, Stuttgart, 1893, S. 23.
[2] **Ibid.**, S. 49.
[3] **Ibid.**, S. 73.
[4] **Ibid.**, S. 265.

basically used the term "force" in only one meaning, having in mind energy, Helmholtz at times used the term as Mayer did, but at other times used it in its "primordial" meaning of force as conceived in Newton's mechanics. Nor did Helmholtz strictly delimit these basic physical concepts, which testifies to a lack of clarity in his notion of energy as a qualitatively new characteristic of motion. Nevertheless, in any given case one can understand exactly what the author of *Über die Erhaltung der Kraft* (1847) had in mind.

Examining various physical phenomena, Helmholtz established an absolute measure for "vital force"(the magnitude of the work obtained or expended), which Mayer did not do. Like Mayer, Helmholtz opposed the fluid theory of heat and demonstrated its lack of foundation. He recognized the inseparability of "forces" from matter, understanding matter as everything existing in nature. He wrote that "natural phenomena should be traced to the motion of matter".[1] (Examination of his works permits us to assert that Helmholtz recognized the inseparability of motion from matter.) He reduced the multiplicity of the "forces" of nature to two "forces" that were, in his opinion, fundamental: "tension"and "vital forces". For Helmholtz, all forms of energy were either potential ("tension") or kinetic ("vital forces"), the total energy being the sum of these "forces". This understanding of energy in effect made concrete study of the different forms of the motion of matter superfluous. We should note, too, that in introducing the concept of potential energy under the term "tension", Helmholtz provided no succinct definition of the concept, and this in subsequent years caused appreciable difficulties in physics. Moreover, this

[1] H. Helmholtz, **Über die Erhaltung der Kraft**, Leipzig, 1907, S. 5.

simplification of the concept of energy obliterates the qualitative features of the different forms of energy.[1]

Engels pointed out Helmholtz's one-sided approach to the concept of energy; Engels emphasized the great importance of taking the qualitative aspect of this important scientific concept into account.

We see, then, that the formulation of a scientific concept, even one as general as energy, can have subjective as well as objective moments. This indicates the great importance of scientists' views of the world for the development and interpretation of scientific concepts and laws.

Mayer, Joule and Helmholtz established that there is a quantitative relationship between qualitatively different forms of motion, the general measure of this relationship being a new value—energy.

One of nature's remarkable phenomena, the conversion of one form of motion into another, at last found a more or less satisfactory explanation. As Engels wrote: "All the innumerable acting causes in nature, which had hitherto led a mysterious, inexplicable existence as so-called forces—mechanical force, heat, radiation (light and radiant heat), electricity, magnetism, chemical force of association and dissociation—have now been proved to be special forms, modes of existence of one and the same energy, i.e., motion.... A given quantity of energy in one form always corresponds to a given quantity of energy in some other form."[2]

With the establishment of the law of the conservation and transformation of energy, the concept of energy came to include the property, common to different forms of the motion of matter, of being able to change into each other in strictly equivalent quantities.

[1] Max Planck, **op. cit.**, S. 42.
[2] Frederick Engels, **Dialectics of Nature**, p. 196.

This moment of universality in the concept of energy is dialectically complemented by a moment of the particular, for the concept of energy, expressing the essence of motion, covers the entire range of particular forms of energy, thereby depriving mechanicism—which reduced this multiplicity to a single form of energy, the energy of mechanical motion—of ground to stand on. The unsoundness of the mechanist view is attested by the entire history of the development of science.

Energy taken in general is an abstraction, for there exist only different forms of motion and specific forms of energy, not energy in and of itself. In every specific form of energy, both the general and the singular have a real existence. However, the singular (for instance, some specific form of energy) taken by itself does not correspond fully to the general concept of energy, for the latter reflects the totality of all aspects of a specific group of phenomena in reality and of their interaction (e.g., different forms of matter's motion). The connection and unity of the general and the particular in the concept of energy are manifest, first, in the law of the unity and conflict of opposites; and second, in the step-wise succession that is inherent in the process of the cognition of a given range of the phenomena of objective reality.

The universal concept of energy is disclosed through its specific forms. For instance, while this concept first joined two forms of energy, kinetic and potential, it later expanded to cover new regions of material reality. Thermal energy, elastic energy, electrical energy, chemical energy, radiant energy, nuclear energy, and so on, were isolated and obtained their form of expression.

The development of the concept of energy is a good example of the dialectical process of cognition. It absorbed the information on motion known at the

time to become a generally accepted concept of science but it did not solidify in that shape and continued to develop, generating new ideas. It became itself a tool of cognition, an instrument for the development of new theories. Its appearance marked, on the one hand, the culmination of a period of development in science, and on the other hand, raised a number of new problems. In essence, it is itself an important scientific and philosophical problem, a problem of the contradictory relationship between form and content, the general and the particular, a problem of the localization and transfer of energy in space and, finally, a problem of its link with other scientific concepts.

The ideas of the localization and transfer of energy in space were advanced by N. A. Umov, who formulated the regularity of the movement of energy and introduced the notion of the energy flux vector (1874). These ideas were developed further in the work of the English physicist John Poynting. Making consistent use of the law of the conservation and transformation of energy, Umov came to the conclusion that there is a material vehicle for all forms of energy. He connected the forms of energy with different forms of motion, and viewed motion as inseparable from material particles. "The element of volume, taken arbitrarily within any milieu, whose particles are in motion," he wrote, "includes at a given moment in time a specific quantity of energy."[1] Umov introduced such then novel concepts as energy flux, the direction and velocity of energy, the density of energy, and so on.

Physical notions of energy transfer emerged from the development of flow mechanics (the theories of

[1] N. A. Umov, **Selected Works**, Vol. 1, Moscow-Leningrad, 1950, p. 151 (in Russian).

elasticity and hydrodynamics), where the media function as the vehicle, the material substratum of the motion of energy, and was then applied to classical electrodynamics.

The essence of energy transfer is the transfer of material motion on the basis of the law of the conservation and transformation of energy. This process has a contradictory character and is reflected in the expressions "energy flux" and "energy-flux density". Consequently, in order to understand the inner nature of the motion of matter, we must analyze profoundly the essence of the concept of energy.

The accumulation of new aspects and attributes of the concept of energy reflects the expansion, scope and depth of the real process of cognizing different levels of moving matter. Reflecting the essence of all known physical forms of the motion of matter, this concept seems to be one of the richest in its content. We see in it both the movement of scientific thought from the concrete to the abstract and movement in the other direction—from the abstract to the concrete: the universal concept of energy, as we have noted already, is an instrument for specific knowledge, i.e., is applied in our analysis of the forms of matter's motion.

Developing in the general channel of cognition, the concept of energy develops by quantum jumps—through the discovery of specific facets of the motion of matter (qualitative and quantitative, changeability and stability, and so on)—but at the same time it is based on a unity of analysis and synthesis.

In modern physics, "energy" is one of the concepts most frequently employed. But, like the concept of mass, it has as yet not received a more or less uniform definition—different definitions are found in different texts on physics. Arnold Sommerfeld, for instance, writes: "*Any thermodynamic system possesses a value*

characterizing its state—its energy.... If one wishes to translate the word energy, which is not entirely advisable, one might use 'store of work'."[1] "The notion of energy," we read in Jean Rossel's *Physique générale*, "is derived from the concept of force, i.e., work=force×displacement is energy."[2] Writes A. Kitaigorodsky: "Energy, i.e., the capacity for work, is a function of the state of the body."[3] And I. Kashin: "The greatest value of a system's capacity for work in a particular state is called its energy in that state.... A special term, energy, was introduced, and this concept has proven to be closely linked with the magnitude of mechanical work."[4] S. Frish emphasizes that "an enormous number of interrelated facts indicate that it is possible to give an objective description of the concrete forms of moving matter treated in physics if we use a physical value—energy—which represents a simple function of the state of a system, the change of which is defined by the sum of the mechanical equivalents of all external actions upon the system."[5]

Energy, then, is defined by many authors as a "function of the state of a system" or as the "store of potential work, the capacity for work". However, analysis of the place and role of the concept "energy" in the system of physical knowledge gives us good grounds for holding that the definition of energy as a function of a state or as the "capacity for work" is incomplete and inadequate.

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[1] Arnold Sommerfeld, **Thermodynamik und Statistik**, Wiesbaden, 1952, S. 12.

[2] Jean Rossel, **Physique générale**, Neuchâtel, 1970, p. 37.

[3] A. Kitaigorodsky, **Introduction to Physics**, Moscow, 1959, p. 46 (in Russian).

[4] I. Kashin, **A Course on Physics**, Vol. 1, Moscow, 1961, p. 67 (in Russian).

[5] S. E. Frish, "The Notion of Mass and Energy in Modern Physics", **Uspekhi fizicheskikh nauk**, 1952, Vol. XVIII, Issue 2, p. 179 (in Russian).

The definition of energy as the function of a state of a system was applied initially to macroscopic systems. In order to define appropriately the function of a state of such a system, it is first necessary to describe its state. And for this one must know the value of each variable, the totality of which define the given state of the system under consideration, for "the state of a material system at a given point in time is the aggregate of all the magnitudes, the momentary values of which determine the course in time of the process occurring in the system".[1] This definition of energy is very handy for practical use. But it has a drawback in that it ignores external actions, while the total energy of a material system depends in part on external conditions. The definition of energy as a function of a state can be considered the most general definition only in the case where energy is a function of the state of a material system itself. In other words, the concept "energy" includes, quite importantly, the function of a state, but cannot be reduced to or exhausted by this notion.

The definition of energy given by Max Planck merits attention. "The energy of a system, then," he wrote, "is the sum of the mechanical equivalents of all actions that are introduced into the system from without, when the system changes—in whatever manner—from the given state to a certain state taken as normal."[2] As the store of work, the energy of a material system can only be defined in relation to some arbitrary zero state of the system.

Engels dealt with the problem of energy from the point of view of the requirements for developing dialectical materialism, but, guided by the general

[1] M. Planck, **op. cit.**, S. 121, 120.

[2] Max Planck, **Vorlesungen über Thermodynamik**, Berlin, 1954, S. 39. See also his **Das Prinzip der Erhaltung der Energie**, S. 104,

methodology of cognition that he and Marx had developed, he advanced a number of propositions on energy that ran far ahead of the development of the physics of his time. For example, in analyzing the concept of energy, Engels proceeded from the general philosophical principle (which he had advanced) of the unity of conservation and change. Only in the second half of the 20th century did physics accept this proposition.

This principle has been given concrete expression in the work of a number of Soviet philosophers. "The concept of energy," writes N. F. Ovchinnikov, for example, "reflects the internal activism of matter."[1] "In modern physics, the content of the concept of energy is disclosed by the general doctrine of the interconvertibility of the forms of the motion of matter."[2] And further: "Energy in classical and in modern physics remains as before a measure of motion, a measure that comes to light in the process of the qualitative transformation of the forms of the motion of matter."[3]

In another study, Ovchinnikov develops his views on the definition of energy and makes them more precise. "The concept of energy," he writes, "reflects the *contradictory unity of conservation and transformation*. A fuller definition of the concept of energy is thus to describe energy as the *measure* of the motion of matter during a qualitative transformation of the forms of motion"[4] (*Author's emphasis*). "The

[1] N. F. Ovchinnikov, **The Concept of Mass and Energy in Their Historical Development and in Their Philosophical Import**, Moscow, 1957, p. 171 (in Russian).

[2] **Ibid.**, p. 178.

[3] **Ibid.**, p. 181.

[4] N. F. Ovchinnikov. "The Laws of Conservation in Physics and the Causality of Natural Phenomena", **Problems of Causality in Modern Physics**, Moscow, 1960, p. 164 (in Russian).

general measure of motion," writes B. M. Kedrov, "is expressed in the very concept of energy, a concept in which the quantitative aspect of motion (indestructibility) is merged with its qualitative aspect (its capacity to change forms)."[1]

This approach to the definition of the concept of energy makes it possible to express what is most intrinsic to it as a characteristic of the physical forms of the motion of matter, for unity of conservation and change is inherent in motion.

Energy is proper to all processes that occur in nature, and since they are all causally conditioned, they always occur through the transfer of material motion and, hence, of energy. One of the most important underpinnings of a real causal connection is the profound qualitative transformation of the forms of the motion of matter. One cannot but agree with Max Planck's statement that "the relatively astonishing speed and ease with which a proposition of so enormous a range as that of the conservation of energy, after overcoming the first difficulties, was accepted is to be attributed not only to the many individual inductive proofs, but rather for the most part to the notion of its inner connection with the law of cause and effect".[2] It is in this light, too, that we understand Mayer's initial premise in the formulation of the law of the conservation of energy: "cause= effect".[3]

In examining the essence of the concept of energy and of the law of the conservation and transformation

[1] B. M. Kedrov, **Engels and Natural Science**, Moscow, 1947, pp. 105-06 (in Russian).

[2] M. Planck, **Das Prinzip der Erhaltung der Energie**, S. 30.

[3] Some aspects of the link between the causal conditionality of natural phenomena and the law of the conservation and transformation of energy are examined in **Problems of Causality in Modern Physics**, Moscow, 1960 (in Russian); see the articles by I. V. Kuznetsov and N. F. Ovchinnikov.

of energy, the dialectical approach, which has proved to be a very effective methodological principle of scientific cognition, is of crucial importance. From this standpoint we can appreciate the enormous importance of Engels' interpretation of the law of the conservation of energy as a law not only of the conservation, but also of the transformation of energy.

Immediately after establishment of the law of the conservation of energy, i.e., beginning with the second half of the 19th century and down to the beginning of the 20th century, the function of conservation was in the foreground in physics. It was then presumed that it was this function which speaks of the impossibility of emergence from nothing and transformation into nothing—that was fundamental in the concept of energy.[1]

Later, the function of change was taken to be basic, because it expresses the interconnection and interdependence of different forms of energy (and, consequently, of motion).

Only much later did physicists detect the limitations of this metaphysical approach. The inner logic of the development of science required a dialectical reconsideration of conservation and change, taken as the essence of the concept of energy itself, as well as of the law of the conservation of energy.

The discovery of the law of the conservation and transformation of energy was linked primarily with the development of mechanics. Subsequently, however, thanks to new experiments and the theoretical treatment of their results, it became clear that the substance of this law is considerably more profound, that it is a universal law of nature. This made rapid development of the theory of thermal processes possible, and this in turn led to the emergence of

[1] See M. Planck, **op. cit.**, S. 30-31.

thermodynamics. The law of the conservation and transformation of energy played an especially important role in the study of electrical and magnetic phenomena, the uniqueness and specificity of which did not permit the application of other concepts whose origin lay in mechanics.

A physical analysis of the law was carried out brilliantly by Max Planck in *Das Prinzip der Erhaltung der Energie*, published in 1887. It should be kept in mind that Planck's physical considerations and inferences are interwoven with his philosophical assertions. For instance, he sees in the principle of the conservation of energy not only a statement of the unchangeability of the sum of a system's energy (a negative and quantitative assertion), but also an indication of the necessity of change, of the passage of energy from one form to another (the affirmative, qualitative aspect), for the single equation of constancy can be expanded into a number of equations describing the change of energy in different parts of the system. One may describe changes in the system over time in like manner.

In addition, Planck, as distinct, for example, from Helmholtz, was not a proponent of a universal mechanical description of all natural phenomena; Planck stated flatly that this mechanical principle in no way follows from the law of the conservation of energy, while that law must be the point of departure for physics.

The philosophical sense of the law of the conservation and transformation of energy was most fully and profoundly disclosed by Engels. He considered this law the great fundamental law of motion. He stated: "The unity of all motion in nature is no longer a philosophical assertion, but a natural-scientific fact."[1]

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[1] Frederick Engels, **Dialectics of Nature**, p. 197.

The establishment of the law of the conservation and transformation of energy was, along with the discovery of the cell and Darwin's theory of evolution, one of the three great, fundamental discoveries of the 19th century that provided the foundation in the natural sciences for dialectical materialism. Engels himself noted that, thanks to these discoveries, by the 1850s "empirical natural science made such an advance and arrived at such brilliant results that not only did it become possible to overcome completely the mechanical one-sidedness of the eighteenth century, but also natural science itself, owing to the proof of the interconnections existing in nature itself between the various fields of investigation (mechanics, physics, chemistry, biology, etc.), was transformed from an empirical into a theoretical science and, by generalizing the results achieved, into a system of the materialist knowledge of nature."[1]

Matter cannot exist except in motion, that is, in a continual process of change of its states. Since motion is one of the basic forms of the existence of matter, and the latter may take on different forms, there is, too, a multiplicity of forms of motion capable of passing into each other. But the sum total of motion within an isolated region cannot change, and the transformation of one form of motion into another occurs in quantitatively rigorous proportions. This means that there is a specific measure of motion—a quantitative characteristic common to all the forms of its manifestation. Engels quite correctly took energy to be this fundamental characteristic of motion.

Engels stressed that the most essential aspect of the law of the conservation of energy is its "positive idea of the *transformation* of energy, in which for the first time

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[1] Frederick Engels, **Dialectics of Nature**, p. 196.

the qualitative content of the process comes into its own, and the last vestige of an extramundane creator is obliterated".[1]

Some Other Laws of Conservation in Classical and Modern Physics

We have noted already that the motion of the physical forms of matter is characterized not only by energy, but also by impulse and momentum.

The law of the conservation of impulse (or of its projections) holds for an isolated system (or in a direction in which the field component is equal to zero). For example, given the movement of a charged particle in a uniform electric field, two projections of its impulse will be conserved in a plane perpendicular to the field.

The law of conservation of momentum (angular momentum) holds for an isolated system or for a system in the field of a central force (if the moment of the forces acting on the system is equal to zero).

The history of the cognition of these laws of mechanics, and of the development of the corresponding concepts, is inseparable from the development of technology and the general increase in scientific knowledge. However, both have a more limited sphere of macroscopic manifestation than the law of the conservation of energy, so the notion of their universality was possible only with the development of electrodynamics, kinetic theory and static physics, the theory of relativity and, finally, quantum mechanics.

The theory of relativity showed that energy and impulse are components of a single measure of motion, a measure that is a four-dimensional vector of energy—an impulse. Relativity theory also established

[1] F. Engels, Anti-Dühring, pp. 18-19.

the need to apply the concept of impulse to the electromagnetic field, though this had even before been an obvious consequence both of Maxwell's theory and Lebedev's experiments with light pressure.

The "golden rule" of ancient mechanics can be considered the earliest manifestation of the law of the conservation of the angular momentum in a static sense. Kepler's law of areas is itself a law of the conservation of angular momentum for a dynamic value.

The transfer of the concept of angular momentum to non-mechanical forms of motion became possible only with the emergence of the concept of the spin (spin is a quanto-mechanical characteristic of micro-objects, a characteristic linked with their interior angular momentum) of elementary particles and the application of this concept to the electromagnetic field, i.e., in quantum mechanics and quantum electrodynamics.

The further development of physics led to a synthesis of two different laws of conservation (of mass and energy) into a single law of conservation that can be expressed in terms either of the conservation of the total mass of an isolated system (of mass in a new sense), or of the total energy of an accelerated system (energy in a new sense). This was one more step toward overcoming the mechanical view of nature according to which there is an impassable gulf between matter and motion and, consequently, between such characteristics of the former as mass and energy.

The inseparability of matter and motion, their uncreatedness and indestructibility, established by dialectical materialism as a summation of man's knowledge of nature, ceased to be merely philosophical assertions and became facts of natural science.

Parallel with this expanding application of the laws of conservation, there was a deeper penetration into their essence. In 1918, the German mathematician Emmy Noether obtained a very general result explaining the origin of the conserved values and the means of obtaining them in any theory (the so-called Noether theorem). It follows from the theorem that the laws of the conservation of specific characteristics of a material system are directly connected with the presence in the system of corresponding properties of symmetry, so that the transformation of coordinates, which does not violate the symmetry of the system, leaves the Lagrange function unchanged. From this we deduce the existence of a specific additive integral of motion. As applied to classical mechanics, this proposition leads to the following conclusions: if a material system is isolated or if its external conditions are constant, then the Lagrange function clearly does not depend on time, which means that it does not change on the transition from one instant of time to any later instant; as a consequence of the invariance of the immutability of the Lagrange function with respect to infinitely small changes in time, we obtain the conservation of the total energy of a system. In an analogous fashion, an infinitely small linear displacement in space of a closed integral system introduces no physical changes in its properties, and this is why impulse is conserved. Finally, the law of the conservation of angular momentum in a closed system follows from the invariance of the Lagrange function with respect to infinitely small rotations in space. Thus, from the fact of the invariance of a system—given a shift in time, or a displacement or rotation in space—we derive the conservation of the corresponding additive value.

Quite incredibly, it turned out that formal mathematical operations connected with the principles of invariance and symmetry permitted the disclosure of

objectively existing connections between the properties of space and time (uniformity) and the properties of moving matter that are described by energy, impulse and the moment of impulse. However, the forms of moving matter studied by physics also possess other properties, and other physical values were introduced to describe them; these physical values are conserved just as those that we have already examined.

One very important characteristic of moving matter, such as substance, is the electrical charge. Thompson's discovery of the electron at the end of the 19th century and Millikan's measurement of the charge of the electron in 1916 confirmed the discreteness of the structure of any charge.

In nature, as we have already noted, no charge less than the charge of an electron is known, and every known charge is a multiple of the charge of the electron. Experimental attempts to detect fractional charges (e.g., the work of Ehrenhaft) have not been successful. In recent years, the notion that there are special elementary particles—quarks—with fractional electrical charges has been advanced, but there is as yet no experimental confirmation of their existence in a free state.

We should say a few words about the laws of conservation in quantum mechanics and the theory of elementary particles. Quantum mechanics has not only contributed to our understanding of the known laws of conservation, it has also revealed the existence of new conserved values—and in every case, the conservation of a specific value is connected with the presence of a specific symmetry in the physical system studied.

The laws of conservation themselves (with the exception of the law of the conservation of parity) in quantum mechanics are in the nature of inhibitions imposed on states and processes. These features of the quantum laws of conservation can best be examined in the individual cases.

Take, for example, mirror-image transformation, where the signs of the coordinates of the object under study are reversed. No law of conservation in classical mechanics corresponds to this transformation, because the latter is not continuous and cannot, therefore, be made infinitely small. In quantum mechanics, however, there is a concept of parity and the conservation of parity in a closed system or in a system located in a centrally symmetrical field — and this corresponds to mirror-image transformation. The action of the parity operator on the wave function ψ consists in the substitution of $-\vec{r}$ for $\vec{r}$. Since double application of the parity operator P^2 is an identity transformation, the proper values will be $+1$ and -1, that is, its proper functions in the first case will be any even ψ, in the second case any odd ψ. The law of the conservation of parity, then, involves the following: if the state of a closed system possesses certain parity, this parity is conserved. However, it has become clear since 1956 that this law is violated given weak interaction.

Research has shown that all *K*-particles (mesons), earlier thought to have different decay processes, in fact have, within experimental limits, identical masses and lifetimes. In particular, this concerns the so-called θ and τ-particles, which decay in the following manner: $\theta^+ \rightarrow \pi^+ + \pi^0$; $\tau^+ \rightarrow \pi^+ + \pi^+ + \pi^-$ (where $\pi^\pm$ and π^0 are charged and neutral π-mesons).

There is thus a dilemma: either parity is not violated, and these are different particles, which contradicts the experimental fact of the equality of their masses and lifetimes, or these are identical particles and therefore parity is not conserved, which contradicts the notions that have taken shape over the entire course of the development of theoretical physics. Doubt was therefore expressed as to the precision of the relevant experiments. Tsung Dao Lee and Chen Ning Yang, theoretical physicists working in the United States, then offered the bold hypothesis that the law of the conservation of parity does not hold for weak interactions. Proceeding from this general proposition, they indicated the concrete effects in the area of β-decay and the decay of mesons and hyperons that would directly confirm the assertion that the law of the conservation of parity was violated.

An experiment carried out by the Wu group on β-decay of cobalt nuclei oriented in the magnetic field confirmed the non-conservation of parity. The asymmetry of $\pi \rightarrow \mu \rightarrow e$-decay established by the Lederman group pointed to the non-conservation of parity in this case, too. Subsequent experiments by many scientists have unequivocally confirmed the Lee-Yang hypothesis.

However, simple renunciation of the principle of parity contradicts our fundamental notions of the properties of space, in which there is no inherent difference between right and left. The way out of this situation was offered first by the Soviet physicist L. Landau (Lee and Yang arrived at an analogous solution independently).

Landau posited that weak interactions violate not only the conservation of parity, but also the symmetry of particles and anti-particles, a symmetry that leads to the rigid law of conservation in the case of strong interactions; but Landau then posited the invariance of the laws of nature with respect to the combination of the two transformations, this combination being called combined inversion. At present, new data have cast doubt on the existence of combined inversion, which testifies to the limited sphere of action of parity as a characteristic of quantum objects.

The action of the laws of the conservation of energy, impulse, moment of impulse and parity in the micro-world is connected with the properties of spacio-temporal symmetry (testifying to their uniformity and isotropism), and this once again confirms that space and time are the basic forms of existence of moving matter.

The most general properties of material objects are space and time, and it is for this reason that the laws of conservation that we have discussed are so important in the cognition of material processes and the structure of material objects. However, there are other types of symmetry in nature, symmetry conditioned by the structure of material objects. The laws of conservation corresponding to them reflect the immediate structure of these objects and their nature. Such are *charge symmetry* and *isotopic invariance.*

The notion of charge symmetry first came up when examining Dirac's equation for the fast-moving (relativistic) electron. A consequence of this equation was the need for the existence of electron states with negative energy. As a way out of this formal difficulty, Dirac advanced the notion that all such states are occupied by electrons, and on the strength of the Pauli inhibition electrons with positive energy cannot pass into these states. This filled-in "background" of negative energies, is, in the absence of other particles, a vacuum.

If an electron with negative energy receives sufficient energy, it passes into a state with positive energy. The "hole" left in Dirac's "background" behaves as a particle with a mass equal to the mass of an electron, but with an opposite charge. Two particles emerge, then, different in the sign of their charge and capable of disappearing under interaction (the electron fills in the "hole"), releasing a corresponding amount of energy. The existence of anti-particles capable,

together with their particles, of jointly "emerging" or "being annihilated", i.e. capable of turning into photons and emerging as the result of the interaction of photons in the field of the nucleus, was thus predicted in theory.

Soon thereafter, the American physicist Carl Anderson in fact discovered a new particle in cosmic rays—the positron, or electron with a positive charge. This was a triumph for theoretical prediction. Dirac's equation not only correctly describes the behavior of electrons, it also reflects an intrinsic property of the symmetry of nature: every particle must have a corresponding anti-particle. Corresponding to the proton is the anti-proton, to the neutron the anti-neutron, and so on. True, as with any induction Dirac's hypothesis could not be accepted without question, and before the discovery of the anti-proton there was only a high degree of probability that it was correct.

The anti-proton, discovered in 1955 by Segré and others, and the subsequent discovery of the anti-neutron, were new triumphs for theory. Anti-particles have now been found for all known particles.

From the existence of particle – anti-particle symmetry was deduced the concept of *charge conjugation*—a transformation under which all particles are transformed into anti-particles, and anti-particles into particles, so that all electrical charges and magnetic moments, as well as electromagnetic fields, change their sign. At the same time, equations describing the movement of a system, should remain invariant with respect to charge conjugation. Specifically, the charges and masses of particles and anti-particles, atomic spins and magnetic moments must be of equal magnitude.

This has been confirmed experimentally with a good degree of precision for the pairs

$$e^+ - e^-; \quad \mu^+ - \mu^-; \quad \pi^+ - \pi^-;$$

The original model of the phenomenon under consideration (the so-called Dirac "background") proved to be a unique sort of scaffolding which has assisted in the erection of the theory itself. Subsequent development of the theory of elementary particles revealed the limitations of the original notions of the Dirac "background".

Consistent description of the behavior of a system of particles and anti-particles is provided by the theory of secondary quantization, with its operators for the "birth" and "absorption" of particles and anti-particles.

The anti-particle is treated as a particle in charged conjugation with the particle proper. The basic property of the anti-particle is the capacity of being transformed into radiation on interaction with the particle.

From the fact of the existence of the world around us follows the stability of heavy particles, in the sense that they cannot be transformed wholly into light particles. For example, since a hydrogen atom can in principle exist for an infinite length of time, we must accept that there is an inhibition against the complete transformation of a proton on the capture of an electron, into, let us say, two photons, against the transformation of a proton into a positron, and against such like processes.

This stability of nuclear matter can be formulated as a *law of the conservation of the number of nucleons*. With a view to hyperons and anti-particles, the law can be formulated as follows: the difference between the number of heavy particles and the number of corresponding anti-particles is a constant of motion. Conservation of the number of heavy particles takes a quite simple, graphic form: under all interactions, the total nuclear charge of a closed system must be conserved.

One of the most clearly expressed laws of conservation associated with the properties of the symmetry of a material object is the law of the *conservation of isotopic spin.*

The neutron and proton are very similar particles. The slight difference between their masses, the equality of their spins, leads us to ask: can we not consider them different states of one and the same particle? Almost immediately after the discovery of the neutron and the development of the proton-neutron model of the nucleus, Werner Heisenberg proposed the introduction of a new degree of freedom for the description of a neutron and a proton—a "charged variable" assuming two values corresponding to two states of the nucleon: uncharged (neutron) and charged (proton). This was an attractive idea, but it did not have adequate physical support. Further, the great similarity of the properties of the so-called mirror-image nuclei was noted—each mirror-image nucleus passes into the other when neutrons are exchanged for protons and protons for neutrons. Finally, experiments on nucleon scatter showed that the nuclear forces between nucleons (P-N; P-P; N-N, where P is a proton and N a neutron) are, given low energies, approximately identical for states with equal moments and parities. This symmetry indicated the existence of specific properties of symmetry in nuclear forces.

The number of laws of conservation in quantum theory and the theory of elementary particles is still growing; they all confirm that the number of characteristics of moving matter is as infinite as the properties of matter and the forms of its existence are inexhaustible.

Taken as a whole, the principles of conservation and symmetry play a fundamental role in all respects in modern physics.

Kenneth Ford, a well-known physicist, writes that in modern science there is "a new view of the world, in which conservation laws appear naturally as the most fundamental statements of natural law. This new view is a view of order upon chaos—the order of conservation laws imposed upon the chaos of continual annihilation and creation taking place in the submicroscopic world. The strong hint emerging from recent studies of elementary particles is that the only inhibition imposed upon the chaotic flux of events in the world of the very small is that imposed by the conservation laws. Everything that *can* happen without violating a conservation law *does* happen".[1]

However, we must keep in mind that the laws of conservation themselves have a limited sphere of application, that they are of an historical nature and must not be made into dogma. They include an element of absolute truth, but are not the same as the latter. We should also note that emphasis on the connection between the laws of conservation and symmetry sometimes obscures the moment of transformation, which (as we shall see shortly) is related to the interaction of symmetry and asymmetry. A non-dialectical approach to the relationship between symmetry and asymmetry results in a situation in which the violation of certain laws of conservation, violation that occurs under specific conditions, serves as the basis for far-reaching conclusions, up to and including denial of the uncreatedness and indestructibility of matter and its attributes. This view of things disregards the proposition that the universal law of the conservation of matter is expressed through an infinite set of partial laws of conservation and transformation. Some of them have only limited application, may change their forms, may reveal a

[1] Kenneth W. Ford, **The World of Elementary Particles**, New York, 1963, p. 82.

connection with other laws of conservation and principles of symmetry.

Proceeding from the existence of an objective dialectic of the tendencies to symmetry and asymmetry in nature, one may with every reason maintain that one of the most important tasks of modern physics is the study of the connection between conservation and transformation, on the one hand, and symmetry and asymmetry (as the antipode of symmetry), on the other. It should be kept in mind that it is not the laws of conservation in and of themselves that are rigidly connected with symmetry, but specific forms of the manifestation of these laws that are so connected.

The laws of conservation and transformation are of enormous heuristic importance in the cognition of the physical forms of moving matter. This is to a certain extent connected with the heuristic role of the categories of symmetry and asymmetry in the process of human cognition. It is the view of the Soviet philosopher A. D. Ursul that "the process of cognition, the isolation of laws in phenomena, of the identical in the diverse, of the constant in the changing, of the general in the particular and so on, is in principle the isolation of symmetry in asymmetry.... The principle of symmetry (and its special manifestation, the principle of invariance as a symmetry of laws) is the necessary condition for the process of cognition.... In the very phenomenon there is something identical, and this is the ontological basis of the manifestation of symmetry in cognition. But the essence or totality of laws is something identical in the diverse".[1]

Of course, cognized identity does not encompass and does not express the differences, the asymmetry of phenomena, and cognition therefore continues by

[1] A. D. Ursul, **Symmetry and Information**, Moscow, 1966, p. 23 (in Russian).

passing on to identities of a higher order, encompassing an appreciably greater range of diversity. Cognition is a dialectical process of symmetrization and asymmetrization, for laws reflect real processes incompletely and crudely; no law points up the infinite asymmetry of phenomena. In more general theories, new laws (connected with the preceding principle of correspondence) encompass more that is diverse and different in the identical (i.e., more asymmetrical); consequently, cognition of reality becomes more adequate.

Cognition of the material world leads to the development of a more precise scientific picture of this world, by no means unimportant elements of which are the laws of conservation and transformation and their interconnection. These laws reflect interconnection between different concrete forms of matter and motion, space and time, and mark with especial emphasis the existence in nature of a variety of forms of symmetry.

Lenin noted the infinity of matter as regards its depth. There is no doubt that research into the structure of elementary particles and their interaction will result in the new invariant characteristics of motion; it will also shed light upon the mechanics of the known laws of conservation.

All the phenomena and processes known to modern physics correspond satisfactorily to the notion that spacio-temporal continuum is continuous but the material world consists of separate material objects and continuous fields. This gives us ground to expect that the real physical space—time has both continuous and discrete structures. Lenin, well before experimental data on a complex structure of the micro-world had been obtained, developed materialist dialectics by advancing the idea of the unity of the continuous and the discontinuous in motion, space and time. "Motion," he noted, "is the unity of continuity (of time and space) and discontinuity (of time and space). Motion is a contradiction, a unity of contradictions."[1]

Obviously, with the acquisition of new experimental data on the structure of elementary particles, on intra-nuclear forces and other properties of the micro-world, it will in the future be necessary to broaden our picture of space and time, to replace approximate notions on continuous space-time with more precise notions that take the discreteness of space-time into account.

In the example of the discovery and development of the laws of conservation and their use in generalization from new experimental data and in the elaboration of theories we see the contradictoriness, the complex nature, the dialectic of the process of man's cognition of the phenomena of nature.

[1] V. I. Lenin, "Conspectus of Hegel's Book 'Lectures on the History of Philosophy'", **Collected Works**, Vol. 38, p. 258.

THE REFLECTION OF THE CONTINUITY AND DISCONTINUITY OF THE MATERIAL WORLD IN COGNITION

Modern science disposes of numerous facts indicating that material objects may be both continuous and discontinuous. Philosophical studies often define *continuity* as the retention of a particular quality in the process of a specific quantitative change. Things and phenomena exist continuously to the extent that they retain their quality, while *discontinuity* is a qualitative change in the state of a thing, process or phenomenon. Qualitative change is a breach of continuity, a result of discontinuity. The continuous is the retention of quality during a change in quantity.

The continuous transformation of the forms of motion is thus an infinite succession and conception of quantities and qualities. Every such individual transition is a jump, a break in a specific concrete continuity. Discontinuity functions as a moment of the resolution of the internal contradictions of a specific quality, contradictions that condition this quality and prepare its transition into another quality. One and the same process at one and the same time has, in different concrete relationships, the character of both qualitative and quantitative change—it is both continuous and discontinuous.

The concepts "continuous" and "discontinuous" are organically linked with the concepts absolute and relative. For example, space and time as universal

forms of the existence of moving matter are absolute and continuous, they continuously attend the existence of matter, they are conditions of its existence, but as forms of the existence of matter they are wholly determined by the concrete forms of moving matter, that is, they are discontinuous, depend on the properties of moving matter and are consequently discrete. We are persuaded of this by the structures of the macro- and, especially, the micro-world. Discontinuity of material states introduces discreteness in the continuity of space as well. For instance, the finite extension of objects introduces discontinuity in continuous space. The beginning and end of a process introduce discontinuity in the continuous flow of time.

The reflection of the objective dialectic of the continuous and the discontinuous in the categories of the same is a process that is far from complete.

In physics, the philosophical categories of continuity and discontinuity play an important methodological role, especially in connection with the understanding of the nature of particle-wave duality in quantum mechanics. In classical physics, the notion of particles and waves was based on a clear dichotomy between particles and waves, on the absolute mutual exclusiveness of the two properties. In many respects, the properties of waves and particles were taken to be directly opposed to and unconnected with each other.

Particles have such properties as mass and spacial localization and the property of carrying electrical charge and magnetic properties. Particle motion is described by a reading of specific trajectories in a given system. Unless acted upon by external forces, particles have constant impulse and energy. Particle interaction has been understood as collisions of different types (elastic and non-elastic, central and non-central) through which an exchange of impulses and energies occurs. Particles were considered to be the structural elements of matter. Every moving particle transfers matter (and with it energy and impulse) and mass from one place to another.

Classical physics considered waves to be a flow of perturbation in a medium, a deformation of a medium's surface (e.g., waves in a sea), the compression and expansion of a medium (sound waves), or a change in the medium's electromagnetic state (electromagnetic waves). A number of features are inherent in waves. Specific parameters of the perturbation of the medium are periodic in space and time, i.e., the parameters repeat—e.g., maximum and minimum perturbations of the medium (amplitude) over specific intervals of time (period of oscillation) and over specific distances in space (wavelength). Waves propagated in space do not transfer matter, but they do transfer energy and impulse. Waves do not have trajectories, though they are propagated in space in specific directions. If a wave meets with no obstacles, it fills all space; consequently it is not spacially localized. The basic parameters of a wave are length, frequency, amplitude and phase. In classical physics, the energy transferred by a wave is proportional to the square of its amplitude. One of the most important properties of waves is their ability to skirt obstacles and, given the appropriate conditions, to become superimposed on each other (interference).

In classical physics, then, waves and particles were differentiated as follows: particles move along trajectories, while waves have no trajectories; particles are localized in space, while waves lack such localization—oscillations are transferred from one place to another, i.e., from point to point. Particles cannot skirt obstacles, while waves can. Particles cannot be superimposed, while waves interfere. At the same time, classical physics established that waves transfer energy and impulse just as particles do.

Obviously, waves have a number of intrinsic features of continuity, while particles feature discreteness. On a more general level, then, the juxtaposition of waves and particles in classical physics is the juxtaposition of continuity and discontinuity. However, even in classical physics—since it to a certain extent reflects objective reality—the rigid juxtaposition of waves and particles was gradually eroded. The notion of the electromagnetic field—at first only formal, but later as a notion reflecting a real object of nature—gradually led to the conclusion that electrically charged particles (discrete objects) are inseparable from a continuous object—the electromagnetic field.

Gradually, the gravitation field, too, came to be treated as a continuous object connected with every discrete material object. Thus, the development of the notions of fields and particles provided the foundation for a more general inference to the effect that discreteness and continuity are always found in association. Even before the notion of fields as a physical reality took hold in physics, thermal rays were detected with all the characteristics of waves, above all the capacity for diffraction and interference; this made it possible to picture heat flow not only as a chaotic particle motion, but also as a wave process having, as was established later, an electromagnetic nature.

Physics obtained, too, new confirmation of an earlier proposition to the effect that one and the same motion can be interpreted as both particle and wave motion. The Huygens-Fresnel principle made it possible to explain the rectilinear propagation of light from the standpoint of wave motion. Light reflection is explained both by corpuscular and wave theory. The optico-mechanical analogy, already familiar in the first half of the 19th century, makes it possible to correlate certain corpuscular and wave parameters. What this meant was that discreteness and continuity, no matter how mechanistic thinkers attempted to separate them, demonstrated their dialectical unity through a wide range of facts.

By the end of the last century, a number of similarities between waves and particles had been established. Both particles and waves transfer energy and impulse (the latter had been proved by Lebedev's subtle experiments, which first demonstrated the existence of light pressure). High frequency (short wavelength) waves behave in many respects like particles. For instance, a form of motion such as heat includes a wave component—thermal radiation. The same must be said of the motion of electrically charged particles—it is always associated with electromagnetic waves, though the reverse is not always the case. There is, too, a certain analogy between the motion of particles and the motion of waves. For instance, rectilinear particle motion is analogous to spherical wave front propagation.

However, a rather substantial distinction between particles and waves was retained. The situation began to change after the creation of the special theory of relativity, which established the universal proportional dependence between energy and mass; this led to the conclusion that waves, in transferring energy, also transfer mass. The distinction that the special theory of relativity established between rest mass and motion mass subsequently made possible the notion of particles possessing only motion mass and in this parameter quite close to fields and, hence, to wave processes.

In other words, classical physics had already detected some underlying connections between particles and waves and their motions, and had thereby provided a great deal of material for establishing the

connection between discreteness and continuity as well. But the establishment of a connection between contrasting aspects does not yet mean that the unity of the latter has been established. The scientific, dialectical materialist concept of unity includes not only interconnection, but also interconvertibility, interpenetration and the equating of opposites. Establishment of this sort of unity between discreteness and continuity on the basis of the unity of particles and waves was the achievement of the new quantum physics.

The notion of classical physics concerning the transfer of energy as a continuous process was first shaken in the case of the problem of equilibrium between radiation in a closed cavity and its heated walls, and was later entirely overturned when it was established that energy is always radiated and absorbed in specific proportions—quants. After this, one could speak of the continuity of energy transfer only given an insignificant difference between quants, i.e., when the spectrum of energy being transferred takes on a continuous, very fine structure. Taking into account both the fact—known to classical physics—that an electromagnetic wave transfers energy, and the law of the discrete character of energy transfer discovered by Max Planck, Albert Einstein developed the photon theory of light. According to this theory, light is not only radiated and absorbed in quants, it is also propagated in such a manner that for every light wave there is a photon with an energy proportional to the wave's frequency: $E=h\nu$. The photon-particle and the electromagnetic wave are, in Einstein's theory, two aspects of a whole—a propagated electromagnetic field. One may say that the photon exists in the electromagnetic wave, and vice versa. Discreteness and continuity are functions of each other and exist through each other. The less energy a photon carries, the greater the length of the wave associated with it and the more clear the wave properties in the propagation of the electromagnetic field. A long wavelength corresponds to a low-energy photon, and such a wave manifests corpuscular properties only to a very slight extent. On the other hand, the greater the energy of the photon, the shorter the length of the electromagnetic wave and the more pronounced the corpuscular properties in the propagation of the electromagnetic field.

The next major step in disclosing the unity of the conceptions of wave and micro-particle, and by the same token the unity of continuity and discreteness, was made by de Broglie, who advanced a theory of the universality of the correlation between the impulse-energy parameters of particles and such specific parameters of oscillation and waves as wavelength and frequency of oscillation. According to this theory, the energy and frequency, impulse and length of a wave are proportional not only in wave processes, but also in processes of micro-particle motion. This means that micro-particles can also have properties specific to waves (diffraction, interference, polarization); this was confirmed experimentally.

Whether the objects of nature manifest corpuscular or wave properties depends on such parameters as mass and velocity. Since these parameters change as objects interact, or to put it another way, in the different states of the objects' motion, they are relative so that their corpuscular and wave properties are also relative. In some interactions the micro-object behaves as a particle, in others as a wave. Hence the conclusion that the concepts of particles and waves are in principle applicable to one and the same object—the concepts are both identical and different. Consequently, then, the more general concepts on which the concepts of particle and wave are

based—continuity and discontinuity—are both identical and different.

Operating with the concepts of particle and wave, of continuity and discontinuity in quantum mechanics, we continually move from their difference to their identity and back again. Such shifts constitute the essence of the unity of the concepts of wave and particle, of continuity and discontinuity, which reflect one of the aspects of the dialectic of nature itself.

The unity of identity and difference that is inherent in continuity and discontinuity is also expressed through the unity of the wave and corpuscular properties of the objects of nature. And one of the aspects of the unity of these properties is the fact that they are analogous to each other, that they are correlative and interchangeable. This means that particle motion can be described by concepts characterizing the propagation of waves, while the propagation of waves can be described by concepts characterizing the motion of particles. This is possible only because particles and waves are in many respects identical. The analogy between the concepts of mechanics and wave optics is a reflection of objective moments of identity between particles and waves.

Thus, the unity of the concepts of particles and waves in de Broglie's theory, or to put it differently, their unity in light of the principle of particle-wave duality, is also disclosed in their identity, their correspondence and their interchangeability.

Heisenberg's uncertainty principle made a major contribution to the dialectic of the concepts of particles and waves. This principle imposes limits on the application within the micro-world of notions of motion of classical mechanics along a trajectory and of the strict localization of particles in space and time. The non-trajectory motion of micro-particles is analogous to the propagation of waves. In such motion, the phenomena of diffraction and interference are quite logically manifested in the particles' interaction with the medium.

However, the uncertainty principle does not completely rule out trajectory motion by micro-particles. If the wavelength corresponding to the impulse of the particle is sufficiently short as compared with the distance that the particle crosses (say, between the walls of a cathode tube), motion can be considered to occur along trajectories. In this case, electrons, to take one example, behave not as waves, but as particles occupying a specific position in space at a specific point in time. The uncertainty principle, on the one hand, brings the concepts of wave and particle even closer together and, on the other hand, indicates when and under what circumstances these concepts must be viewed not in their identity, but in their difference, when corpuscular properties may be separated from and juxtaposed to wave properties. This principle also establishes a yardstick for determining when waves and particles should be equated and when we should differentiate between them.

From the indeterminacy relation $\Delta \rho_x \cdot \Delta x \geqslant \hbar$ for the coordinate and impulse of a particle, we see clearly that if changes in the coordinate as a result of a change in the impulse, or changes in the impulse as a result of a change in the coordinate, are insignificant in comparison with their values, the changes can be disregarded and particle motion can be viewed as that of classical physics and it is not necessary to take into account the wave properties that are potentially inherent in it.

We cannot in quantum mechanics reduce the concept of particle to the concept of wave, or vice versa. Quantum mechanics eliminates neither of these concepts. It merely indicates that the difference between particles and waves is relative, that in some

interactions the object acts as a wave, in others as a particle, that in the manifestation of wave or corpuscular properties a major role is played by the relationship between the spacio-temporal parameters of the medium and the object (this means that the spacio-temporal characteristics of matter interlock with its dynamic characteristics).

Experimental proof that micro-particles possess wave properties in no way proves that they are waves; micro-particles remain micro-particles, and they can no more be reduced to waves than discontinuity can be reduced to continuity.

Quantum electrodynamics, which is based on quantum mechanics, has introduced a number of new concepts relating to motion, energy and mass. These include, first of all, the concept of zero motion and zero energy. In classical physics, it was held (as we have already seen) that at a temperature equal to absolute zero, motion within a system ceased entirely, which means that kinetic energy was entirely lacking as well. However, this conforms neither to reality nor to theory, for it contradicts the uncertainty principle, according to which the coordinates and impulses of particles cannot simultaneously have strictly determined values. In the case of absolute rest within a system, all the system's particles have constant coordinates, Δx is for them equal to zero, as are the impulses of all the particles in the system. Since there can be no doubt as to the truth of the uncertainty principle, we must presume that even at absolute zero internal motion in the system does not cease, which means that the system's internal kinetic energy does not disappear. The motion of a system's particles at absolute zero and the energy intrinsic to that motion are called zero motion and zero energy, respectively.

The uniqueness of zero motion and zero energy is that they can in no manner be removed from the system. The concepts of zero motion and zero energy express the inseparability of motion from matter and energy from mass. It is obvious from this that zero motion and zero energy may be pictured as the minimum magnitudes of the impulse and kinetic energy of particles in any system, at any temperature.

The state of particles with minimum impulse and energy is called the ground state of a system. Various excited states of the system are arranged around both sides of the ground state. It follows, further, that states analogous to the state at absolute zero exist in any system, at any temperature. Particles in the ground state obviously have spectra of energy and impulse that are continuous, since the differences between their impulses and energies are very small. And this means that in their parameters of energy and impulse ground states can be treated as continuous states, as states without particles, as states analogous to a field.

Thus, the discrete aggregate of particles belonging to the ground state of a system has impulse and energy characteristics clearly expressing continuity; one may say, then, that continuity enters discontinuity as one aspect, as a characteristic of the latter.

We find an analogous situation, in effect, with the characteristics of any aggregate of particles that are strongly connected with each other. The aggregate of particles forming liquid and solid bodies can be viewed as a continuum. This confirms once again that continuity is a characteristic of discontinuous aggregates, of the states of such aggregates. There can be discontinuity in a state of continuity, and continuity in a state of discontinuity.

It has been established that an electromagnetic field is an aggregate of photons, their system—in other words, discreteness is here a state of continuity. Every object in nature exists both in a state, a form of discreteness (discontinuity) and in a state, a form of

continuity. This is an extremely important proposition for philosophy as well as for natural science. If at the given stage of science we know only one state of the objects of nature, this must in no way be taken as ultimate knowledge. What in the development of our cognition is a step is in nature itself one of the states, one of the forms of the existence of the objects of nature under study. The stages of our cognition of nature have as their objective base the inexhaustible variety of the states of objects. What exists in nature simultaneously is disclosed in our cognition at different times, at different levels of the development of cognition.

In other words, the step-wise process of cognition does not at all mean that the properties and states of the objects under study change in the order in which we take cognizance of them. This will be clear from an example. In the course of studying the chemical interaction of atoms, the first thing established was that atoms are stable and unchanging. Later, at a different stage of cognition, it was discovered that they are variable and transmutable. Can this be taken to mean that it is not our knowledge of atoms that has changed, but the atoms themselves have acquired properties contrary to those we learned of first? Of course not. They have always had these properties: in some interactions they are stable, in others they take on variability.

The basic property of the laws of change is the fact that these laws express both the dynamic and static dependencies of the phenomena upon each other. Among the laws of change are the laws of Newton's mechanics, the laws of relativity mechanics, some of the laws of quantum mechanics (the Schrödinger equation), the Maxwell-Hertz-Lorentz laws of electrodynamics and the laws of quantum electrodynamics. The laws of change can be both dynamic and static.

The essence of the laws of conservation is that they determine the value and interrelations of the conserved magnitudes in the processes of the transformation and interaction of physical objects. The laws of conservation determine the potential for and limits on the change of physical parameters and indicate the sources on which particular processes in nature draw.

The laws of conservation provide the foundation for the laws of change only in the sense that no law of change can contradict any law of conservation. For example, there can be no law of the change of the parameters of any phenomenon that contradicts the law of the conservation of energy.

In our view, it is just as impermissible to reduce the laws of change to the laws of conservation (equating the two), as Ernst Mach did, for instance, or to oppose them to each other without qualification. These laws must be viewed in their dialectical unity.

It must be kept in mind that there are in physics laws the essence of which is a combination of specific aspects and features of the laws of conservation and change. A graphic example is Lentz's law, which involves not only the dependency between the movement of a conductor and the appearance in it of an electric current, but also one of the manifestations of the law of the conservation of energy.

We speak of the "laws of physics", but we must always remember that these laws are of human construction: in nature itself, laws are not divided into laws of conservation and laws of change, just as they are not divided into dynamic and static laws. The various classifications of the laws of physics refer, in effect, not to the laws of nature itself, but to our own models of the stable, necessary, intrinsic and diverse connections among the phenomena of nature.

We repeat, the inexhaustibility and infinite diversity of properties, relationships and states inherent in the

phenomena of nature are realized in knowledge that is historically cumulative. Therefore, no new physical concept can be considered in isolation—it is always organically linked with other concepts of physics and philosophy, on the condition, of course, that both the new and the "old" concepts reflect objective reality and are not abstract constructions devoid of substance. The history of science provides many examples of concepts that have disappeared utterly from scientific circulation because they have not been confirmed experimentally (the concept of phlogiston, for instance).

The categories of continuity and discontinuity reflect some of the universal properties of matter and its attributes. These categories are applicable to all the interconnections, relationships, changes and transformations of material objects. Continuity and discontinuity represent the unity and disunity of the structural elements of matter and its attributes, they are inseparable from each other and objectively exist only in their unity. This does not, however, rule out the accentuation of continuity or discontinuity in specific situations and at different levels of our knowledge.

It follows that it is not the complementarity or "coexistence" of these categories, but their dialectical unity that serves as a methodological principle of our cognition. The principle of the unity of continuity and discontinuity must be viewed in its connection with other principles and categories of materialist dialectics, in particular with the principles of the unity of space and time and the unity of the world and its development.

Continuity and discontinuity are manifested in many ways, which we may summarize in the following table:

Discontinuity	Continuity
Isolation	Interrelation
Disjunction	Fusion

Intermission	Progression
Localness	Non-localness
Finite divisibility	Infinite divisibility
Periodicity	Aperiodicity

The interdependency, interpenetration and interlinking of these manifestations of continuity and discontinuity constitute their unity.

The objects of nature possess, in effect, a unity of discreteness and continuity both in the combination of the above-listed manifestations and in their interdependency and interpenetration. The field of elasticity in a crystal, for instance, is not localized but is distributed throughout the crystal, while its energy and impulse may be localized in the form of phonons in certain regions of the crystal. There may be leaps in any gradual change and gradual changes in leaps. Two electrons continuously repulse each other with their fields, but the formation of these fields proceeds in a process of discontinuous emission and absorption of photons. Exciton wave formation is propagated gradually through a crystal, but localized at the lattice points of the crystal, it passes by discontinuous jumps from one point to another. On a deeper study of any process, we can detect a unity of the manifestations of continuity and discontinuity.

There have been attempts in science to reduce the essence of processes studied to continuity or to discontinuity, to separate these qualities from and oppose them to each other. A clear example of the reduction of all changes to discreteness is Cuvier's catastrophism; Herbert Spencer's theory of linear evolution is an example of the reduction of all change to continuity.

Bohr's principle of complementarity, which asserts that if a particle has corpuscular properties it cannot have wave properties, and vice versa, partially admits of a gap between continuity and discontinuity.

According to this principle, the presence of discreteness excludes continuity, while continuity excludes discreteness. Academician V. A. Fok has quite rightly noted that when a micro-object has corpuscular properties its wave properties are suppressed, but they remain in potential and given a change of the conditions of the micro-object's existence are capable of becoming actuality. The unity of continuity and discontinuity in the existence of micro-objects is not violated, then, but is manifested in the unity of the potential and the actual. What in actuality is continuous is in potentiality discrete, and vice versa. The unity of discreteness and continuity is expressed in many forms. It is expressed through the unity of quantitative and qualitative changes, through the unity of the potential and the actual, through the unity of contingency and necessity, and so on.

The manifestations of continuity and discontinuity and of their unity are, then, inexhaustible in their nature. Our knowledge of these manifestations will continually develop and become more refined.

Material objects, processes and phenomena are characterized by a dialectical unity of the continuous and the discontinuous. The continuity and integrity of an object or a process is the foundation for subsequent formations of a new continuity through the system of interacting parts (discontinuities) of this continuity.

Discontinuity is the condition for the existence and development of continuity. Asymmetry and heterogeneity in the interconnection of the elements of the whole, the contradictoriness in the structure and functions of these elements, lead to the change, the motion of objects, the continuous existence of which is connected with the uncreatedness and indestructibility of moving matter.

THE PRINCIPLE OF SYMMETRY AND ITS ROLE IN COGNITION

Our examination of the philosophical aspects of physical knowledge has required us repeatedly to make use of the concepts "symmetry" and "asymmetry". What, then, are symmetry and asymmetry, and what is the essence of their methodological importance?

Over the millennia, in the course of practical experience and the cognition of the laws of objective reality, mankind has accumulated much information pointing to the existence in the surrounding world of two tendencies: on the one hand, strict order and harmony, on the other—violation of order and harmony. Men long ago noted the regularity of the forms of crystals, flowers, beehives and other natural objects, and they reproduced this proportionality in works of art and in objects that they created; and they developed the concept of symmetry. "Symmetry," writes the well-known scholar James Newman, "establishes a ridiculous and wonderful cousinship between objects, phenomena and theories outwardly unrelated: terrestrial magnetism, women's veils, polarized light, natural selection, the theory of groups, invariants and transformations, the work habits of bees in the hive, the structure of space, vase designs, quantum physics, scarabs, flower petals, X-ray interference patterns, cell division in sea urchins, equilibrium positions of crystals, Romanesque cathedrals, snow flakes, music, the theory of relativity."[1]

The word "symmetry" has two meanings. In one sense, "symmetrical" designates something highly proportional or balanced; symmetry indicates the capacity for congruence of many parts, which through this congruence are joined into a whole. Polyclitus, followed by Vitruvius, used the word in this sense, and to Polyclitus is attributed the assertion that "the use of a large number of magnitudes almost necessarily engenders regularity in a sculpture".

The other sense of the word is equilibrium. Aristotle spoke of symmetry as a condition characterized by a proportion of extremes.

Pythagoras and his students paid close attention to symmetry. There were in Pythagoras' time numerous mystical schools and sects, but the Pythagoreans had, in addition to what united them with these mystic tendencies, something special—a method by which they could allegedly commune with God. This communication was achieved, they thought, through mathematics, which was a constituent element of their religion. "Their doctrine proclaims that God has ordered the universe by means of numbers. God is unity, the world is plurality and it consists of contrasting elements. It is harmony which restores unity to the contrasting parts and which moulds them into a cosmos. Harmony is divine, it consists of numerical ratios....

"According to Heraclides of Pontus, Pythagoras said that 'Beautitude is the knowledge of the perfection of the numbers of the soul.' "[2]

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[1] James R. Newman (Ed.), **The World of Mathematics**, New York. 1956, p. 670.

[2] B. L. Van der Waerden, **Science Awakening**, Groningen, 1963, pp. 93, 94.

The Pythagoreans proceeded from the notion that number is the essence of the entire world around us. They reduced cognition of the world to cognition "of the numbers governing it". Having taken up the mathematical sciences, Aristotle said, the so-called Pythagoreans were the first to move them forward, and, being brought up on them, began to consider them the beginning of all things ... numbers occupied first place in all Nature, the elements of numbers were presumed to be the elements of all things, and the Universe was "proclaimed" harmony and number.[1]

The basic tenet of Pythagorean philosophy, according to Aristotle, was that the number is the essence of all things and that the structure of the Universe in its definitions generally represents a harmonious system of numbers and their relations.

Citing this passage from Aristotle's *Metaphysics*, Hegel asks: What are we to make of this proposition? The number is mainly defined as a measure. If we therefore say that everything is quantitatively and qualitatively determined, then magnitude and mass are only a property, only one side of things. The idea here, however, is that the number is itself the essence of things, the substance, and not the form.[2]

Hegel describes this as astonishingly bold and lauds Pythagoras for eliminating the sensual essence and turning it into a thought essence.[3]

Proceeding from the doctrine of numbers, the Pythagoreans provided the first mathematical treatment of harmony and symmetry, a treatment that has not lost its importance to our day.

The views of Pythagoras and his school were further developed in Plato's doctrine of cognition. Plato

[1] See Aristotle, **Metaphysics**, 1, 5, 985a 20-986.

[2] See G.W.F. Hegel, **Vorlesungen über die Geschichte der Philosophie**, Erster Band, Leipzig, 1971, S. 330, 335.

[3] **Ibid.**, S. 330.

maintained that only what is free from contradictions can be known, and since motion and change contain contradictions, the sensible world is unknowable. He held that the concrete exists only to the extent that the absolute, abstract idea, eternal and unchanging, exists. According to Plato, the world soul is not simply a wise, accelerated with mathematical precision mechanism of operating forces, but also a harmonious mechanism.

Plato's views on the structure of the world are of special interest. For Plato, the world consisted of regular polygons possessing ideal symmetry. Plato combined a doctrine of ideas with the Pythagorean doctrine of numbers. He held physical bodies to lack materiality; he treated them as ideal mathematical essences made up of triangles. Plato considered the world soul to be the principle conditioning the unity of this mathematically ordered world of sensible things.

Of the later naturalists and philosophers who analyzed the category symmetry we should mention René Descartes and Herbert Spencer. For Descartes, God, having created asymmetrical bodies, imparted to them a "natural" circular motion, as a result of which they grew into perfect, symmetrical bodies. Spencer dealt with the question of symmetry in especial detail in connection with the philosophical generalization of biological data, the morphology of plants and animals in particular. Pointing to the degree of biological complexity and to changes of symmetry, he concluded that change is causally dependent on the symmetry or asymmetry of the conditions of the environment.

The question of symmetry in inanimate nature is treated in most detail in crystallography. The perfection of the external form of crystals long ago attracted the attention of naturalists and philosophers. As man's knowledge of nature expanded, so did his efforts to find the causes of particular phenomena in the surrounding world. The symmetry of crystals (among other questions) was studied, but many centuries passed before, toward the end of the 18th century (1783), the French scientist Romé dé Lisle discovered one of the most important laws of crystallography—the law of the constancy of dihedral angles in crystals. The law states that the angle between the corresponding facets of all crystals of the same substance is constant. It is important to note here that Romé dé Lisle, proceeding from the study of particular crystals, arrived at a high level of scientific generalization, applying the law of the constancy of angles to crystals of all substances.

Another French scientist, René Just Haüy, continued Romé dé Lisle's work and established another important law—the law of whole numbers, which without question influenced Dalton's discovery of the law of whole numbers in chemistry. As distinct from Romé dé Lisle, who held that nature concealed the inner essence of crystals from us and that it was unknowable, Haüy, proceeding from a materialist point of view, in order to explain the essence of the law of whole numbers developed a theory that the internal structure of crystals consists of polyhedral molecules. Drawing upon experimental data, including the fact that on the splintering of a crystal, of rock salt for instance, the fragments have the regular form of parallelepipeds, he arrived at the conclusion that molecules of rock salt must have the same form. Though his notion of the form of molecules was completely wrong, the idea of the molecular structure of matter was the basis on which he discovered the law of whole numbers, which was subsequently confirmed experimentally.

In 1819, Eilhard Mitscherlich discovered that substances of a similar composition crystallize in identical forms, which he called isomorphic. (The great Russian chemist, Mendeleyev, who in 1869 discovered

the law of the periodic manifestation of the chemical properties of elements, also studied this phenomenon, on which he wrote his dissertation: "Isomorphism in Connection with Other Correlations of Crystal Form with Composition.") Three years later, in 1822, Mitscherlich discovered the phenomenon of polymorphism, which consists in the fact that some substances can, under different conditions, form crystals of different symmetry and form. We know that carbon has two crystalline forms, graphite and diamond. Graphite is black and is a good conductor of electricity, diamonds are transparent and do not conduct electricity. Diamond is the hardest of natural substances, while graphite is one of the softest minerals; the specific gravity of graphite is 2.22, that of diamond—3.51. Thus, differences in the spacial distribution of one and the same atoms, differences in crystal lattices (in graphite, hexagonal; in diamond, cubic), give rise to polymorphic modifications that often have sharply differing physical properties.

The phenomena of isomorphism and polymorphism have great philosophical import. They are one of the many testimonials to the truth of the law of the transition of quantitative into qualitative change. Here there is a further enrichment of the category "quantity", since it includes not only a change in the number of elements or parts that make up the whole, but also a change in the spacial distribution of the parts.

One of the fundamental properties of crystals is their *anisotropism*, i. e., the fact that they have different physical properties along different axes. At the same time, crystals are homogeneous bodies. This means that two regions of a crystal of identical form and identical orientation have identical properties.

Molecules of one and the same composition and form can be "packed" in a crystal in different ways,

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and on this depends the physico-chemical properties of a substance.

In 1813, the English scientist Wollaston advanced the idea of spherical molecules that can in the extreme case be depicted as mathematical points. The regular distribution of these points in space gave rise to the concept of spacial crystal lattices, the concept of lattice symmetry.

The crystal lattice is a concept of the same type as the concept of the element of symmetry with which we are concerned when studying, say, the external form of a crystal. This mathematical abstraction (the crystal lattice) makes it possible to describe the periodicity of crystalline structure. Consequently, structure designates the concrete distribution of material particles in a crystal, while the crystal lattice is only the mathematical image of this structure.

Symmetry is manifested in the external form of crystals, in physical phenomena occurring within them, in the interaction of crystals with the surrounding medium, in the changes that crystals undergo under the action of external influences.

But the laws of symmetry apply not only to the external form of crystals, their internal structure is also subordinate to them. External form is the manifestation of the internal structure of crystals.

In 1830, Johann Friedrich Hessel demonstrated geometrically that there are only 32 classes of crystals in nature. However, Hessel's work was ignored at the time and the same system was rediscovered in 1867 by the Russian Aksel Gadolin.

The internal structure of the crystal yields a considerably greater variety of elements of symmetry than its external form. This was reflected in the isolation of all possible combinations of the elements of symmetry in space by the outstanding Russian scientist E. S. Fedorov in 1890. Fedorov demonstrated that

there are 230 such spacial groups of symmetry. He counted all existing spacial lattices long before the appearance of X-ray diffraction analysis, which showed that Fedorov's calculations were correct. This was a scientific triumph, persuasive proof of the power of scientific insight. Not a single crystal form has yet been found that does not belong to one of Fedorov's groups.

The French scientist Pierre Curie made a major contribution to crystallography, especially the study of symmetry. In her memoirs, Marie Curie remarked that Pierre Curie was very interested in the physics of crystals. His theoretical and experimental studies in this field were grouped around a common principle, the principle of symmetry. He wrote:

"When certain causes produce certain effects, the elements of the symmetry of causes must reappear in the effects produced.

"When certain effects reveal a certain dissymmetry, this dissymmetry should be found, too, in the causes of the given phenomena.

"The reverse of the two propositions does not hold, at least in practice, that is, consequences may be more symmetrical than their causes."[1]

Real crystals, of which for all practical purposes all inanimate nature consists, are a combination of elements (atoms, molecules, ions) that can be characterized as a dynamic unity of order and disorder, symmetry and asymmetry. The Soviet physicist A. I. Kitaigorodsky writes: "Study of the elements of disorder in a regular molecular structure, and the reverse, study of the elements of order in the chaos of the disorderly distribution of particles, led to the establishment of new and important regularities linking the structure of substances with their

[1] Marie Curie, **Pierre Curie**, Paris, 1955, p. 29.

properties and explaining a number of phenomena by changes in the degree of a structure's order."[1]

Typically, the most interesting scientific results have been obtained when violation of symmetry has been established. This line can be traced, for example, in astronomical observations. Galileo held that planets move along natural circular orbits. The violation of the axial symmetry of planetary orbits discovered by Kepler led to the creation of classical mechanics.

The concepts of the simplest types of symmetry (the isotropy and homogeneity of space) appeared at the dawn of human cognition.

The invariance of the laws of mechanics on transition to a uniformly moving system of coordinates (also known as invariance with respect to Galileo transformations) was the first non-simple symmetry discovered. This symmetry was one of the initial principles in Newtonian mechanics. The consequences that stem from this principle of symmetry underwent intensive study in the 19th century and yielded a number of important results—above all, the classical physics' laws of conservation.

The development of the special and general theory of relativity lent the laws of symmetry new significance: the connection between the laws of symmetry and the dynamic laws of physics proved to be considerably tighter and mutually determinable to a greater extent than in classical mechanics. Until the appearance of quantum mechanics, the principles of symmetry were not widely applied in physics. But their importance has now grown enormously. The quantum numbers that describe the state of a system often coincide with the quantum numbers defining the symmetry of a system. A good example is the fact that the existence of anti-particles—the positron, anti-proton and anti-neutron, to be precise—was predicted theoretically as a consequence of the invariance of physical laws with respect to Lorentz transformations.

[1] A. I. Kitaigorodsky, **Order and Disorder in the World of Atoms**, Moscow, 1959, p. 3 (in Russian).

The concepts of symmetry and asymmetry used in particular scientific disciplines do not come close to reflecting the symmetry and asymmetry of the real world; they are constantly developing and acquiring new meaning. As the history of science shows, these are concepts that can be used to explain many phenomena and to predict the existence of new, as yet unknown properties of nature. It is not the order of "creation" that is established through use of the idea of symmetry, but symmetry and asymmetry that are a reflection of the objective properties of the material world.

We find in monographs in the field of physics and other disciplines various definitions of symmetry, the sense of which—as we have already seen—can be boiled down to the concept of proportionality, of harmony, while the concepts of anti-symmetry, asymmetry and dissymmetry are used in the sense of a violation of symmetry.

At present, in natural science the categories of symmetry and asymmetry are overwhelmingly defined through a listing of their specific traits. For instance, symmetry is defined as a set of properties: order, homogeneity, proportionality, harmoniousness, and so on. Asymmetry is usually taken to mean the absence of indications of symmetry—disorder, disproportionality, heterogeneity, etc. All the traits of symmetry in this sort of definition are, naturally, taken to be of equal weight, to be equally fundamental, and in specific cases any of them may be used to establish the symmetry of a phenomenon. For instance, in some cases symmetry is homogeneity, in other cases proportionality, and so on. As our knowledge expands, we can add to the number of traits of symmetry.

The same applies to the definitions of asymmetry in use in the individual disciplines. This means that in concept definitions formulated through the enumeration of the properties of objects reflecting these concepts, there is no connection between the properties enumerated. Properties of symmetry, such as homogeneity and proportionality do not follow from each other. It is another matter when definition is based on the isolation of the intrinsic, fundamental aspects of an object, aspects that are, moreover, interconnected. Such definitions have the character of necessity and provide a profound understanding of the object at issue. This does not, however, mean that the above-mentioned definitions of symmetry and asymmetry are useless. Quite to the contrary, they are extremely useful and necessary. Without them it would be impossible to provide more general definitions of symmetry and asymmetry as the categories of cognition, either, for on the basis of empirical—if we may put it this way—definitions of symmetry and asymmetry are formed definitions of a more general character. After all, the essence of general definitions is in the correlation of individual traits of symmetry and asymmetry with specific universal properties of moving matter.

The general concepts of symmetry and asymmetry should be such that they subsume all known and even presently unknown types of symmetry and asymmetry. This requirement stems directly from the following propositions:

first, scientific data tell us that these concepts apply to all attributes of matter known to us, that they reflect the links among them and that no meaningful general definitions of these concepts can be given on the basis of individual attributes of matter, but only through the disclosure of their interrelationship;

second, these concepts are based on the dialectic of

the correlation of identity and difference between the attributes of matter and between their states and traits;

third, the unity of symmetry and asymmetry is one of the forms of the manifestation of the law of the unity and mutual exclusion of opposites.

The immediate basis in logic for the definition of symmetry and asymmetry is, in our view, the dialectic of identity and difference. Identity and difference are viewed in dialectics only in specific relationships, in interaction, in the inclusion of difference in identity, and identity in difference.

Identity appears only in specific relationships and specific processes—identity is always concrete. It follows that identity has a multiplicity of states. Identity includes: equilibrium, equipollence, conservation, stability, equality, proportionality, periodicity, and so on. Identity does not exist eternally, it originates and becomes, it is a process of the formation of similarity in the different and contrary.

The dialectical understanding of identity necessarily presumes the following: identity does not exist exterior to difference and contrariety, identity originates and disappears; identity exists only in specific relationships and emerges under specific conditions; the fullest expression of identity is the total transmutation of opposites into each other.

There is an infinite multiplicity of the manifestations of identity. It follows that in the process of cognizing the phenomena of the world one cannot confine oneself merely to the establishment of identity between them, it is necessary to disclose how this identity emerges, under what conditions and in what relationships it exists. We have offered the following definitions of symmetry and asymmetry on this basis[1]:

[1] See V. S. Gott and A. F. Pereturin, "The Category of Symmetry and Asymmetry in the Physics of the Micro-World", **Philosophical Problems of Quantum Physics**, Moscow, 1971 (in Russian).

Symmetry is a category designating a process of the existence and becoming of identical moments, in specific conditions and in specific relationships between different and opposite states of the phenomena of the world.

From this definition of the concept of symmetry follow these methodological requirements: in studying phenomena, events, states of moving matter, it is necessary first of all to establish the differences and contrarieties inherent in them, and then to disclose the identical in them and under what conditions and in what relationships this identical originates, exists and disappears. From this follow, too, some general rules for the formulation of hypotheses (this rule is often referred to scientific intuition). If the existence of some phenomenon or state has been established, or if some properties and parameters of a phenomenon or state have been established, one must presume the existence of contrary phenomena, contrary properties and parameters; it is necessary to postulate further that in certain relationships and under certain conditions there exist and originate moments of identity between the contrary conditions. These two rules express in a general way the application of the concept of symmetry in specific studies.

Together with processes of the origination of identity in the different and the contrary, there are processes of the emergence of differences and contrarieties in a single, identical whole. If we can take emergence of the integral to be the basis of symmetry we must posit that the basis of asymmetry is the bifurcation of the integral into contrary aspects.

The category designating the existence and conception, under specific conditions and in certain relationships, of differences and contrarieties within the unity, identity and integrity of the phenomena of the world, is called *asymmetry*. Asymmetry is just as

necessary a moment in structure, in change and in the interconnection of the phenomena of the world as symmetry.

It seems to be more precise to speak, not of the "principle of symmetry", but of the "principle of the unity of symmetry and asymmetry", for "pure" symmetries and asymmetries do not exist in nature, they can exist only in our cognition as abstractions expressing boundary conditions.

In all real phenomena, symmetry and asymmetry are combined. And one must suppose that all valid scientific generalizations, that is, generalizations that are in accord with reality, encompass not just particular symmetries or asymmetries, but specific forms of their unity. For instance, in the Galileo and Lorentz transformations, traits of asymmetry exist alongside traits of symmetry: all states of rest and uniform, rectilinear motion are symmetrical, but states of rest and accelerated motion are asymmetrical.

The task of finding the unity of symmetry and asymmetry in given phenomena comes down to finding groups of operations that disclose both the identical in the different and the different in the similar. It follows that before proceeding to find symmetry with respect to certain groups of operations in a specific phenomenon or set of phenomena, it is necessary to establish the differences between aspects of the given phenomenon or among all the phenomena, since symmetry is not the presence of identity in general, but of identity in the different. If we have a totality of absolutely identical phenomena, there can be no symmetry with respect to any group of operations.

This means that before seeking symmetry, it is necessary to find asymmetry. And the reverse is also true. Before the symmetry of protons and neutrons was established with respect to strong interactions, the difference, a certain asymmetricality between them, was found. Particles and anti-particles are asymmetrical because they have identical moments, on the strength of which they are mirror-images of each other. It would seem that the unity of symmetry and asymmetry consists in the fact that they precede each other. This feature of the contradictory unity of symmetry and asymmetry is manifested clearly in the development of our cognition.

As physics developed, two mutually exclusive optical theories—wave and corpuscular—emerged almost simultaneously. And for a long period of time optics was clearly asymmetrical. It was subsequently discovered that the corpuscular and wave aspects of optical phenomena are in many respects equivalent, include moments of identity and are therefore much symmetrical with respect to each other. Even today there is a clearly expressed asymmetry in electromagnetic theory, an asymmetry that stems from the fact that opposite electrical charges exist autonomously, while opposite magnetic fields only exist together, though electrical and magnetic fields are completely symmetrical. The search, which has lasted for many years, for the magnetic monopole predicted by Dirac, is in essence a search for symmetry between electrical charges and magnetic poles.[1] Finally, we should note in this connection that the symmetry of rest and uniform rectilinear motion was established on the basis of their contrariety. The unity of symmetry and asymmetry, then, must be viewed as a universal phenomenon inherent both in objective reality and in our cognition.

We mentioned above that the definition of symmetry

[1] Kenneth W. Ford, "Magnetic Monopoles", **Scientific American**, December 1963, pp. 122-31.

and asymmetry draws upon such universal categories as identity, difference, change and becoming. In turn, the categories of symmetry and asymmetry are of substantial importance for describing other universal categories of our cognition.

Let us examine this question by taking as an example the category "law". Every law expresses a certain order, a certain regularity in the spacial distribution of phenomena and of their succession in time. For example, the laws of crystal structure express the order in the distribution of their elements: molecules, ions, atoms, and groups of the same. The laws of chain reactions (in physics, chemistry, biochemistry) express the order of the succession of their states and stages.

"Law" also expresses a certain homogeneity inherent in different phenomena and in their interactions. Here the concept of homogeneity designates the identity of their connections, relationships and structures. For instance, such different phenomena as sound and electromagnetic waves have a number of identical links and dependencies: between wavelength and frequency, between phase and the group velocity of the propagation of waves, and so on.

Order or regularity (they are one and the same) and homogeneity are intrinsic aspects of the laws of the world. Some authors are even inclined to consider them the principal feature. The eminent physicist Eugene Wigner in particular gives the following definition of physical laws: "The regularities in the phenomena which physical science endeavors to uncover are called the laws of nature."[1] Wigner has without question identified an important characteristic

[1] Eugene P. Wigner, **Symmetries and Reflections**, London, 1970, p. 39.

of laws. And since another aspect—symmetry—is associated with it, it would seem that symmetry is also important and intrinsic to an understanding of the laws of nature.

Lenin noted as one of the characteristics of a law the following: "Law is the identical in appearances."[1]

This characteristic indicates that there is another route to the cognition of laws: the disclosure of that which is identical in different phenomena or aspects of phenomena. As we have established above, symmetry is also the identical in the different and contrary. Finding symmetry in and between phenomena is, then, the cognition of certain aspects of their laws. In other words, with the use of symmetry we may disclose extremely important laws of the phenomena of the world. Every law includes a specific symmetry—specific, since identity in the different and the contrary (and hence, symmetry in the same) may in different situations be either fundamental or unessential. Understandably, identity (symmetry) can be included in the definition of a law only if it is fundamental.

The identity existing between the proton and the neutron with respect to strong interactions (symmetry of charge independence) expresses a fundamental aspect of the law of their interaction, a law that is, we should note, not yet fully understood. Knowing the symmetry of phenomena is not of itself complete knowledge of their laws. Symmetry does not encompass the total content of the law, but only one important aspect of the law. Consequently, it is absolutely inadmissible to equate laws and symmetry. One cannot, therefore, develop a complete theory of

[1] V. I. Lenin, "Conspectus of Hegel's Book 'The Science of Logic'", **Collected Works**, Vol. 38, p. 151.

elementary particles solely by discovering the symmetries inherent in them.

The basis for a connection between laws is the presence in them of substantial moments of identity. For example, in the law of universal gravitation and Coulomb's law, the form of the dependence of force on distance is identical. In the laws of the free fall of bodies and the fall of bodies along an inclined plane, the dependence of the velocity of motion upon the height of the fall alone is identical. Drawing upon the definition of symmetry given above, then, one may describe the interconnection between laws as their symmetry.

The symmetry of laws is the presence of moments of identity between the connections that are a part of them. In this sense, the most diverse laws, applying to different areas of nature, may be symmetrical.

The symmetry of laws is an essential aspect of their unity.

The laws of phenomena operate under specific conditions. The question of the symmetricality of laws with respect to different conditions arises in this connection. If there are no moments of identity in the conditions under which the laws operate, the laws do not possess symmetry. Given the existence of such moments, symmetricality of the laws with respect to the given conditions is obligatory. The task is to find these moments of identity in the diverse conditions under which the laws operate.

Among the most general aspects of these conditions are: location and orientation in space, intervals of time and states of motion. Experience has shown that all locations and orientations in space, all intervals of time and all states of uniform, rectilinear motion have moments of identity. Therefore, in whatever location in space a system functioning according to specific laws may be, the action of the laws will everywhere be identical. The same holds for location in time, velocities of uniformly rectilinear motion and orientations in space. A change in these parameters changes nothing in the operation of the laws—they remain wholly symmetrical.

We have noted above that one of the foundations of the connection between laws is presence of moments of identity, that is, of symmetry, in their differing contents. It would seem that if we understand asymmetry somewhat formally (as the absence of all elements of symmetry), the conclusion seems to follow that the presence of asymmetry in laws excludes a connection between them. But this is not the case. First, the presence of asymmetry in the content of laws does not obliterate their content and does not exclude the existence of symmetry. Second, asymmetry, like symmetry, is a basis for the existence of a connection between laws. Here is a graphic example: the clear, it would seem, asymmetricality of the content of the law of entropy increment in no way ruptures the link between this law and the law of the conservation and conversion of energy. In fact, the opposite is true, as is confirmed by such physical magnitudes as thermodynamic potentials (thermodynamic potential, free energy, entropy).

The laws of the conservation of energy and impulse contain an element of mutual asymmetry: energy is a scalar, impulse is a vector, but there is a profound link between them, a link disclosed by the theory of relativity.

We repeat, then, that interconnection of laws is conditioned both by symmetry and asymmetry. Moreover, a connection between laws that is founded on the existence of elements of asymmetry in them is apparently even more profound than a connection based on symmetry.

In effect, every law is asymmetrical with respect to certain changes and conditions. Newtonian laws of mechanics, for instance, are asymmetrical with respect to the group of Lorentz transformations. The law of energy increment is clearly asymmetrical with respect to the interconversion of different types of energy and establishes, as we know, the tendency toward the preferential conversion of all types of energy into thermal energy. Maxwell's law on the distribution of the velocities of molecules of gas establishes the dominance of molecular velocities close to the mean with respect to their higher or lower velocities. The law of the interaction of conductors with rapidly alternating currents conditions not their mutual acceleration, but the acceleration of only one of them. And, finally, the connection between Kepler's laws and the law of universal gravitation was established on the basis of the violation of axial symmetry in planetary motion, which is expressed in Kepler's first law.

"It would not be much of an exaggeration to say," writes Ya. A. Smorodinsky, "that the most interesting results are obtained in physics when laws of the violation of symmetry are elucidated."[1]

Let us now consider in more detail the question of asymmetricality between laws and the conditions under which they operate. This assymetricality appears when, in the conditions under which they operate, in their aspects, moments of difference rather than moments of identity come to the fore. Under conditions, for example, of non-homogeneous space, in which all locations are different rather than identical, the mutual displacement of bodies occurs under different laws. Laws that govern the displacement of bodies under conditions of identity lose their stability under conditions of non-identity and perish in the

[1] **Uspekhi fizicheskikh nauk**, Vol. 84, Issue 1, 1964, p. 3.

chaos of changes. The invariance of laws disappears with respect to asymmetrical conditions.

But can we draw from this the conclusion that with respect to asymmetrical conditions there can be no laws and that laws operate only given symmetrical conditions? Such a conclusion would be hasty in the extreme. One must be extremely cautious in drawing such conclusions, keeping in mind the limitation, the relativity of our knowledge at this point. Experience tells us thus far one thing: symmetry always lurks behind asymmetry, and vice versa. We know, for example, that Riemann space-time is asymmetrical, but we have no grounds for supposing that there is no symmetry in it. We do not yet know this. A second example: the same experience indicates that there is no precise delimitation between laws and the conditions under which they operate. Asymmetrical conditions are scarcely an exception: laws operating in them should, it would seem, have unique features in which, as we see it, along with functional connections a fundamental role must be played by inverse connections. It is possible that laws for asymmetrical conditions have more profound statisticity than do the laws of quantum mechanics and quantum field theory.

It would seem that another conclusion is more meaningful and stimulates cognition to a greater extent: asymmetricality of conditions does not exclude the existence of regularities. Nor does asymmetricality of conditions exclude the invariance of laws. This proposition is based on the fact that symmetry is not the only source of invariance, that the invariance of laws is also ensured by the attributive connections that are a part of their content.

Study of the connection between the categories of symmetry, asymmetry and law, then, makes possible a more profound picture of the content of these categories and of their role in our cognition.

The supposition that the space and time of moving matter has properties as yet unknown rests on the solid foundation of the knowledge already acquired, on the general laws of materialist dialectics. It is an example of concrete analysis of a concrete situation with the aid of philosophical categories and scientific concepts.

THE PRINCIPLES OF PHYSICS AND THEIR PLACE IN COGNITION

What Are the Principles of Science?

The principles of physics are generalizations from specific objective regularities of physical phenomena. In nature itself there are no physical, chemical, biological, or such like principles. They exist only in our cognition, but they have an objective content.

Consequently, the establishment of the laws of physics and the formation of the principles of physics proceeds through the detection or positing of a connection between the operation of these laws and the properties of a wide range of physical phenomena. If this connection is established by experiment, then principles of physics take shape; if the connection is supposed, then we have to do with postulates.

In physics, postulates are principles based on a supposed, hypothetical link between laws being generalized and the properties of a certain group of physical phenomena. To put it another way, postulates in physics are a special type of physical hypotheses (e.g., Bohr's postulates in the atomic model he offered in 1913).

A basic moment in the formation of new principles of physics is the establishment of a connection between the laws of physics, the forms in which they appear and other physical principles.

It follows from the above that analysis of the content of a particular principle of physics necessarily includes disclosure of its connection with other laws and principles of physics.

No principle of physics manifests itself in finished form; in effect, there can be no completed, fully stable principles of science. As science develops, every scientific principle is made more precise; its import is expanded or, at times, narrowed. Obviously, the point of departure for the formation of physical principles is practical experience, experiment. It follows that the method of studying the objective content of principles in physics includes the following:

1) analysis of the development of the formation of principles of physics and their application;

2) analysis of their connection with other laws and principles of physics;

3) analysis of the principles of physics as generalized practical experience, experiment, as unique stages in the logical reflection of reality.

Principles of "inhibition" hold a special place in a number of physical principles. The number of such principles is quite large, but far from all of the inhibition principles are of general import. Inhibition principles in physics have a dual meaning: on the one hand, they establish the impossibility of certain physical phenomena in nature and, consequently, the impossibility of observing them or replicating them in experiment; on the other hand, they define the direction of thought, they lend it a certain order, they *forbid*—not nature, but thought—certain goals and means to attain those goals.

Properly speaking, all the principles and laws of physics now known have certain moments of inhibition—either in its first or second sense. Moments of inhibition are graphically expressed in the laws of conservation, in the Heisenberg uncertainty principle, in the principle of the constancy of the speed of light, and so on. Inhibition principles establish, too, an "empty" class of problems—for example, the problem of the means by which to achieve perpetuum mobile.

As a matter of course, there are also inhibition principles for postulates.

Naturally, inhibitions are of varying degrees of generality and have differing ranges of application. But there are inhibitions of absolute import. Such are the inhibitions that are a part of the laws of conservation and transformation within the limits of their operation. In general, one must approach inhibitions concretely, though from the point of view of thought some aspects of inhibitions are of an absolute character. For instance, one can never think of matter without motion. This inhibition is a consequence of the fundamental methodological tenets of dialectical materialism.

Inhibition principles play an important role in cognition. Some scientists, the English physicist and mathematician Edmund Whittaker, for one, consider them the foundation of all physics.[1] But this notion is ill-founded.

There are a number of different opinions with respect to inhibition principles and their role in the cognition of physical phenomena. Some physicists hold that inhibition principles express non-causal laws of nature; others view them as a condensed expression of our negative experience, experience that shows that some processes and phenomena cannot exist; still others suppose that inhibition principles are a consequence stemming from the foundations of physical theory.

In our opinion, the abovementioned views do not

[1] See Max Born, **Physics and Politics**, Edinburgh and London, 1962, p. 39.

provide a complete characterization of the peculiarities of physical inhibition principles. They are either one-sided or simply distort the true significance of these principles.

As with any other principles of physics, inhibition principles are based on experimental data and serve as the first stage in the cognition of the laws of physical phenomena. And at this stage they do in fact generalize primarily negative experience, that is, data showing that certain processes or phenomena cannot occur. For this reason, inhibition principles are often called exclusion principles.

Let us consider some of the principles of physics that play an important role in the cognition of the micro-world.

Quantum mechanics, which reflects the qualitative peculiarities of the objects and processes in the micro-world, has shown that Laplacean determinism, with its unconditional requirement of determinacy, is inapplicable to the micro-world. However, we are not in this instance speaking of outright, metaphysical rejection of the principle of determinacy. Thanks to quantum mechanics, it has become clear that phenomena in nature are governed by a causality that rests on a balance of determinacy and indeterminacy in processes of the interaction and transformation of actual phenomena; they are governed, that is, by dialectical causality.

Physics came up against objective indeterminacy in the processes transpiring in the micro-world with the Bohr atomic model, above all in the postulate of the correlation between the energy levels of an electron in the atom and the frequency of the emission or absorption of electromagnetic waves: $\frac{E_2 - E_1}{h} = \nu$, where E_2 and E_1 are energy levels, h is the Planck constant, and ν is the frequency of emission or absorption of light.

As we see from this ratio, an electron's emission frequency depends not only on the level from which it is moving, but also on the level to which it is moving. However, one cannot say beforehand to what new level it will move. This is indeterminacy. We have to do here not with the certainty of the passage of an electron precisely to a given level, but with a certain probability of this transfer. Obviously, indeterminacy is expressed here through potential and probability. One must note that where there are a multitude of possibilities, where they emerge and disappear, there is objective indeterminacy.

The transition from rigid determinism to indeterminacy led many scientists to an impasse, above all those scientists who were, methodologically, unprepared for this transition. They saw in the "strange" behavior of the electron no more and no less than that it allegedly has "free will", that is, "freedom of choice".

This, it would have seemed, is where philosophers should have come to the aid of naturalists and dispelled their delusions. But who could do this? The old natural philosophers? They were themselves imprisoned by limited Laplacean determinism. Idealist philosophers? For them, the "strange" behavior of the electron could not have been more apropos: they seized upon it to reinforce their position, which had been undermined by the advances of natural science.

Only those philosophers could be of assistance who occupied the ground of materialist dialectics, from which it was clear that the "strange" behavior of the electron speaks not of the electron's "free will" but of a new quality of the principle of causality as applied to the micro-world, of the fact that in the micro-world laws have the character of probability. Indeterminacy is an objective property of processes and phenomena occurring in the micro-world.

The presence of objective indeterminacy in the phenomena of the micro-world is profoundly and immediately expressed in the Heisenberg uncertainty principle, introduced by him simultaneously with providing a mathematical interpretation of the phenomena of the micro-world. This principle reflects the objective indeterminacy of the spacio-temporal and impulse-energy states of micro-particles in their dependence upon each other. To put it another way, the determinacy of one state engenders the indeterminacy of other states. A special case of this dependency is the fact that a determinacy of the spacio-temporal state of a micro-particle, such as the presence of micro-particle trajectories, is possible only given indeterminacy of their impulse-energy states.

The Heisenberg uncertainty principle shows that the determinacy and indeterminacy of phenomena of the micro-world cannot be treated in isolation, but only in their interconnections and in their interconversions.

In physics, especially in quantum mechanics, we speak mainly of indeterminacy, of the uncertainty principle, and this means that we pay insufficient attention to the objective link between determinacy and indeterminacy and the reflection of this link in scientific theories.

In his many-sided activity, man often comes up against determinacy and indeterminacy, against processes in which they undergo interconversion. Each of us, in our intercourse with others, tries to eliminate the uncertainty of a situation, for instance by asking questions and analyzing the answers received. After all, before getting an answer several answers are possible (i.e., there is uncertainty), while the answer given eliminates the existing uncertainty. Let us assume that we are attending the finals of a tennis match and that we are rooting for one of the finalists.

He has two possibilities, winning or losing. Before the match is over, there is objective uncertainty and only the victory of one of the players turns this uncertainty into certainty. However, along with certainty his victory engenders new uncertainty, for one cannot predict absolutely identical results for his future matches.

In the cognitive process, man also tries to eliminate existing uncertainties, to reduce the number of suppositions, guesses and hypotheses and thereby increase the proportion of certain, reliable knowledge.

Looking back over the path of man's cognition of reality, we may note that philosophers have taken an interest in the problem of determinacy and indeterminacy for millennia. We have not the opportunity to take an excursion through the millennia, so we shall confine ourselves to the 19th and 20th centuries.

At a time when the metaphysical approach to the phenomena of reality still reigned in natural science, when attention was focused primarily upon determinacy, the great dialecticians—the idealist Hegel, the materialists Marx, Engels and Lenin—were already using such paired categories as determinacy and indeterminacy in their philosophical studies. In a certain sense, they ran ahead of the development of natural science and other disciplines and prepared the cognitive apparatus for them.

The development in the 20th century of the physics of the micro-world, the emergence of cybernetics, control theory and other sciences prompted increased scientific attention toward these concepts. It was established, for example, that in the realm of micro-phenomena there is no sharp boundary between elementary particles and the medium in which they exist, that the concepts "interior" and "exterior" in this case lose their determinacy and become relative. With respect to elementary particles, one may speak of

the identity of interior and exterior, that is, one may view these particles as a field, and a field—as an open system of strongly connected particles. The result is the indeterminacy of such parameters of elementary particles as energy and mass, an indeterminacy that finds expression in particular in the uncertainty relation for energy and time. Therefore, the law of the conservation of energy-mass must be applied to elementary particles, for which substantial role is played by wave properties, not on the basis of the notion of an isolated system, but on an understanding of the limitations of this notion.

Uncertainty with respect to the value of the energy of micro-objects cannot be treated positively on the basis of the concept of an isolated system. In physics, a system is considered isolated if it does not interact with other systems and if the value of its total energy does not depend on time.

The limitation of the concept of the isolated system for the description of the total energy of objects in the micro-world has been noted by many of the world's leading physicists, who quite justifiably hold that micro-objects simply do not exist in isolation from their medium. The indeterminacy of the energy of elementary particles in short intervals of time is to be explained by the profound unity of the interior and exterior in their existence; it is the result of their inseparability from the medium in which they exist. The shortcomings of the concept of the isolated system stood out especially in quantum electrodynamics, which showed that the object of study in the micro-world must be the totality of particles and their fields considered as an aggregate.

The uncertainty relation for energy and time $\Delta E \Delta t \approx \hbar$ contains the interconnection and dependence of micro-particles and the aggregate of electron-positron-electromagnetic fields. Heisenberg and his associates demonstrated that the Coulomb field of the nucleus itself also acts on the vacuum, which leads to its polarization: in a manner of speaking, it pushes aside electron-positron pairs. This in turn leads to the fact that the diminishing of the Coulomb field of the nucleus is not strictly proportional to the inverse of the square of the distance. This non-linear interconnection of fields and particles leads to statisticity in time and indeterminacy in the value of the energy of micro-objects.

The uncertainty relation for energy and time, then, expressing the profound unity of interiority and exteriority in the existence of micro-objects, deepens and expands our notions of energy, discloses new qualitative peculiarities of this characteristic of the motion of matter for open, non-isolated systems.

It is completely obvious that in objective reality itself there are no systems isolated from, say, the gravitational field, or in any way absolutely isolated from other systems. There is only relative, not absolute, isolation, when we can, in dealing with certain questions, abstract a given system from the action of other systems.

Classical physics, as well as the non-relativity physics of the micro-world, developed on the basis of the notion of absolutely isolated systems, which appreciably simplified the solution of a number of tasks but disregarded the real connection between determinacy and indeterminacy, between isolated and non-isolated, closed and open systems. An open, non-isolated system is always richer in properties, but at the same time it may function with respect to specific systems and interactions as an isolated, closed system.

Drawing on what we have said above, we may characterize indeterminacy as one of the forms of the objective existence of the phenomena of the world, utilizing the following hallmarks: first, distinct

boundaries between the properties and states of phenomena, for instance between protons and neutrons in the atomic nuclei are lacking; second, the dependence of properties, states and phenomena upon each other predominates over their relative independence; third, necessity does not take the guise of inevitability, but of possibility and contingency.

Determinacy is a form of the objective existence of the phenomena of the world with the following hallmarks: first, there are sharply defined boundaries between the states of the phenomena of nature—a clear difference, for instance, between protons and neutrons in electromagnetic interactions and in their free states; second, properties, states of phenomena are relatively independent of each other—for example, mass is relatively independent of velocity when the value of the latter is small as compared to the speed of light in a vacuum; third, necessity is expressed through the inevitability, the invariance of the transition of possibility into actuality, and through the existence of impossibility of certain states. We should note here that the existence of objective independence for certain states, transitions and transformations is one of the principal tokens of the determinacy of the phenomena of nature. There is a profound connection and interdependency between indeterminacy and determinacy, and this is reflected ever more fully in the principles and laws of modern science, the physics of the micro-world included.

The objective content of quantum mechanics, the reflection in it of the dialectical character of the processes of the micro-world through the use of quantum mechanical principles and laws, refutes all idealist assertions as to the subjectivity of quantum mechanics, the dependence of micro-processes on the observer, the ultimate unknowability of micro-processes. These and similar idealist notions obstruct the cognition of the unknown, but they cannot halt the development of science.

The dialectically understood and materialistically treated relationship between determinacy and indeterminacy plays a major role in the cognition of the micro-world, though many physicists merely grope their way, not knowing of or ignoring the achievements of the dialectical materialist theory of cognition.

The category of interaction and the principle of superposition play an important role in the physics of the micro-world.

Even the laws and principles of physics now known disclose the unusual richness of the philosophical category of interaction. In its turn, the category of interaction (along with other categories and laws of dialectics) equips scientists for a deeper cognition of the essence of physical processes.

The Soviet *Philosophical Encyclopaedia* provides the following definition of the category of interaction, a definition with which we may basically agree: "Interaction is a universal form of the connection of bodies or phenomena, a connection realized in their mutual change."[1]

Interaction is just as inexhaustible as moving matter. Therefore, we have always faced and will continue to face the problem of expanding and deepening our understanding of the interaction of material objects and phenomena. In analyzing the categories of interaction, we must proceed from the fact that interaction has a number of intrinsic aspects, of which we will touch on only some that are exterior and interior. The exterior aspect of interaction is above all the "interconnection of the individual motions of separate bodies".[2]

[1] **Philosophical Encyclopaedia**, Vol. I, Moscow, 1960, p. 250 (in Russian).

[2] Frederick Engels, **Dialectics of Nature**, p. 230.

And these individual motions and individual bodies correlate with each other as immediately given, already existing phenomena. Interconvertibility and the interior interdependency of phenomena are not manifested directly in the exterior aspect. They are shielded by their relative autonomy, their relatively "individual" existence. The causes of phenomena here function as external actions and forces independent of each other.

Engels provided a pithy characterization of the interior aspects of interaction: "*Reciprocal action* is the first thing that we encounter when we consider matter in motion as a whole from the standpoint of modern natural science. We see a series of forms of motion, mechanical motion, heat, light, electricity, magnetism, chemical union and decomposition, transitions of states of aggregation, organic life, all of which, if *at present* we *still* make an exception of organic life, pass into one another, mutually determine one another, are in one place cause and in another effect, the sum total of the motion in all its changing forms remaining the same."[1]

Mutual transformation and transition, mutual dependence and mutual connection occupy the foreground in the interior aspects of interaction. Causal connections are here more profound; they involve both the dependence of causes upon each other and the reciprocal action of effects upon causes. It is obvious that the exterior aspects of interaction are limited manifestations of its interior aspects. Taken in the totality of its exterior and interior aspects, interaction is characterized by the following features:

a) interaction is the correlation of simultaneously existing, relatively separate motions and bodies;

b) interaction consists of both mutual

[1] **Ibid.**, p. 231.

transformation and the interior dependence of the phenomena of the world;

c) interaction also includes different types of connections between phenomena, including the various forms of causal dependencies. Interaction is the generalized expression of varied relations, connections and transformations of the phenomena of the world.

How is the interaction of physical phenomena expressed in the principle of superposition? The principle of superposition expresses some of the exterior aspects of interaction, to be precise, the correlation and exterior connection between simultaneously existing relationships of individual motions and bodies.

It also involves certain forms of causal dependency that are marked by the following: a) causes are independent of each other; b) the reciprocal influence of effects on causes is insignificant. One may therefore say that superposition is interaction without transformation, without interior dependency and reciprocal connection. The principle of superposition has a specific, objective content: it expresses the exterior aspects of interaction and some features of causal dependency, but it is only a first approximation of the total content of interaction, a somewhat simplified picture of the interaction of the phenomena of the world.

The principle of superposition presumes the relative autonomy and independence of the interacting phenomena. This permits us to disregard the mutual conditionality of causes and the reciprocal influence of effects on their causes, that is, it makes it possible to eliminate the reciprocal connection. On the strength of this, interaction can be considered the addition of individual motions and their characteristics, their parameters: the whole is the sum of the parts, and

interaction is the process of summation.[1] In those aspects of interaction that express the principle of superposition, two moments stand out graphically: the relative independence, the isolation of the elements of interaction, and their combination, addition, superimposition upon each other. Both of these moments presume mutual existence, they cannot exist one without the other.

With respect to the methods of scientific cognition and thinking, the principle of superposition is one of the forms of the application of the analytic method in physics. The analytic method involves not only the fragmentation of a whole into parts and the disclosure of the links between these parts, but also the establishment of the order and succession of these links. The properties of the whole are determined in analysis through the addition, the superimposing of its parts. When the connections between the parts of the whole have been established and the principle on which these connections are constructed found, it is possible to deduce from this principle the various properties of the whole, taken as a sum, as a resultant of the superimposition of its parts.

All these features of the analytic method are expressed in the principle of superposition. The objective bases of the analytic method and of the principle of superposition lie to an equal extent in the features of the exterior manifestations of the interaction of the phenomena of the world.[2] The

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[1] This notion of interaction is without question linked with the notion of atoms as indivisible, unchanging particles existing in isolation from each other, the combinations of which upon decay produce the very same atoms.

[2] In general, the methods of cognition one way or another have as their base aspects of the interaction and development of the phenomena of the world. The regularities, both general and specific, of the phenomena of the world are always generalized in the methods

principle of superposition is therefore a concrete form of the application of the analytic method in physics. Thus, the limitations of the principle of superposition are inseparable from the limitations inherent in the analytic method of cognizing the world.

Since the principle of superposition provides a first, approximate picture of interaction, it can be applied, as a first approximation, to the study of all types of the physical interaction of the phenomena of the world.

One of the methodological presuppositions of Bohr's theory of the structure of the atom is that atoms are independent of each other—i.e., one of the moments of the principle of superposition.

In quantum mechanics, the principle of superposition is applied in conjunction with the principle of the indivisibility (discontinuity) of quantum processes. Since quantum objects possess corpuscular and wave properties, quantum superposition reflects (through the superimposition of continuous and discontinuous changes) this feature of exterior interactions in the micro-world.

Philosophical study of the interaction of physical phenomena has become especially urgent in connection with the continued discovery of new types of physical interaction and the need to criticize attempts to interpret them from the standpoint of contemporary positivism and agnosticism. One frequently comes across, for instance, assertions that it is impossible in principle to examine the interaction of particles in the micro-world.

Of course, we meet in the micro-world new types of interaction that we cannot approach with our accustomed yardsticks, based on the regularities of the macro-world. Good examples are the Pauli principle

of cognition. The methods of cognition form the processes of the development of cognition and are specific generalizations of cognition.

and the principle of the identity of equivalent micro-particles.

In 1922, Niels Bohr delivered a series of lectures on the theoretical analysis of Mendeleyev's periodic law of chemical elements. In these lectures he posited that there may be a general rule of the filling of any of the atom's electron envelopes. The answer to this question was the Pauli principle. The immediate basis for the initial formulation of this principle was experimental study of the splitting of the spectral lines of light emitted by atoms (of alkaline metals, in particular) in strong magnetic fields. Pauli advanced the hypothesis that it was necessary to introduce a special quantum number to describe the state of electrons in order to explain existing experimental data.

As Pauli saw it, this number describes a special interior property of electrons, a property he termed "duality". Soon, the physicists Uhlenbeck and Goudsmit postulated that electrons have an internal property analogous to their angular momentum. This property they called spin.

We should note that Pauli objected to attempts to picture this property of the electron as completely analogous to the classical concept of angular momentum. He emphasized strongly that this property of electrons is of a specific, quantum mechanical nature. The development of physics has shown that Pauli was right. Subsequent experiments confirmed the existence of spin not only for electrons, but for all the elementary particles. We wish to emphasize that spin is of fundamental importance in all existing formulations of the Pauli principle.

Pauli maintained that electrons in any system, intra-atomic electrons in particular, cannot have identical states of motion, that is, have four identical quantum numbers. We should recall that these four quantum numbers describe a particle's energy, orbital momentum, orbital magnetic moment and spin. Only one particle can be in a state with a given four quantum numbers.

Here the notion of the spin of particles—of electrons in particular—was advanced to the fore, which of course linked the process of the filling of an envelope with electrons to the interaction of the spins of electrons.

In light of the Pauli principle, it became clear that Mendeleyev's periodic law expresses the lamellar structure of the electron envelopes of atoms and that at the basis of the periodicity of the chemical and optical properties of atoms lies the periodicity of the configuration of the outer electrons. But the Pauli principle itself grew out of Mendeleyev's periodic law.

Obviously, deeper understanding of the Pauli principle and of the spin interactions that it expresses is connected with understanding the essence of spin. To picture the spin of micro-particles as a complete likeness of classical angular momentum is, of course, incorrect. There are weighty reasons militating against this notion.

First, the spin of micro-particles is a specific, quantum mechanical value that on boundary transition to classical mechanics is equal to zero.

Second, the notion that spin is classical angular momentum, the result of the rotation of the particle around its axis, contradicts the theory of relativity, and it has been demonstrated beyond doubt that the theory of relativity must be applied to the motion of micro-particles.

Third, spin is a state of particles in which the unity of corpuscular and wave properties of micro-particles is graphically evident, which again speaks of its specifically quantum mechanical nature.

But considering spin further, we must also keep in mind that new concepts never emerge from a vacuum—they always emerge from older concepts. In

fact, new concepts emerge from old, schematically speaking, along a spiral line (negation of the negation). Therefore, certain analogies between the concept of spin and the concept of mechanical angular momentum, and notions of the vortex-like interior state of particles (Descartes, Kelvin, Helmholtz) are permissible.

It seems to us that what is most important here is not to characterize the concept of spin on the basis of the notion of rotation of spheres on their axis, but to use some of the connections that mechanical angular momentum has with other parameters of motion—with energy, impulse, and so on. The connection between angular momentum and energy, and between the law of the conservation of angular momentum and the law of the conservation and transformation of energy, is of special importance. This connection is also known in classical mechanics. In the theory of spin and spin interactions, it stands out clearly in the form of the dependency of the energy of micro-particles on their spin. It is possible that the development of the notion of micro-particles as dynamic systems will make it possible to interpret spin on the basis of a certain analogy between their interior motion and unique vortexes. At present, we may say of spin that it is a specific value describing the interior properties and states of micro-particles and having a profound connection with the energies of their motion and interaction. We should add that the spin of particles is internally connected with their magnetic moments.

Spin can, as we know, assume a number of discrete values, fractions for some particles (1/2, 3/2,...), whole numbers for others (0, 1,...). There are particles in nature with both integral and half-integral spin.

The interaction of particles with integral and half-integral spin has some unique features.

The Pauli principle expresses the interaction of particles with half-integral spin.

What are the features of these interactions?

The interactions of particles with half-integral spin have the feature that in these interactions there is a process of the exclusion of some possible states, a certain impermeability of some states for others. We are referring here not to the impermeability to bodies, but to the impermeability of states, to dynamic impermeability, if we can put it this way.

In elucidating the meaning of this principle, analysis of the concept "equivalent particles" is of major importance. What particles can be called equivalent? The preliminary answer to this question is quite simple and tautological: equivalent particles are those that have equivalent properties! For instance, all electrons are equivalent particles since they all have equivalent magnitude and charge sign, equivalent rest mass and equivalent spin value. But at the same time electrons also possess differing properties: they may vary in mass, and hence in energy, may have different spin orientations, possess different wave characteristics, e.g., different wavelengths, and so on.

Identity of some properties does not exclude differing properties for particles. Equivalent particles are, then, simultaneously, differing particles. But even when treating the equivalent properties of, say, electrons, the situation is quite complicated. The value and sign of the charge are identical for all electrons. But anti-protons, negative π-and μ-mesons and many other particles have the same charge value and sign. In short, the concept of the identity of particles is a relative concept. It cannot be defined as the sum of particular particle properties. In quantum mechanics, this concept has a dynamic sense, according to which particles become equivalent when they can replace each other without any physical changes in the system

in which the exchange occurs. A special case of the exchange of some particles for others is their spacial transposition. In other words, the identity of particles involves a situation in which any particle of a given type (an electron, for instance) can assume precisely the same state as the particle that it has replaced. Total identity of particles occurs in the process of their interaction, in the process of the emergence of specific systems of particles (atoms, crystal lattices, etc.). The identity of particles is based on the passage of the different into the identical. There are no identical particles in general, they become identical in a concrete physical system.

Thus, the identity of particles is the expression of one of the conditions of the dynamic stability of specific systems. Let us take a closer look at the proposition we have just formulated. Atoms interacting with other objects continually lose some electrons and acquire others, remaining stable dynamic systems. The conservation of the stability of atoms under what is in effect continual electron exchange in its envelope is possible only because electrons exchange for each other identically, acquiring the same states. Thus, the stability of the electron envelope emerges in the process of electron exchange.

Having characterized the concept of the "identicity of particles", we may now formulate more precisely the principle of the identity of equivalent particles. We should note at the outset that the identity of, let us say, two objects never means the absence of differences between them. What is identical is at the same time different. Objects are identical only in specific relationships. Therefore, the concept of identity must be flexible, otherwise it will not reflect reality. As applied to the question of the identity of particles, what has just been said leads to the conclusion that one and the same particles are in one connection identical, in another different. Protons and neutrons are different, non-equivalent particles, and this is so in many relationships. The same protons and neutrons, however, taken in their relationships to intra-nuclear forces, become identical particles (charge independence).

The quantum-mechanical principle of the identity of equivalent particles is in essence a form of the manifestation of the dialectical unity of identity and difference. It reflects the objective connection between the identical and differing states of micro-particles. This principle is thus of great methodological import. Therefore, it plays a methodological role in the cognition of the properties and interactions of micro-particles. Examining it at the level of our cognition, this principle acquires another expression, obtains another formulation—to be precise, as the principle of the indistinguishability of equivalent particles. The latter means that it makes absolutely no sense to attempt to establish, say, precisely which position in a given physical system an electron occupies: after all, the substitution of other electrons in the given position in the system does not change the state of the system in any way. In its objective content, the principle of the indistinguishability of equivalent particles coincides fully with the characterization of the concept of equivalent particles already given. In accordance with the objective features of micro-particles, indistinguishability spares cognition questions that have no objective meaning.

The principle of indistinguishability is thus only another form of the expression of the principle of the identity of particles—it is its gnoseological aspect.[1]

[1] One may also say the reverse: the principle of identity is the ontological aspect of the principle of indistinguishability.

The connection between the Pauli principle and the principle of the identity of equivalent particles consists above all in the fact that the Pauli principle is applicable only to interactions of equivalent particles with half-integral spin. As already mentioned, however, equivalent particles have the ability to substitute for each other, that is, to exchange their states, so that the overall state of the system in which they are located does not change.

Particles with half-integral spin may, if they are equivalent, replace each other, they may be identical, but they cannot occupy one and the same state in a single system. In a single system they can only occupy different states. The identity of particles with half-integral spin is, therefore, inseparable from their necessary difference in one system. The Pauli principle expresses this connection between identical and different states of particles.

The complexity of the specific forms of interaction of micro-particles when they possess spin, identity and specific classes of symmetry has led some leading Western scientists to rather "strange" interpretations of the interactions of micro-particles, especially of those interactions connected with the Pauli principle.

Pauli noted that in order to give a graphic picture of the features of, for instance, the interactions of electrons in an atom, some physicists began to speak of "pacts" concluded between electrons; or they said that electrons behave as though they "know" each other's states. True, the great majority of physicists speak of "pacts" and "knowing each other" metaphorically, without attributing real meaning to the words.[1] However, taken literally the metaphor is sometimes advanced as an argument in favor of an indeterministic

[1] W. Pauli, "Die allgemeinen Prinzipien der Wellenmechanik", **Handbuch der Physik**, Zweite Auflage, Bd. XXIV, Erster Teil, Berlin, 1933, S. 193.

interpretation of the regularities of quantum mechanics.

Many leading Soviet physicists opposed idealistic, positivistic interpretations of quantum mechanics even as it was first taking shape. Stressing the paradoxality of the principles of new theory from the point of view of classical physics, they showed that these principles reflect the specific features of the micro-world.

From the Pauli principle, from its connection with the concept of particle spin, with the principle of identity, with classes of the symmetry of the state of a system of micro-particles and with the Heisenberg uncertainty principle, it is possible to establish the interactions on which this principle is based and which it expresses. First, these interactions are quantum-mechanical and cannot be reduced to the classical forces of interaction.

Second, it is the interior parameters (e.g., spin) of the interacting particles, rather than the exterior ones (e. g., distance), that are crucial in these interactions. Such exterior parameters as distance and impulse are among the necessary conditions for the occurrence of these interactions, but they do not determine their essence.

Third, the special forces (spin, exchange, etc.) generated in these interactions cannot be reduced to the forces of classical mechanics. These forces do not produce acceleration and are not governed by Newton's third law.

Fourth, a special type of dynamic impermeability of micro-particle states is created in these interactions; and this leads to the rule of the exclusion of identical states of micro-particles with half-integral spin in any aggregate of micro-particles.

Fifth, interactions of this sort occur under conditions in which the uncertainty principle operates and therefore involve virtual processes.

We should like to consider the question of virtual processes and particles, a question of great importance for physics and philosophy.

The concept of virtual processes holds a major place in the physics of the micro-world. It is used in the quantum theory of radiation in describing the structure of elementary particles and their interactions, and it is used in the theory of the vacuum states of physical fields and in other areas.

The uniqueness of virtual processes gives rise to a number of intricate philosophical questions. Do virtual processes and particles occur in nature or are they only concepts, "mathematical images", mental schemes of as yet inadequately studied phenomena of the micro-world? If virtual particles and processes occur in nature, what are the peculiarities of their objective existence? We shall attempt to answer these questions. We should note immediately that virtual particles and processes are often opposed to real particles and processes, with the non-objectivity of the former underscored. However, relying on factual analysis and proceeding from general methodological principles, we hold that virtual particles and processes have an objective existence in nature, i.e., they are real.

Many physicists and some philosophers hold that virtual particles and processes do not occur in nature and that the concepts of these particles and processes are of but ancillary significance in the description of some properties and processes of the interaction of elementary particles. From this point of view, concepts of virtual particles and processes do not have an objective analogue in nature. But there is a contrary point of view, which recognizes the occurrence of virtual particle and processes in nature and, hence, of an objective analogue to our concepts of these particles and processes. Which of these opposing points of view is correct? We must first answer a more general question; what criterion can be employed to differentiate precisely between occurrence in thought alone and occurrence in objective reality? Obviously, what exists in thought does not necessarily occur in objective reality as well. Therefore, we cannot conclude from the existence of the concepts of virtual particles and processes in our thinking that the objects making up the content of these concepts occur in actuality. It does not at all follow from the fact that there is in mechanics, in its mathematical apparatus, a concept of the reversibility of time that in nature, too, time may flow from future to past. We note here that postulating an objective analogue for every concept, i.e., in the final analysis the equating of occurrence in thought with occurrence in reality, is proper both to objective idealism and to metaphysical materialism (though the two schools attain this end from different points of departure and by different means).

Denial of the objective analogue of some concepts does not at all contradict dialectical materialism's theory of cognition. There may be, indeed should be, in science concepts that, having no analogue in objective reality, participate through other concepts in the general process of reflecting reality in our cognition. These include, for example, the concept of imaginary numbers, negative energy, n-dimensional spaces, and so on. It follows that the fact of denying that the concept of virtual particles and processes has an objective analogue does not necessarily mean retreating from a materialist view of the world.

It is worth noting that some concepts that have no objective analogue at a given stage of cognition subsequently acquire objective content, content that is often quite unanticipated. Thus occurred, for example, with the concept of negative absolute temperature. This concept was for a long time considered only a formal result of the formula for the Boltzmann energy

distribution of particles, a result irrelevant to nature. But it was later shown that this concept can be used to describe objective temperature states in some spin systems. Thus, the point of view rejecting the existence of an objective analogue for the concepts of virtual particles and processes should be judged primarily in its argumentation and within the framework of a specific stage of knowledge. Might it be, in fact, that these concepts do not, at the present stage of the development of physics, have objective content? Before examining the basic arguments put forward by the proponents of this point of view, we should dwell briefly on the essence of the criterion that permits us to distinguish between occurrence in thought alone and occurrence in objective reality.

As was shown in the works of the founders of Marxist-Leninist philosophy, the decisive criterion for distinguishing occurrence in thought alone from occurrence in objective reality is men's sensible and practical activity taken together, not passive sense perception alone.

Sensible contemplation does not always distinguish the real from the imaginary; illusory notions often take the place of the real. In the process of practical activity, however, our sense perceptions acquire strict certainty, for here they are determined only by objectively occurring phenomena and refer only to the latter. We can, for example, picture in our minds a bridge over a river, but we cannot cross this imagined bridge. Crossing a real bridge, we in practice sensibly apprehend an objectively existing object. Our sense organs can and do give us a correct reflection of objective reality, but only on the basis of our sensible-practical activity. Our practical activity indicates that an object that exists objectively cannot be changed in the process of passively apprehending or thinking about it. It can be changed only by practical action, i.e., with the help of other objective things and processes. Practice also shows that what exists only in thought cannot be an implement for acting upon things that exist objectively. In the process of practical activity, we change and replicate objectively existing phenomena, using for this purpose other objectively existing phenomena, and thereby demonstrate the objective existence of both the former and the latter.

As inferences from our practical activity, the following features of the objective existence of phenomena come to the fore. First, what exists objectively can be used to satisfy our real (as opposed to imaginary) requirements. Second, an objectively occurring phenomenon can be altered only by being acted upon by other objectively existing phenomena. Third, an objectively occurring phenomenon can be an implement for acting upon other objectively occurring phenomena. Fourth, objectively occurring phenomena cannot be created in processes of apprehension and thought alone. Fifth, objectively occurring phenomena are a source for sense perceptions, both direct and indirect.[1]

Detecting these features in the occurrence of a phenomenon is demonstration of its objective existence.

Given this, we can now examine the principal argument advanced by those who deny the objective occurrence of virtual particles and processes. These particles and processes, say the proponents of the point of view in question, cannot in principle be observed, and that which is in principle unobservable does not possess objective existence. It is in principle impossible to observe virtual particles because they can exist for only extremely short intervals of time, on the order of

[1] In light of these features of objectively occurring phenomena, it is obvious that all objects created in our practical activity possess objective existence.

10^{-24} seconds. To observe a virtual particle (or an actual particle emitting a virtual particle), it is necessary to impart so much supplementary energy that only an actual particle can be detected (with this supplementary energy an actual particle will emit only an actual particle, while a virtual particle, having absorbed this supplementary energy, will become an actual particle). To put it briefly, this means that any apparatus can be used only to detect an actual particle.

The following should be said of this argument. First, there is nothing in the world that is unobservable in principle. Everything that objectively exists can directly or indirectly be an object of observation. The non-observability of objects is for our cognition a temporal phenomenon. In some relations and in some processes an object may be unobservable, in other relations and in other processes it is observable. For instance, in chemical processes conversions of atomic nuclei are unobservable while in nuclear reactions they are observable. When an experiment is made with the use of processes leading to the transformation of virtual radiation into real radiation and virtual particles into ordinary, real particles, there is nothing surprising in the fact that the experiment detects only actual particles. But there can be (and are) experiments in which the action of virtual particles and processes on ordinary particles and processes is detected.

For instance, experiments for measuring the Lamb shift of electron energy levels in hydrogen atoms detect the interaction of electrons and virtual quants of the electromagnetic and electron-positron vacuums. This is, in fact, observation of the action of virtual particles on ordinary particles, which means that virtual particles themselves are observed. With the recent major advances in obtaining beams of particles (electrons, in particular) accelerated to extremely high energies, there have appeared new opportunities for the experimental study of virtual particles. Experiments, for instance, on the scattering of high-energy electrons by nucleons allow us at present to study the details of nucleon structure down to $7 \cdot 10^{-16}$ cm, which detects the existence of a virtual pion envelope around the nucleon radical. This envelope determines many features of the angular and energy dependence of effective cross-sections of elastic and non-elastic electron scatter by nucleons. These experiments, which show the processes of electron scatter by virtual particles, thereby demonstrate the objective occurrence of virtual particles.

Existing experimental data indicate that virtual particles act on ordinary particles, determine some of their properties (e.g., the magnetic moments of neutrons), can pass into ordinary particles, can cause perturbed states of ordinary particles, and so on. Virtual particles, then, experience the action of other objects and are themselves a means for acting on other objects. And though current experimental data are as yet far from sufficient for a precise description of virtual particles and processes, they do permit a positive answer to the question of the objective occurrence of these particles. Virtual particles can no longer be considered merely imaginary or hypothetical since their objective occurrence has been experimentally confirmed.

That the concepts of virtual particles and processes emerged not from experimental data but as a logical inference from the theory of quantum radiation is another matter entirely. Many concepts in science arise in this way. Only later do they acquire an objective content, i.e., turn out to be reflections of objective processes and phenomena. One may say that virtual particles, processes and states, originally introduced as a mathematical devise, were "fleshed out" with the development of the physics of elementary particles.

The objective existence of the phenomena of the world can have differing forms and states. Many categories of Marxist dialectics express not only key moments in the process of the interconnection and development of the phenomena of the world, but also the peculiarities of the forms of their objective existence. Among such categories are those of becoming, possibility and actuality. The category of becoming, as an expression of the unity of conception and annihilation as a moment of development, at the same time characterizes a special type or form of objective existence—process, transition. The category of possibility, describing one of the principal moments of development—preconditions for the emergence of the new from the old—at the same time describes a special form of objective existence—existence in potential. The category of actuality, expressing already emerged stages of a process, describes objective existence that has already come to culmination, that has taken shape, objective existence in which new processes of becoming occur and new possibilities emerge. There is a profound internal connection between the moments of development described by the above categories. There is a similar connection between the forms of the objective existence of the phenomena of the world. Existence in becoming, in process, in possibility and in actuality are internally connected. There are, too, various transitional states in-between these forms of objective existence. The peculiarities of the objective existence of virtual particles can, in our view, be expressed with the aid of the categories of becoming, possibility and actuality and their internal connection.

What is noted first in describing virtual particles and processes is their brief existence: they come into being and disappear in an interval of 10^{-24} sec. One may say of virtual particles that their objective being is characterized by a unity of conception and annihilation. In other words, their existence is a transition from conception to annihilation and back again. In the existence of virtual particles there is no sharp boundary between conception and annihilation. Here conception and annihilation merge, as it were.

In quantum physics, there is a number of such "median states", in particular states midway between possibility and actuality, between contingency and necessity. Analyzing the concept of probability, Heisenberg concluded that the concept lends a strange aspect to physical reality, which is located approximately midway between possibility and actuality. In our view, one may speak of the existence of virtual particles not only as a midpoint between conception and annihilation, but also as a midpoint between possibility and actuality. This means, in other words, that the peculiarities of virtual particles must be described on the basis of the unity of becoming, possibility and actuality.

A first conclusion from this methodological proposition is the assertion that virtual particles cannot be examined independently of ordinary particles, that in a number of characteristics virtual and ordinary particles cannot be differentiated. In fact, when virtual particles are mentioned one is never speaking of a special type of particle, but of special states of ordinary elementary particles. Science does not know virtual particles that are not virtual states of photons, electrons, pions, protons and other known elementary particles. Consequently, the cognition of virtual and ordinary particles is a single process. As possibility is known through actuality, so are virtual particles known through the interactions and transformations of ordinary particles.

In describing virtual particles, it is of fundamental

importance to take into account the fact that all elementary particles exist in interactions and mutual transitions, functioning as dynamic systems with multiple interior transformations.

The idea that elementary particles must be viewed as processes has been advanced by many physicists (Gell-Mann, Rosenbaum, and others). For instance, theory has explained the behavior of the electron in electromagnetic fields on the basis of the notion that every electron continually emits and absorbs photons. These pulsations, one may say, are the "vital processes" of the electron. Considering elementary particles as processes, we can isolate different stages and states in them. One such stage or state is the birth in one particle of some other particle. The particle being born exists for the time being only as possibility, and if the necessary conditions for the transition of this possibility into actuality are not present, then the particle is called virtual. It follows that virtual particles exist only as stages in the processes of the interaction and interconversion of elementary particles. Virtual photons exist only in the process of electromagnetic interactions, virtual pions only in strong interactions, and so on.

The existence of virtual particles is not autonomous; this is existence in another and through another. Corresponding to this feature of the existence of virtual particles are such traits as their brief life and rigid spacial localization. As potential for the conception of some particles from others, as potential not passing into actuality, virtual particles do not have a sharp boundary between conception and annihilation, they exist only in the interval of time in which they come into being and disappear. The value of this interval depends on the value of the energy necessary for the transition of a virtual particle into an ordinary one. The greater the value of the energy required, the briefer the existence of the virtual particle. Corresponding to the period of its existence is its spacial localization. A virtual particle cannot leave the spacial limits of the interaction, the moment of which it is. For example, virtual pions exist only within the spacial area of strong interaction. The radius of action of strong interaction (10^{-13} cm) determines the spacial region of the existence of virtual pions. Virtual photons, as moments of electromagnetic interaction, cannot pass beyond the limits of this interaction, though these limits can be quite broad.

We should note one further characteristic of the occurrence of virtual particles. Virtual particles can be considered quants of the interaction and interconnection of elementary particles inseparable from the latter. We shall return to this feature below. For the time being, we should note the very important difference between virtual and ordinary "elementary" particles. The former, as already noted, cannot exist independently, exterior to their sources, exterior to specific interactions and transformations. The existence of elementary particles, on the other hand, is based in themselves, and they may pass beyond the limits of the particle interaction in which they emerge. Such elementary particles are, therefore, often called free particles.

Considering the existence of virtual particles as existence only in specific states of the interaction and interconversion of elementary particles, we should take special note of the intermediate nature of these states. We know that protons and neutrons in atomic nuclei are continually transformed into each other. There are in these transformations states in which the neutron has not yet become a proton or the proton a neutron. Here they exist in a dissociated mode: the neutron as a neutron and virtual negative π-meson, the proton as a proton and a virtual positive π-meson.

The virtual π-mesons generated in these states by the neutron and proton, respectively, are inseparable from the nucleons and do not exist without them. The state of the proton and virtual π-meson, for example, cannot be pictured on analogy with a proton-electron system, i.e., on analogy with a hydrogen atom. The fact is that the electron is at all times located in space around the proton and the probability of its location in this space is at any moment of time equal to unity; while the virtual meson is for some part of the time located within the proton, and the probability of its location around the proton is at any moment of time less than unity.

The intermediate states of protons and neutrons when they are in a dissociated mode are integral states to which alone their energy characteristics refer. Virtual π-mesons and the nucleons without which they cannot exist have a common mass and energy. The emergence of virtual pions in intermediate states of the nucleons can be viewed as a process of the redistribution of the energy and mass within the nucleons themselves. Therefore, there is of course no violation of the law of the conservation of energy in the dissociation of the nucleons.

The law of the conservation of energy does not rule out such nucleon dissociation. But it does forbid the removal of the virtual π-mesons outside the limits of nucleon interaction unless there are additional sources of energy, that is, it forbids the transformation of virtual particles into ordinary elementary particles. Speaking of virtual π-mesons, we should note that under the law of the conservation of energy these π-mesons cannot depart from the nucleon that gives them birth, i.e., cannot manifest themselves as free π-mesons, unless there is external action.

Virtual π-mesons occurring in the process of nucleon interconversion continually emerge and disappear, and their being is being in becoming. The existence of virtual pions (as of all virtual particles) is an intermediate existence between emergence and annihilation, between possibility and actuality.

In fact, virtual particles, since they are the possibility of the emergence of elementary particles, possess some of the features of the latter and can produce various effects and act on them. We have already given examples of this.

Elementary particles and fields are inseparable from each other. Virtual particles, too, may be viewed as structural elements of fields existing within the elementary particles themselves. This means that a field is for particles not only their exterior medium but also their interior content. Consequently, one may say that virtual particles are elements of the structure of fields that are part of the content of elementary particles.

This inference must be refined. After all, not only virtual but also ordinary particles are inseparable from fields. Both can be viewed as quants of fields. In our view, the refinement required consists in the fact that virtual particles can be equated, in a number of relationships, with the vacuum of physical fields. For example, the literature on physics often equates the interaction of the multiplets of particles with virtual particles and maintains that they interact with a vacuum. It is held that interactions with virtual particles lead to multiplet splitting. Consequently, in certain respects the peculiarities of the occurrence of virtual particles can be treated in the light of the features inherent in the vacuum of physical fields. We shall confine ourselves to this general formulation and proceed to the question of the role of virtual particles in the structure of elementary particles.

Basing ourselves on the proposition that all particles are inseparable from and interconvert with fields, we

may say that to the extent that every particle is connected with many fields that in their ground state enter the content of the particle, the structure of the particle is the aggregate of its connections with other particles and of its potential for turning into other particles. But the quants of the ground states of physical fields are virtual particles. Consequently, one may say that the elements of the structure of elementary particles are virtual particles, through which the connections of elementary particles among themselves and fields, as well as the potential for their transformation into each other and into different physical fields, are expressed.

From this follows a conclusion that is, in our view, rather strange: in their virtual states, all elementary particles enter each other. In the neutron, for example, there exist in virtual state various π-mesons, K-mesons, nucleon-anti-nucleon pairs, and so on. One may say that all elementary particles to one extent or another make their contribution to the concrete guise of every other elementary particle.

This means that the elements of the structure of elementary particles are not their "constituent elements" in the ordinary sense of the word, but their connections with other particles and fields and the potential for their conversions. Current notions of the divisibility of matter differ substantially from our earlier notions. Previously, there seemed to be only two alternatives—either we can divide matter into ever smaller bits, or we will arrive at a smallest, indivisible particle. It now turns out that there is a third possibility: we can attempt to split matter further, for which we need ever greater energy, but in doing so we will never obtain smaller particles because of the possibility of generating pairs, particles and anti-particles. Therefore, as Heisenberg has observed, there emerges a paradoxical situation well described by the formula: every elementary particle consists of all the other elementary particles.[1]

The physics of elementary particles has arrived at a new form of atomism that rejects not only the Aristotelian notion of the infinite divisibility of matter, but also the earlier atomists' notion that there exists an indivisible, ultimate and untransmutable primal element. The structure of elementary particles includes the virtual states of those particles into which they can be transformed under the given conditions. And since conditions change, so, too, do the manifestations of the elementary particles change. One may even say that in one type of interaction elementary particles have one structure, in another type of interaction—another structure.

The manifestation of the structure of elementary particles always occurs only in specific interactions and transformations. This confirms once more that the elements of their structure—the virtual states of particles—exist only as moments of the interaction and transformation of ordinary particles, i.e., in their becoming. A correct understanding of the dynamic structure of elementary particles is inseparable from the understanding of virtual particles as processes of the interaction and interconversion of ordinary particles.

One cannot now understand or make sense of any result of the physics of elementary particles without bringing in the concept of virtuality. And we have no difficulties when using this concept in practice—in carrying out various calculations; we operate formally with virtual particles in the same way as we operate with ordinary particles.

There are differences only when we are concerned with values depending on the kinematic characteristics

[1] W. Heisenberg, **Introduction to Unified Field Theory of Elementary Particles**, London, New York, 1966, p. 5.

of particles: although the apparatus of four-dimensional δ-functions automatically ensures the observation of the laws of the conservation of energy-impulse for all processes observed in experiment, the square of the four-dimensional impulse q of a virtual particle is positive, while formal calculation of the mass $m=\sqrt{-q^2}$ yields an imaginary result.[1] Thus, the difference between ordinary and virtual particles has no intrinsic meaning, it is connected with a kinematic variable describing not the particle in and of itself, but the process in which the particle participates.

However, in the literature on physics and philosophy one meets to this day various misunderstandings, even crude mistakes, in the treatment of virtual particles; to eliminate the paradoxes, various terminological contrivances are employed or mental, natur-philosophische constructs are devised.

Since virtual particles were introduced in physics for purely theoretical reasons, as the result of the formal procedure of secondary quantization, and at first glance (as we have already noted) seemed incompatible with the law of the conservation of energy, they were for a long time viewed as a graphic but quite conventional interpretation of some elements of the mathematical apparatus of theory, useful for carrying out calculations, in other words, as an auxiliary image. The mathematical objects correlated with virtual particles were met only at intermediate stages of calculation, so this interpretation produced no difficulties and was for a long time generally accepted. However, with the further development of theory it became apparent that it was possible to introduce two intrinsically different virtual particles: so-called

[1] One is easily convinced of this if we transfer into a system of coordinates where the impulse of both electrons is equal.

The condition $q^2 \geqslant 0$ (for γ-quants $q^2 > 0$) can be taken as the definition of a virtual particle.

"naked" virtual particles, corresponding to operators for the absorption and emission of point (structureless) particles, and "clothed" virtual particles, which have the same complex internal structure as the ordinary particles observed in the initial and final states of reactions. The first type may conditionally be called "mathematical particles", the second—"physical particles" originating in theory as the result of the action of special "physical" operators for generation and absorption or as a complex aggregate ("cloud", "coat") of virtual "mathematical particles".

While "mathematical particles" can still be considered artificial images (or more precisely, a crude approximation of "physical particles"), "physical particles" do not in their properties differ in any way from ordinary particles observed in experiment, though the processes of the absorption and emission of these particles occur with an apparent violation of the law of the conservation of energy.

In the standard formulation of the theory of elementary particles, which is based on free field equations, and in which particle interaction is introduced as an excitative term, in all intermediate states we have to do with "mathematical particles" and combinations of the same. Equation of particles in the initial and final states with "physical particles" occurs in this case with the aid of an artificial renormalization procedure. It is this approach that was the basis for the assertion that modern theory is founded on the conception of point particles, and all virtual particles in intermediate states have the meaning only of auxiliary objects and are intrinsically different in their properties from "real" particles observed in experiment. However, given a more consistent formulation, theory from the outset treats "physical particles" that in the free state do not interact with each other but always interact with vacuum fields. In

this treatment, the properties of particles in virtual intermediate states differ in no way from the properties of particles in the observed initial and final states of a reaction.

As a rule, in all cases where the current literature on physics speaks of virtual particles as auxiliary symbols or as unobservable objects, it is referring to "mathematical particles".

Experimental study of the structure of nucleons and analysis of so-called "peripheral interactions" described by diagrams with a single virtual particle in an intermediate state confirmed not only the reality of the occurrence of virtual particles in nature, but also detected no deviations of their properties from the properties of ordinary particles.

In current quantum theory, both ordinary and virtual particles (whether or not they are treated as point "mathematical" or structured "physical particles") are described by identical absorption and emission operators; in the theoretical apparatus there are no values that would describe any "special states" of elementary particles, just as there is no means by which, without measuring the value—dependent on concrete external conditions—of the kinematic invariant q^2, to establish whether the particle is virtual or ordinary. For instance, the virtual photon already emitted by an electron and no longer interacting with the latter must be viewed as an ordinary actual particle fixed in experiment if the electron proceeded to interact with the external field (the photon "does not know" of this interaction). The virtuality of a particle is determined not by the properties of the particle, but by the position that the given particle occupies in the process being considered.

While the difference between "physical" virtual and ordinary particles is conventional, virtual processes have an intrinsic peculiarity: in these processes, the law of conservation is not observed for theoretical values of the energy of the particle. This circumstance has been formulated by a number of physicists as an alternative: either the objectivity of virtual processes and renunciation of the universality of the law of the conservation of energy, or recognition of the universality of this law and denial of the objective occurrence of virtual processes.

In order to understand how the real occurrence of virtual particles can be made compatible with the law of the conservation of energy, we must first of all take into account the fact that the conclusion that the law is violated followed from comparison of the values of energy at two different instants of time: the instant of the initial state of the process t_1 and the instant of the final state t_2. However, in accordance with the fundamental law of quantum theory the energy of a closed system cannot be determined without subjecting it to uncontrolled change connected with the indeterminacy $\Delta E \infty \hbar/\Delta t$, where $\Delta t = t_2 - t_1$ is the duration of the process of measurement. Therefore, for the intervals $\Delta t \sim \hbar/mc^2$, where m is the mass of the particle emitted or absorbed, indeterminacy in the determination of energy is $\Delta E = mc^2$, i.e., precisely the same order of magnitude as the difference between the values of the particle's energy $E_{final} - E_{initial}$ (it is important to stress that we always calculate, rather than measure, the energy of a virtual particle; otherwise within the limits of experimental error ΔE we would always obtain the equality $E_{final} - E_{initial}$). We see, then, that in actuality no violation of the law of the conservation of energy occurs in virtual processes, and that within the framework of modern quantum theory this law is strictly observed, though it must be applied with a view to the specific wave nature of phenomena. In the general case, virtual particles do not in their interior properties differ from ordinary particles; in particular, one and the same particle, depending on exterior conditions, can be viewed either as an ordinary or as a virtual particle. At the same time, as an approximation, when their interior structures are not taken into account, virtual particles may function as auxiliary images providing graphic illustration of the mathematical apparatus of quantum field theory.

Thus, the problem of virtual particles and virtual processes, as a physical problem above all else, is related, too, to the theory of cognition, for example to the dialectic of the interconnection of the interior and the exterior, of the object and its image.

The existence in physics of a large number of principles, as well as of a general tendency to a further increase in their number, indicates, on the one hand, the heuristic role of these principles and, on the other, the inexhaustibility of the objects of cognition.

THE DIALECTIC OF THE ABSOLUTE AND THE RELATIVE

Throughout this book we have attempted to show the ways in which the marvellous world of objective reality, the object of study by the physical sciences, is cognized. The question of the correlation between physical theories and actuality is of great theoretical and practical import. We are assisted in framing a proper answer to this question by the dialectic of absolute and relative truth, that dialectic being an important methodological principle of cognition.

There is a close connection between the absolute and the relative, the conserved and the transmutable. Those moments of our knowledge that are conserved in the process of their change but that are capable of being enriched by new aspects and properties are absolute. The absolute moments of our cognition cannot be viewed external to the development of cognition, for they reflect the process of the becoming of stable, ever more profound knowledge capable of further enrichment. The higher the level of cognition's development, the more absolute moments in it.

Knowledge of the absolute, of the universal is truly scientific knowledge only when it is expressed through concrete, relative knowledge. It can be verified and used in practice only if thus expressed. In cognition, the relative expresses the possibility of the change of

cognition and the possibility of applying the knowledge obtained only within specific limits and under specific conditions. But if knowledge is applied within the appropriate limits, it functions in its absolute moments as well. That is, the very contradiction between the absolute and the relative is of a relative character, the boundary between the two is fluid, and in the process of development they pass into each other. The transition from the absolute to the relative is a transition from the conserved to the transmutable, from the more general to the less general, i.e., it designates the establishment of the bounds within which knowledge functions in its absolute moments. And the transition from the relative to the absolute discloses the conserved in changing phenomena, discloses the more general connections of the given objects with other objects.

In modern physical theories and in their philosophical interpretation (by spokesmen of idealism and mechanistic materialism) the dialectic of the absolute and the relative finds no adequate reflection. Even today one can observe a tendency to oppose the absolute to the relative, and find elements of relativism and dogmatism. Max Born, for instance, asserts that "the rise, acceptance and fall of theories is an everyday occurrence; what today is valuable knowledge will tomorrow be so much junk, hardly worth a historical backward glance".[1] With certain qualifications, one can agree with the first half of the statement, but one cannot agree with the second part, which asserts the merely transitory nature of knowledge, for it denies (I think it consequence of poor formulation) succession in the development of knowledge, it violates the dialectic of absolute and relative truth.

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[1] Max Born, **Physics in My Generation,** p. 18.

One can find an excessive accent on the relative aspect of the cognitive process in some statements by the well-known English physicist David Bohm, who also violates the real correlation between the absolute and the relative in cognition. The same retreat from dialectics is to be found in the writings of Richard Feynman, who maintains: "One of the ways of stopping science would be only to do experiments in the region where you know the law. But experimenters search most diligently, and with the greatest effort, in exactly those places where it seems most likely that we can prove our theories wrong. In other words we are trying to prove ourselves wrong as quickly as possible because only in that way can we find progress."[1]

It is unnecessary to contest Feynman's first point: it is quite true. There is nothing in fact more dangerous for scientific progress than treading water. However, one can in no way agree that refutation of "old truths" is the only way to progress; the underestimation of the dialectic of the absolute and the relative in cognition is here obvious.

The statements by Bohm and Feynman indicate a certain philosophical "liberty" on the part of the authors and are in a certain sense an example of the opposing of the absolute to the relative in the development of physical theories. This may in practice lead to elimination of absolute moments from the development of theories. After all, the development of science involves not only the appearance of new knowledge, but also the retention of knowledge obtained earlier. To begin the search for new truths with a denial of known truths is as a rule a course leading not to new truths but to old errors. New truths are disclosed not by combatting old truths (elements of absolute truth), but by combatting old errors.

[1] Richard Feynman, **The Character of Physical Law**, London, 1965, p. 158.

Some scientists hold that in physics absolute moments are increasingly piling up, and that therefore it is indeed possible to cap its development in the sense of cognizing the most fundamental laws of nature. We find this type of assertion in Feynman's writings: "This thing cannot keep on going so that we are always going to discover more and more new laws.... The age in which we live is the age in which we are discovering the fundamental laws of nature, and that day will never come again. It is exciting, it is marvellous, but this excitement will have to go....

"Another thing that will happen is that ultimately, if it turns out that all is known, or it gets very dull, the vigorous philosophy and the carefull attention to all these things I have been talking about will gradually disappear."[1]

There is more emotion than rational argument in this assertion. Since the proposition as to the inexhaustibility of objects has been confirmed in science and practical experience, the proposition that the cognition of these objects is an infinite process holds as well. For our cognition, what is essential is the task of disclosing the absolute moments in relative truths. Only in the light of the dialectical interrelationship of the absolute and relative moments of our cognition is it possible to treat truth as a process. The development of truth involves both refinement and extension, both expansion and restriction.

It is very important to see the difference in principle between the scientific and the philosophical interpretation of relativity. Our notions, concepts and theories reflect objective reality that exists independently of us. At every stage of the development of science these notions express relative truth. That, at any rate, is how the question is put in philosophy. But

[1] Richard Feynman, **op. cit.**, pp. 172, 173.

the situation is quite different in physics. When a physicist says that velocity is a physically relative rather than absolute value, he has in mind the following: one and the same body at one and the same moment of time can have different velocities depending upon the reference points relative to which its velocity is measured.

From the point of view of subjective, idealist philosophy, recognition of the physical relativity of trajectory, kinetic energy, mass and spacial and temporal intervals means to renounce the objective content of these concepts. All these considerations arise from the observer's substitution of his own subjective point of view for a system of readings, from the substitution of the subjective for the relative.

In truth, scientific data are objective, though they are the result of the creative activity of a cognizing subject.

In some publications, the special theory of relativity and its effects are outlined with reference to an "observer", which engenders unscientific judgements as to the subjectivity of this physical theory. In fact, elimination of the observer and substitution of a system of readings do not alter the substance of the theory but eliminate the potential for interpreting it in the spirit of subjective idealism.

Misunderstanding of the objective character of relativity is quite often a consequence of equating relativity with conventionality, understood in the spirit of conventionalism, according to which science is based on arbitrary agreements dictated only by considerations of expediency. The classics of Marxism-Leninism employed the concept "conventional" (or "conditional") as a synonym for the concept "objective relativity"; they did not equate it with arbitrary agreements among people. In *Materialism and Empirio-Criticism*, Lenin wrote: "All boundaries in

nature are conditional, relative, movable, and express the gradual approximation of our mind toward knowledge of matter."[1]

We must differentiate precisely these two interpretations of the concept "conventional". It is for this very confusion of the two different senses of the concept "conventional" that the physicist V. A. Fok criticized the philosopher A. A. Maksimov, who opposed the relativity of such concepts as velocity and simultaneity. Fok wrote: " ...A. A. Maksimov confuses relativity in the sense of the interrelationship and interconnection of the material relationships of objects with the concept of conventionality and subjectivity. But these are completely different things. When we refer to 'relative velocity' or 'relative humidity' in physics or to the relative form of cost in political economy, we are speaking of relativity in the sense of interrelationship; it is clear that this concept has nothing whatsoever to do with conventionality and subjectivity."[2]

Thus, violation or ignoring of the dialectic of the absolute and the relative leads to denial of the objective character of relativity. The entire development of natural science demonstrates that relativity and reality are not mutually exclusive. Both the relative and the absolute exist objectively. And when we speak of the relative character of a particular property in physics, we are speaking of relativity in the sense of interrelationship, we are not dealing with conventionality or subjectivity here, either.

There are no properties or objects that are not relative to something, that is, there cannot exist an absolute that is not manifest in the relative. It is not

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[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 281.

[2] V. A. Fok, "Against Uninformed Criticism of Modern Physical Theories", **Voprosy filosofii**. No. 1, 1958, p. 173.

happenstance that the Soviet physicists Yu. B. Rumer and M. Sh. Ryvkin even propose considering the proposition as to the relativity of the properties of objects the initial postulate of any rational physical theory.[1]

The dialectic of the absolute and the relative, of the objective and the subjective, is clear, too, in the transition from the physics of the macro-world to the physics of the micro-world, where probability acquires a fundamental role. But the concept of probability is introduced into quantum mechanics not because of a lack of knowledge, but rather as a reflection of objective indeterminacy in the state of micro-objects. We can understand the true sense of the indeterminacy relation only if we keep in mind the specificity of micro-particles. And the specificity of micro-particles is such that before a particular interaction no physical parameter can have a definite numerical value. We can say nothing about a number of quantum mechanical parameters of particles if we look at the particle in and of itself. We can learn about them only under conditions of interaction with other material objects.

Proceeding from this, we may formulate in the following manner the prime feature distinguishing quantum from classical physics. In classical physics, values describing the motion of a material point are relative in the sense that they depend on the choice of the system of readings. But within the framework of a specific material system the physical values do not depend on the material medium, that is, they are absolute. It follows that in classical physics the basic properties of objects are manifest in any medium and it is possible to construct a device for measuring, in one

[1] Yu. B. Rumer and M. Sh. Ryvkin, "Some Problems of Contemporary Physical Cognition", **Voprosy filosofii** No. 7, 1964, pp. 61-62.

and the same state of the object, all the values describing its mechanical properties.

The situation in quantum mechanics, where not all pairs of values describing the properties of a micro-object can be measured simultaneously (in one and the same state), is completely different. There are pairs of values that are generally called complementary—coordinates and impulses, for example. The material medium making it possible to manifest a specific impulse eliminates the determinacy of the object's coordinate, and vice versa. The concept of the probability distributions in the quantum mechanical picture of the world differs substantially from the same concept in classical mechanics. It turns out that the bases for a probability approach to the phenomenon under study are bound up in the very state of micro-objects, and the indeterminacy of the value of a physical parameter is merely the consequence of the indeterminacy of the state of a micro-object. The indeterminacy relation refers not only to the statistics of many individual acts of interaction, but also to the values of physical magnitudes of the micro-object prior to interaction.

Some representatives of the so-called Copenhagen school of physics in effect move the unbreakable connection between elementary particles and the medium in which they exist to the background and overstate the interrelationship between the micro-object and the instrument. But the phenomena of the micro-world occur within the micro-world, and the isolation of the micro-system that seemed possible from the standpoint of classical conceptions is in fact unrealizable. Therefore, the question of the action of the uncertainty principle and the statistical character of the laws of the behavior of micro-objects is more intricate than it seems to a number of investigators, The great Albert Einstein was not entirely in agreement with the "Copenhagen" interpretation of the uncertainty principle, though there is no better interpretation in modern physics. As Einstein saw it, the apparatus of quantum mechanics does not provide a means for the full description of reality. Einstein developed this thesis in detail in a 1935 article written jointly with B. Podolsky and N. Rosen, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" The article asserts that the element of physical reality corresponds to physical value only in the case where it is possible to predict it with a probability equal to unity. On the basis of this criterion, the authors concluded that quantum mechanics does not fully describe physical reality and expressed confidence that there is another means for describing phenomena, a means more in accord with actuality.[1]

Bohr notes that this sort of argument does not undermine the fullness of quantum-mechanical description. "On the contrary, this description ... may be characterized as a rational utilization of all possibilities of unambiguous interpretation of measurements, compatible with the finite and uncontrollable interaction between the objects and the measuring instruments in the field of quantum theory. In fact, it is only the mutual exclusion of any two experimental procedures, permitting the unambiguous definition of complementary physical quantities, which provides room for new physical laws...."[2]

Bohr maintains, then, that quantum mechanics is complete because it is adequate to the measuring instruments, which are so constructed that it is impossible simultaneously to measure impulse (*p*) and

[1] **Uspekhi fizicheskikh nauk**, Vol. XV, issue 4, 1936.

[2] N. Bohr, **Atomic Physics and Human Knowledge**, New York, 1958, p. 61.

coordinate (*x*) of the micro-object. As already noted, Bohr advances to the fore the potential of the measuring instruments. He holds that the interference of the instrument alone is the reason for the uncertainty relation.

It is difficult to agree with this. Both in classical and in quantum mechanics, instruments are macroscopic devices. And the essence of the difference between classical and quantum phenomena is rooted not in instruments as such, but in the new nature of quantum objects.

If the concepts of coordinate and impulse were, as in classical physics, of unlimited applicability to micro-objects, the impossibility of measuring them simultaneously would clearly contradict the materialist principle of approximation to absolute truth. But the peculiarity of quantum mechanics is precisely that it expresses regularities proper to objects of a nature other than the material points of classical physics in the language of statistics. In the micro-world, as distinct from the macro-world, it is impossible to abstract the object studied from interaction with the rest of the world, and while in the macro-world there is one and only one real possibility, necessarily realized in actuality, in the micro-world the micro-object, located within specific macroscopic conditions, has an infinite range of possibilities; therefore, it is impossible unambiguously to determine the state of a micro-object with the aid of a finite number of parameters; the state can only be expressed statistically. And while in classical mechanics the concept of probability is connected with the imprecision of our measurements, in quantum mechanics probability reflects the objectively existing qualities of the micro-object.

This is very important. Quantum mechanics is in effect based on the dialectical correlation of determinacy and indeterminacy in the processes of the interaction and transformation of phenomena, recognizing the objectivity of the one and the other.

Let us turn now to the theory of relativity, where the question how exactly the absolute and the relative are connected and correlated has not been given a final answer. This lack of clarity as to the dialectical unity of absolute and relative moments involves, from the philosophical point of view, the difficulty of understanding this theory.

Many authors direct attention to the fact that the theory of relativity's denial of the existence of the absolute exterior to its connection with the relative does not at all mean the denial of all absolute moments. V. A. Fok has argued: "To reflect objective reality, it is necessary to utilize both the absolute and the relative concepts. The theory of relativity does just that. The theory of relativity, indicating the relative character of a number of concepts earlier considered absolute, at the same time introduced a number of new absolute concepts. Most critics of the theory of relativity forget this."[1]

Every law of science is, both in its content and in the forms of its manifestation, a stage in the development of our cognition, a stage at which our cognition does not stop, but goes forward. And we must be able to disclose in every law the unity of absolute and relative moments, for only in this way is it possible to establish the basis for foreseeing what in it can be limited and narrowed, and what can be reinforced and expanded.

Every physical law, every physical theory is only a relative truth, that is, only an approximate reflection of objective reality. However, there is no greater error than the expression "everything is relative". The relative truth of the physical picture of the world in no way alters the fact that it contains features that no

[1] **Voprosy filosofii** No. 1, 1953, pp. 171-72.

revolution either in nature or in human thought can change.

Max Planck understood this well. In his scientific autobiography, he wrote that the search for the absolute had always seemed to him the finest scientific problem. "It might seem," he wrote, "that this contradicts my interest in the theory of relativity. This conclusion rests on a fundamental error. Everything relative presupposes something absolute, it has sense only when the absolute is juxtaposed to it....

"We can always proceed only from the relative. All our measurements are of the relative sort. The material of the instrument with which we work is conditioned by the source from which it comes, its construction is conditioned by the ability of the technician who designed it, its use is conditioned by the special objective which the experimenter wishes to attain with it. From all this data we can deduce the absolute, all that is of general validity, everything invariant that is embodied in it."[1]

Without the precondition of the existence of absolute moments, no concept can be defined, no theory can be constructed. There are a number of forms of the connection between the absolute and the relative, the conserved and the changing, which are in practice realized in the process of the development of physics: the principle of inexhaustibility, the principle of correspondence, the invariance of the laws of different theories with respect to the same transformations.

Let us consider the relation between invariance and relativity. As we have already indicated, the properties of immutability with respect to a certain class of changes in physical conditions are called invariance. The notion of invariance arose in mathematics,

[1] Max Planck, **Wissenschaftliche Selbstbiographie**, Leipzig, 1948, S. 31-32.

In physics, the notion of invariance was first reflected in its clearest form in Galileo's principle of relativity, which holds that the uniform motion of a system does not influence the course of mechanical processes. This uniform motion was possible only in a space not having any manner of distinguishable points or axes. It follows that the formulation of Galileo's principle of relativity presumed, though not overtly, a specific symmetry of space: isotropy and homogeneity. That is, the absolute character of laws was clearly connected with the absolute, universal properties of space already at that time.

The principle of relativity acquires its most complete form in the theory of relativity. The fact that the absolute and relative moments characterizing moving matter occur in unbreakable connection is reflected in that the generalized principle of relativity expresses two contradictory moments: invariance, asserting the conservation of the laws of nature, and the principle of relativity proper. It is this circumstance that provides a wealth of material for the debate around the theory of relativity.

Every closed physical theory involves both invariance and relativity. For example, in classical mechanics the lengths of objects and the durations of events are invariant, while in the theory of relativity they are relative, only their specific union in an interval being invariant. Physical theories relating to different stages of the development of physical science are distinguished not only by the system of their concepts and laws, but also by the system of transformations with respect to which these laws are invariant.

The laws of classical mechanics are invariant with respect to the Galileo transformations, the laws of the theory of relativity are invariant with respect to the Lorentz transformations, the laws of quantum mechanics are invariant with respect to unitary

transformations. Determination of the limits of the applicability of the principles of invariance is an essential aspect in the development of physical cognition.

Every theory has some types of invariance unique to itself. Specific to Maxwell's electrodynamics, for instance, is the requirement of invariance with respect to the so-called calibrated transformation of electromagnetic potentials. The laws of quantum electrodynamics satisfy a new requirement for invariance—the requirement for a calibrated transformation of a different sort, the transformation of charge conjugation, the Salam-Toushek transformation, and the Pauli-Gürsey transformation. The differences in the systems of transformations that the laws of different theories satisfy express the specific character of these theories themselves, their irreducibility to one another.

Though the difference in principle between the laws of classical mechanics and the laws of relativistic mechanics is embodied in the fundamental distinction between the Galileo and Lorentz transformations, the laws do have something in common: both satisfy coordinate-shift transformation, time-shift transformation and the rotation of the system of coordinates. The laws of classical electrodynamics and the laws of quantum electrodynamics have in common the fact that both are invariant with respect to the Lorentz transformations and with respect to the calibrated transformation of electromagnetic potentials.

The fact that the laws of different physical theories, despite the presence of specific types of invariance, satisfy a number of common requirements of invariance is of great import. The invariance of the laws of motion of different objects with respect to one and the same transformations is a special form of the interconnection of physical theories. Pointing up the stability of the laws of nature, the principles of invariance establish, as it were, the connection between one and the same law in different interacting systems and thereby disclose, so to speak, the structure of these laws within the framework of a more general system. This feature of the principle of invariance was noted by the American physicist E. Wigner, who wrote that, just as the laws of nature point up the structure and the interconnection of the aggregate of events, the principles of invariance highlight the structure or interconnection of the laws of nature.[1]

The development of physics proceeds through the passage of one theory into another, more general theory. At certain stages of development, contradictions between new facts and existing theory arise that cannot be explained by the principles and concepts of existing theory. As a rule, in such situations there is already a mathematical apparatus but there is not yet a new physical theory. The task is to connect this apparatus with experimental data relating to the new facts. The basic direction in dealing with this task is the relativization of concepts together with the idea of invariance.

The disappearance of old and the emergence of new concepts is a unitary process: old concepts are subjected to certain relativization and become aspects of new absolute concepts or invariants of a more general theory. For instance, the concept of absolute space and time accepted in classical mechanics disappeared in the theory of relativity, while the corresponding relativistic concepts were established. They became aspects of one of the most important invariants of the theory of relativity, the interval, which is a special sort of union of length and duration.

[1] See E. Wigner, "Events, Laws of Nature, and Invariance Principles", Eugene P. Wigner, **Symmetries and Reflections,** London, 1970, pp. 42-43.

Another form of the connection between the absolute and the relative in physical cognition is Lenin's principle of the inexhaustibility of matter, which provides the necessary foundation for understanding and resolving many difficulties in the physics of our time. The scientific events that have come so thick and fast since the publication of Lenin's *Materialism and Empirio-Criticism* seem to have been specially selected illustrations of the truth of Lenin's notion of the inexhaustibility of the properties of the electron and matter in general. The doctrine of the inexhaustibility and unity of the world involves not only the inexhaustibility of the structure and properties of material objects, but also the inexhaustibility of all the basic forms of the existence of matter: motion, space and time, as well as the regularities of the motion of matter.

Many Soviet and foreign physicists note the great methodological role of the principle of inexhaustibility, but they often fail to give due attention to the fact that a correct evolutionary approach to the study of the material world is possible only given an understanding of the dialectic of the relationship between the absolute and the relative, the conserved and the changeable.

The inexhaustibility of the properties and states of the attributes of matter is scarcely to be seen only in the fact that their properties and states are relative and change in every region of the world. Of course, this does occur, but it is not the crux of the matter. The inexhaustibility of the properties and states of the attributes of matter involves not only the fact that some states are replaced by others on transition from one environment to another, but also the fact that the given states are modified, that they acquire new features and forms.

In understanding the essence of the development of our cognition, the question of the interrelation of old and new knowledge is of great importance. New knowledge negates the old, but this negation does not come down to rejection, to annihilation. It is dialectical negation, which involves moments of annihilation and rejection but cannot be reduced to this. Lenin observed that dialectical negation is a moment of the connection between the new and the old and a moment of the development of the new from the old. Old knowledge paves the way for new knowledge, while new knowledge discloses more profoundly the essence of the old. It follows that the development of cognition can be viewed neither as a complete replacement of old knowledge by new, nor as a summation of knowledge obtained in the past and present. Typical of the process of the change of knowledge is the interpenetration of change and conservation.

The internal mechanism of the accumulation of kernels of absolute truth in physical theories is in a certain aspect disclosed by the principle of correspondence. I. V. Kuznetsov emphasizes the impossibility of explaining this principle within the framework of physics: "The basis of the principle of correspondence can be obtained only from dialectical materialism's theory of cognition, in particular, from the Marxist-Leninist doctrine of absolute and relative truth."[1]

The principle of correspondence was formulated at the empirical level by Bohr and Heisenberg. Bohr showed that in the realm of sufficiently large quantum numbers, the frequency of electron waves calculated on the basis of quantum spectral formulas approximately correspond to frequencies obtained on the basis of the classical theory of radiation. Bohr called this coincidence the correspondence between quantum and

[1] I. V. Kuznetsov, **The Principle of Correspondence in Modern Physics and Its Philosophical Foundation**, Moscow, 1948, p. 93 (in Russian).

classical theories. But the development of physics has shown that the realm in which the principle of correspondence holds is much more extensive.

20th-century physics has passed through a number of stages, which, historically, have been marked out by the emergence of quantum theory, the theory of relativity and quantum mechanics. The restructuring of theories at the threshold of each of these stages was of a profound, revolutionary character. New theories radically changed old theories, but at the same time drew upon the latter, taking up everything that had been confirmed by experiment. The laws of old theory proved to be special, limiting cases of the laws of new theory.

Thus, the philosophical significance of the principle of correspondence consists in the fact that it expresses the logical succession in the accumulation of scientific knowledge, in the fact that it isolates the absolute aspect in the content of physical theories. If a law or concept of some theory is deduced as a special case of another theory of a more general character, it indicates the properties of necessity, of conservation, that is, the absolute aspect of the given law or concept.

However, the import of the principle of correspondence consists not only in fixing the character of the development of physical cognition. Since it is firmly fixed in consciousness and verified in practice, it is one of the implements for constructing new theories. The methodological role of the principle of correspondence in fact plays an increasing role in the development of physical cognition. It played a major role not only in the construction of the first quantum theory of the atom, a theory proposed by N. Bohr, but also in the development of modern quantum mechanics. The role of this principle has also been substantial in the development of the theory of elementary particles. Use of this principle, for example, helps to establish the physical meaning of a number of newly derived concepts. Together with the condition of covariance, unitariness and causality, the principle of correspondence is a sufficient condition for the construction of the so-called scattering matrix, a concept that plays an important role in modern theoretical physics. All attempts to advance the theory of elementary particles have used the principle of correspondence. This refers in particular to attempts to devise a theory of elementary particles on the basis of the idea of the quantization of space and the non-localization of interaction.

The heuristic role of the principle of correspondence has as yet been far from fully studied, and at this level it would be interesting to trace its connection with the principle of the inexhaustibility of matter. Between these two principles there is, as it were, a certain division of responsibilities. The principle of inexhaustibility asserts the objective possibility of and necessity for new theory. It follows from this principle that every physical theory, reflecting a finite number of the aspects of the inexhaustible physical world, is a relative truth, a stage in the cognition of the objective world. The principle of correspondence, for its part, gives some information on the general features of new theory.

The question of the correlation of the principle of inexhaustibility with the principle of the completeness of physical theory is also of extraordinary importance.[1] The fact is that the picture of the world based on the principle of inexhaustibility and the picture of the world based on a given physical theory seem at times to be alternatives: the principle of inexhaustibility has no place in the picture of the world based on a concrete theory. This contradiction between the content of physical theory and the principle of inexhaustibility becomes even more acute if the theory possesses the property of completeness.

Completeness of theory can be defined in different ways. A theory is ordinarily termed complete if it reflects every property of the physical reality that is the subject of the given theory. Completeness of theory in this sense is closely connected with the deductive completeness of theory, which means the impossibility of supplementing the theory with ideas that follow not from its own principles but from new observations and new experimental data. Such a supplementing of theory with new ideas inevitably leads to an expansion of the theory, and this is incompatible with the structure of the theory as a non-contradictory closed system. This is why complete physical theories function as an alternative to the principle of the inexhaustibility of the material world. In recognizing complete physical theories, it would seem that we must renounce the principle of the inexhaustibility of matter. In order to overcome this contradiction in principle, some authors advance the proposition that physical theories cannot be complete. Proponents of this notion ordinarily cite classical electrodynamics, seeing its incompleteness in the fact that it is unable satisfactorily to explain the behavior and properties of the electron. Description of the electron in electrodynamics leads either to the conclusion that the electron is an unstable particle, or to unresolvable paradoxes of infinity.

We must observe, however, that in this instance the concept of the completeness of theory is used in an entirely different sense. Every physical theory, including a complete theory, has a limited range of application. Attempts to use the theory to describe objects to which it is inapplicable inevitably lead to irresolvable contradictions. This is precisely the case

[1] See V. S. Gott and E. M. Chudinov, "The Inexhaustibility of Matter and the Development of Physical Knowledge", **Voprosy filosofii**. No. 5, 1969.

with electrodynamics and the electron. It would seem that electrodynamics cannot be considered a satisfactory theory of the electron.

It seems at first glance that there is a logical contradiction between a complete theory and the principle of inexhaustibility. In fact, this is a dialectical contradiction which is resolved in the very process of the development of physical cognition. One of the prime conditions for its resolution is the fact that all complete physical theories are relative truths. Since reality and relativity are not mutually exclusive, the relativity of the completeness of physical theories does not mean that the given logical property of theories lacks real meaning, that it is fictitious. Though it is relative at the level of the development of physical knowledge, completeness is in fact a property of theories. The relativity of a complete physical theory is manifested in the fact that it has specific limits to its applicability. All attempts to use the theory to describe phenomena outside the range of its applicability lead inevitably to contradictions. And the contradictions that we come up against in using electrodynamics to describe the electron indicate not that the theory is incomplete, but that it is of limited applicability. Classical electrodynamics is the theory of the electromagnetic field, and as such it can be complete. But it cannot be considered a theory of the electron as an elementary particle.

The history of physical cognition is replete with acute conflicts between old theories and new observations and experimental data—or, more precisely, between different theoretical systems, explaining existing experimental data in different ways. The conflict is as a rule resolved in favor of the theory that is more successful in predicting the appearance of new facts as well as in providing more natural explanations for existing data.

At the beginning of our century, Lenin gave a vivid picture of the process of the cognition of nature around us:

"A man in a dark room may discern objects dimly, but if he does not stumble over the furniture and does not walk into a looking-glass instead of through a door, it means that he sees some things correctly. There is no need, therefore, either to renounce the claim to penetrate below the surface of nature, or to claim that we have already fully unveiled the mystery of the world around us."[1]

In the second half of the 20th century we can also say that the mystery of the world around us has been far from completely unveiled, but this is not an obstacle to mankind's aspiration to penetrate beyond the surface of nature.

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[1] V. I. Lenin, "Materialism and Empirio-Criticism", **Collected Works**, Vol. 14, p. 267.

CONCLUSION

Our survey of some of the philosophical problems of modern physics shows that as physics develops it reflects the objective dialectic that rules in nature ever more profoundly in its laws and categories. Recognition of this fact can in the final analysis only lead physicists to adoption of the dialectical materialist point of view, for at the level of philosophy and methodology dialectical materialism most adequately corresponds to the object of physical research—the material world. As Lenin foresaw, naturalists are passing from a position of naive, natural scientific materialism to a position of dialectical materialism.

This complex and difficult process is occurring under conditions of heated ideological struggle stemming from the existence of two opposing systems—socialism and capitalism. This struggle influences all aspects of the life of mankind, the world-outlook principles of science included.

A brilliant, creative use of materialist dialectics allowed Lenin not only to penetrate the very essence of physical discoveries and theories, to find in them the reflection of the objective dialectic, but also to advance scientific forecasts that pave the way for the development of all the sciences. Reliance on and

masterful use of materialist dialectics was the basis for Lenin's brilliant far-sightedness.

It was Lenin who, in his fundamental philosophical work *Materialism and Empirio-Criticism,* asserted: "...however extraordinary may be the fact that the mechanical laws of motion are confined only to a single sphere of natural phenomena and are subordinated to the more profound laws of electromagnetic phenomena, and so forth—all this is but another *corroboration* of dialectical materialism."[1]

This was written at a time when such outstanding physicists as Lorentz, Poincaré and others did not understand and did not appreciate the significance of Einstein's "On the Electrodynamics of Fast-Moving Bodies", which laid the basis for the special theory of relativity. Lorentz, whose work played a major role in preparing the way for the special theory of relativity, wrote of Einstein that the latter requires that we take on faith that the negative result of experiments such as those by Michelson and Rayleigh is not a random compensation of contrary effects, but an expression of a general and fundamental principle.

Throughout this work, we have tried to show that Marxist philosophers, following Lenin, reinforce the alliance with naturalists, generalize the advances of modern physics, enrich the conceptual apparatus of materialist philosophy and help physicists operate the categories and laws of dialectics in dealing with the tasks that face them.

Lenin wrote: "Modern natural scientists (if they know how to seek, and if we learn to help them) will find in the Hegelian dialectics, materialistically interpreted, a series of answers to the philosophical problems which are being raised by the revolution in

[1] V. I. Lenin, **op. cit.**, pp. 261-62.

natural science and which make the intellectual admirers of bourgeois fashion 'stumble' into reaction."[1]

The development of physics, astrophysics, biology and other natural sciences raises questions not only pertaining to the individual disciplines, but also global problems having to do with the philosophical world view. Among these problems, the attention of scientists in different disciplines, of naturalists and social scientists, is attracted by the problem of the future of science, physics included.

In recent years, there have been numerous monographs, pamphlets, articles and anthologies on these questions in the Soviet Union and abroad. A reader with the necessary background will find extremely interesting ideas and propositions, for instance, in Academician V. L. Ginzburg's article "Some Problems of Physics and Astrophysics",[2] and Academician M. A. Markov's article "The Future of Science".[3]

Concluding this book, we must attend to at least some of these publications: even a necessarily brief survey and analysis provide an important addition to the basic idea of this book—the inexhaustibility of the material world and of its knowability in principle.

It is precisely the inexhaustible material world, which is an infinite variety of eternally moving, interconverting, originating and disappearing material objects, that nourishes the certitude that the cognition of this world, too, is an infinite process. This being so, knowledge of the general laws of the motion of matter can be an adequate basis for the general prognosis that science, and physics in particular, will develop.

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[1] V. I. Lenin, "On the Significance of Militant Materialism", **Collected Works**, Vol. 33, p. 234.

[2] See the collection **Physics Today and Tomorrow**, Moscow, 1973, pp. 5-65 (in Russian).

[3] **Uspekhi fizicheskikh nauk**, Vol. 3, Issue 4, 1973, pp. 719-43.

More detailed prognosis and scientific prediction are conditioned by the more adequate reflection in the laws of science, in this case of physics, of the objective laws of that fragment of the material world that is studied by physics. The precision of prognosis is always relative, it is connected with the dialectic of determinacy and indeterminacy in our cognition, a dialectic that reflects the objective dialectic of determinacy and indeterminacy in material actuality.

As history shows, most great discoveries have come unpredicted. The conclusion is often drawn from this that discoveries cannot be prognosticated at all, for they occur at random. But even contingency is a form of the manifestation and complementing of necessity. "Contingency," wrote G. V. Plekhanov, "is something relative. It appears only at the intersection of necessary processes."[1] In our view, then, a different conclusion is more accurate. Reliance on knowledge reflecting objective reality, reliance on rigorously logical demonstrations, on a dialectical materialist analysis of the concrete situation, permit us to anticipate (with a certain degree of precision) the new in science. This approach to the future is optimistic and engenders a desire to know what is yet unknown.

What, then, can we expect from physics, which is developing at so headlong a pace? To what area should energies and resources be directed? These are far from idle questions.

There is no one opinion on this score. Quite authoritative scientists name different problems, but they almost all consider that the micro-world and the space are the areas where we may expect discoveries of marvellous new phenomena and exotic objects. Unfortunately, limitations of space compel us to leave

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[1] G. V. Plekhanov, **Selected Philosophical Works**, Vol. 2, Moscow, 1956, p. 323 (in Russian).

outside our analysis some very important areas of science (genetics, genetic engineering, the entire complex of biological and medical sciences, ecology, the problem of extraterrestrial civilizations, etc.); we shall confine ourselves to physical problems.

In Ginzburg's opinion, very important results for scientific and practical purposes will be brought by the solution of the following physical problems: controlled thermonuclear synthesis, high-temperature superconductivity (till now, superconductivity has been observed at very low temperatures—within a range of 0°K and 21°K. The search for metals remaining superconductive at the temperature of liquid hydrogen —77.4°K, or even better at room temperature, is of enormous interest; superheavy elements (the heaviest natural element is uranium, though we now know a large group of artificially created transuranium elements: neptunium, plutonium, americium, curium, berkelium, californium—and so on down to the 105th element. The search is now going on for distant transuranides in the region of the values ~114 and ~184, where it is possible that relatively stable isotopes may occur); the spectrum of the masses of micro-objects (an important characteristic of micro-objects—mass—is now established experimentally, but we need a theory from which we may determine the masses of elementary particles); experimental verification of the general theory of relativity (all the effects that Einstein indicated could serve to verify the general theory of relativity occur and have been observed: gravitational displacement of spectral lines, the deflection of light rays in the field of the Sun and the displacement of Mercury's perihelion. However, the precision of these observations is not great as yet. In this situation, it is possible to discuss other theories of gravitation competing with the general theory of relativity);

gravitational waves, quasars and galactic nuclei, the character of the evolution of the Universe (Ginzburg writes: "Independent of the nature of the expansion of the Universe, it is quite clear that expansion cannot go on indefinitely." The reader will find in Ginzburg's article a number of quite persuasive arguments in support of this assertion); neutron stars and pulsars, the origin of cosmic rays, of cosmic gamma- and X-ray radiation.

Given the large number of problems in physical science from the investigation of which we may anticipate discoveries important in principle, we should mark out especially research in the realm of high-energy physics.

In his "The Future of Science", Markov analyzes research in the physics of the micro-world and concludes that "there is an historically justified tendency to study phenomena in realms of increasingly diminishing dimensions". Research into the 10^{-5} - 10^{-7} cm range led to the creation of molecular physics, research in the range of $\sim 10^{-8}$ cm opened the world of atomic phenomena to us (the laws of this world are reflected well in quantum mechanics), research into the range of $\sim 10^{-13}$ cm has opened the world of the physics of the atomic nuclei and, finally, research into the $\sim 10^{-14}$-cm range has led to the physics of adrons, strange particles and resonons. Research is now going on at the $\sim 10^{-15}$-cm level.

We see, then, that the transition from one realm of physical phenomena to another that differs in its dimensions by two to three orders has always led to new discoveries of principled importance.

Markov underlines that "the most important and interesting results are unanticipated and unforeseen results at new stages of physical research. Reality, as a rule, turns out to be more fantastic than any unchecked fantasy", and therefore the development of high-energy physics (the physics of even smaller dimensions than those mentioned earlier) inspires the hope of the discovery of something utterly different from what we already know in the micro-world.

For now, however, the flight of fantasy must be stopped in the $\sim 10^{-17}$-cm range. This scale is connected with one of the known types of interaction, weak interaction to be precise, and one may anticipate that on this scale we will get an answer "to one of the most intriguing questions of modern physics, that is: what is the nature of weak interactions? What does the undiscovered secret of weak interactions involve?"

Markov's discussion of the need to seek answers to a number of the important questions of the physics of the micro-world on the way to studying interconnections and mutual influences of known types of interaction has great philosophical import. "In practice," writes Markov, "we long ago arrived at the thought that investigating each of these interactions 'to the end' in isolation is impossible. A point always comes in high-energy physics when all other interactions begin to take part in the behavior of the given effect: this means that it is impossible to withdraw from nature one of its 'elements' without violating everything else ... we are striving and will continue to strive to understand the profound unity of 'elements'. At present, ideas as to 'violated symmetries' have emerged. For the time being, the possibility of creating a unitary theory of weak and electromagnetic interactions glimmers in them."

Translating this from the language of physical terms into philosophical language, we have a program that has at its foundation the cornerstones of dialectical materialist philosophy.

In fact, the possibility of creating a unitary theory of strong, weak, electromagnetic and gravitational interactions is in its very essence the possibility of

reflecting the material unity of the world on a new, higher level, the possibility of taking one more step on the way to a more complete and profound understanding of this unity.

We should pay especial attention to the gravitational field, which does not at present "work" in the theories of the micro-world, making it necessary to look for manifestations of the interconnection of gravitational interaction with other types of interactions at some other structural levels of micro-objects. This search is very important for science, since in the mega-world, for example, where the importance of gravitation is especially great, the laws of the micro-world turn out to be of decisive importance. "After all," writes Markov, "neutron stars are in essence immense atomic nuclei, at some stage even hypernuclei. Neutron stars are a macroscopic form of nuclear material. On the other hand, the global properties of 'black holes' are now being widely discussed, and it may very well be that this state of matter must be taken into account in constructing a consistent theory of elementary particles."

At present, the "big bang" model of the Universe is generally accepted in cosmology. When in 1965 so-called residual radiation with a temperature of $\sim 3^{\circ}$K was discovered, many (especially the authors of popularized works) felt that the picture of the expanding Universe was complete—no questions or problems, everything simple and clear. But is that really so? Suppose that the given picture is close to the truth, that there was a "primal atom" occupying a region of $\sim 10^{-13}$ cm. But to what world did it belong, the micro-or mega-world? Why did it explode, and what preceded its appearance? The number of such questions could be appreciably expanded. One thing, however, is indisputable. Taking the achieved level of knowledge as absolute, equating the model with the object, gives rise to artificial obstacles along the path of cognition, and this occurs most frequently when the dialectic of the absolute and the relative is violated, when the desired is taken for the real.

It should be kept in mind that it is precisely the problems of the history of the Universe, of the laws of its development, that are attracting the increasing attention of spokesmen for idealism and religion, who would like to use reliable knowledge and the as yet unknown for purposes hostile to science and mankind. The well-known neo-Thomist Lelotte has written: "*True science* discovers the laws that God implanted in nature; *true faith* proceeds from the truths that God has communicated to men. God does not contradict himself. So *there can be no opposition* between true science and true faith."[1]

The Catholic Church, which has for centuries fought science, has now been forced not only to recognize the achievements of science but even to attempt to reconcile science and religion, seeing in this one of the possible ways to defend religion. Neo-Thomists, writes the well-known French Marxist Georges Cogniot, "put collaboration on the agenda, but everyone understands that such collaboration can be advantageous only for religion: science has absolutely no need for 'sustenance' from religion; on the contrary, contamination by the slightest element of religious mystique is excessively harmful for any science at any stage of its development. In return, religion couldn't be happier to see scientific theories sustain dogma".[2]

It is possible that there was a "primal atom" and that it exploded, as a consequence of which the galaxies are receding, but this is only a moment in the history of the Universe, a moment preceded by other states of moving matter. As Academician Ya. B. Zeldovich has justly remarked, "it would be more correct to call ... the time that has passed since the beginning of the expansion ... the duration of the present stage of the existence of the Universe".[1]

It would be just, because these words are more precise than, say, "the beginning of the Universe" or "the age of the Universe"; Zeldovich's formulation expresses the idea of the historicity of our scientific knowledge of the astronomical Universe, which abides in the same eternal motion and change as the entire material world. Our Universe is only one of its fragments. The currency in both scientific and popularized literature of less precise formulations is simply harmful if they are used in categorical form, without an explanation of their true scientific meaning.

Soviet philosophers strive, together with naturalists, to obtain adequate answers to the philosophical questions engendered by the headlong progress of natural science, they try to aid the further development of science and at the same time, combining the principle of scientific spirit with the principle of Party spirit, to wage a struggle against all attempts to distort the essence of the achievements of science, against all varieties of reactionary, idealist philosophy.

We have before us an amazing, inexhaustible, but knowable world. Much in it remains as yet unknown, but mankind is proceeding confidently along the path of cognition, putting in service to itself new forces of nature. In the cognition of objective reality, an enormous role belongs to the natural sciences in alliance with Marxist-Leninist philosophy.

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[1] F. Lelotte, **La solution du problème de la vie**, 2 Cahier, Bruxelles, 1947, p. 25.

[2] Georges Cogniot, **La religion et la science**, Paris, 1960, pp. 43-44.

[1] **Zemlya i vselennaya** No. 3, 1969, p. 34.

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