The epistemology of Max Born and of dialectical materialism

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A review is given of the attempt by the eminent physicist, Max Born, to expound his epistemological views in the form of a system allegedly based on "physical methods of thinking", which Born contrasts with the epistemology of dialectical materialism. It is shown in this paper that Born's initial assumptions, i.e., sensations are purely subjective, objectivity can only be defined in terms of experience, and so on, are, in fact, subjectivist in character, whereas the propostion that the theory of probability allows us to admit the existence of a "thing in itself" behind mathematical structures is scientifically contradictory and, on Born's own admission, the idea of a "thing in itself" is partially devoid of objective status. Having admitted the possibility of subjectivist errors in the basic assumptions of his epistemology, Born also treats a number of other epistemological questions in a way approaching positivism, although he does not personally accept this direction in philosophy. It is shown in this paper that, in contrast to Born's epistemology, there is a scientific basis for the epistemology of dialectical materialism, and an examination of certain problems of cognition that have emerged during the evolution of modern physics is used to expose the meaning and efficacy of the epistemology of dialectical materialism.

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In this paper we shall be concerned with the epistemological views of the eminent theoretical physicist, Max Born, formulated by him in 1965. We cannot leave these views unchallenged not only because of the great authority of Max Born as a scientist and public figure, but also because he regarded them as a new epistemology based on "physical methods of thinking," and deliberately contrasted them with the epistemology of dialectical materialism. In contrast to Born, we shall use an analysis of certain physical problems to show that it is precisely the epistemology of dialectical material that enables us to achieve a correct understanding of the true process of cognition.

A few words first about the author of the new epistemology. Max Born was an outstanding theoretical physicist, the author of many papers and monographs on crystal-lattice dynamics and optics, but his main achievement was as one of the founders of quantum mechanics, whose role in its development has not as yet been adequately investigated and evaluated. In contrast to many other theoreticians who were concerned with the development of mathematical theories and regarded them merely as the computational apparatus of physics, Born was always concerned with the process of acquisition of knowledge, which became particularly complicated during the development of atomic physics. His numerous papers[1)] contained quite a number of interesting and profound opinions on the various philosophical ideas that have influenced modern scientists, as well as searches for ways of resolving the difficulties in the acquisition of new knowledge that had arisen in atomic physics. Let us briefly review some of his early philosophical ideas.

In many of his papers, Born persuasively showed that the results of modern science refuted Kant's *a priori* ideas, and the subsequent development of his epistemology was founded on these conclusions. Positivism, which reduced everything to sensations, was unacceptable to the scientist. However, he also accused materialism of inflexibility in that it was allegedly incapable of resolving the difficulties of cognition that arose in modern physics. This is why, maintained Born, having failed to find any guiding ideas among existing philosophical systems, physicists were forced to develop ways of resolving these difficulties by their own methods. Here, Born had in mind the ideas that arose and were developed by Bohr and his school in Copenhagen, and by Born's own school in Göttingen. They eventually led to the principle of complementarity, the acceptance of statistical methods, and a number of other principles. However, while emphasizing the epistemological significance and novelty of these principles, Born understood that they were formulated in an *ad hoc* fashion as successive difficulties arose in the various particular investigations. Naturally, Born continued to feel the absence of a developed theory of knowledge that would combine individual epistemological ideas into a complete system.

In the 1960's, toward the end of his life, Born tried to analyze his views and expound his theory of knowledge.[2)] Although Born published this in a very condensed form, his epistemology emerged in a sufficient-

[1)] Many of these papers have been translated into Russian; cf., for example, Fizika v zhizni moego pokoleniya (Physics in My Generation), IL, M., 1963; Moya zhizn' i vzglyady (My Life and My Views), Progress, M., 1973; papers other than those included in the first of these collections were published in Russian in Usp. Fiz. Nauk **69**, 105, 173 (1959) and elsewhere [cf. Phys. Bl. 14, 207 (1957) and Z. Physik, 153, 372 (1958)].

[2)] He did this in the article "Symbol und Wirklichkeit," Phys. Bl. **12**, (1964) and 2, 3, (1965); the Russian translation of this paper is based on the English version [Max Born, Physics in My Generation, Springer-Verlag, New York (1969)] and is given as Chap. 5 in the book, Moya zhizn' i vzglyady (My Life and My Views), Progress, M., 1973. We have used the German (and more complete) text of this particular paper.

ly clear and complete form.

I.

In this section, we shall consider Born's interpretation of the basic assumptions, problems, and methods of epistemology, and how his solutions differ from those of dialectical materialism.

1. Born's 1965 philosophical credo: Basic assumptions and the meaning of a philosophical problem

There is no doubt that cognition begins with the information about the object of cognition that is obtained through sense impressions. However, these impressions are subjective—maintains Born—because I cannot transfer to another person my own sense impressions, for example, the sensation of green light. The philosophical problem is to "understand how to free oneself from the subjective and to arrive at objective statements."

The question is—what does Born mean by the words "arrive at objective statements?" One possibility is that he is concerned with the question as to whether or not our conclusions are simply representations of the external world based on information supplied by sense impressions. In fact, Born interprets these words in a different way: he is concerned with "statements valid for all individuals." Whether or not the external world exists as a source of our sense perceptions was not a question that occupied Born. It is precisely from the standpoint of the above interpretation of objectivity that Born critically reviewed all the philosophical ideas which he acknowledged as influencing contemporary scientists.

Thus, noting that the concept of a "thing in itself" is indeterminate and the weakest point of Kant's philosophy, Born nevertheless maintains that this concept had to be introduced by Kant in order to understand "how the sense perceptions and their conceptual elaborations of the single individuals can lead to objective statements valid for all individuals." The weakness of Kant's position is that it leads to a contradiction: on the one hand, he justifies the fact that sense perceptions of different individuals are identical by introducing something external, namely, the "thing in itself," i.e., he places outside these individuals a *cause* independent of them; on the other hand, Kant considers the category of causality as an immanent property of our reason, the objectivization of which is not allowed in Kant's system. This contradiction was noted by all subsequent philosophers. It led Bertrand Russell to the conclusion that if we adopted Kant's justification of the identity of perceptions by the "thing in itself," then "we are already inside the network of *a priori* concepts operating within the understanding."

Born clearly had difficulties with the problem of objectivization and positivism: in all positivist theories (Mach, Margenau, and others) it is always found—says Born—that "the world of sensual perception is 'the same' for all individuals. What this means is left open."

"The 'materialism' of the communist bloc of Eastern nations"—the phrase used by Born to describe dialectical materialism—has been the subject of the most stringent critique. Born writes that this philosophy is in violent opposition to positivism and "maintains, of course without proof, just as an axiom, the existence of a reality independent of the subject. Marx and Engels seem to have regarded this like the naive realist: matter is primary, consciousness of mind is one of its manifestations. This 'mechanical materialism' however was not easily reconciled with the results of progressing physics. For here the primitive ideas about matter were dissolved and replaced by the concept of 'field' and eventually by still more abstract ideas. Therefore Lenin invented the 'dialectical materialism,' where the old term 'matter' is preserved but understood in such a general way that nothing of its meaning is preserved.... The fundamental axiom is 'the existence of a real, objectively knowable external world'." Modern materialist philosophy is regarded by Born not as science but as a kind of "official religion."

This is the basic position of Max Born in the development of his epistemology. It can be stated in the form of the following propositions:

1. Experience obtained through sense impressions—and there are no other sources—is always subjective; sense impressions cannot be transferred from one person to another.

2. Objectivity is none other than the body of all the sense impressions and views of all the different individuals.

3. None of the existing philosophies has provided an explanation of the possibility of cognition; Born sees a solution to this problem through the application of methods of thinking developed by physicists.

2. "Physical foundations" of Born's theory

Born enumerates the following methods (or rules) of thinking that should be placed at the basis of the theory of knowledge: 1) the principle of decidability, 2) the comparability (objectivization) of impressions and the use of symbols, 3) correspondence and coordination (of symbols and perceptions), 4) mathematical structures of thinking, 5) probabilistic methods, and 6) the principle of complementarity. In Born's view, these methods will cover all problems in epistemology.

We shall briefly review them below in relation to one another.

"I suggest—wrote Born—the expression 'decidability' for a fundamental rule of scientific thinking (although I did not find the word in the dictionary): use a concept only if it is decidable whether it can be applied in a special case, or not."

This is Born's definition of the principle of decidability. He invests the term Entscheidbarkeit with a significance close to that widely known in physics literature as the "principle of observability" (Beobachtbarkeit). This is clear from the fact that, in similar examples in his other papers, he directly refers to the

principle of observability. However, in the paper, "Symbol and Reality," he uses the other term, probably in order to emphasize the fact that each concept should be associated with a particular single experiment (the question of decidability should be resolved through experiment) and not with the possibility of sensory perception of the entity to which the concept refers, as might be concluded from the phrase "principle of observability."

According to Born, modern physics came to this conclusion having overcome the developmental difficulties facing it. As an example of the application of this principle, Born cites the rejection of the concept of simultaneity of events at different places. This concept was found to be inadequate because the velocity of light was finite. The idea of relative simultaneity has since been part of the foundations of the special theory of relativity. Another example cited by Born is the rejection of the idea of electron orbits in atoms, which are unobservable in principle, and the subsequent insistence on the use of observable phenomena, which resulted in the development of a new and fruitful theory. All these examples of the abandonment of certain concepts by physicists are well known.

We must now consider the role of the "principle of decidability" in Born's theory of knowledge and why, at first sight unexpectedly, this principle appears as the first of the physical methods in this theory. This principle has an auxiliary role: Born needs to justify the possibility of transition from an initial assumption resulting in an impasse ("the statement 'he perceives the same as I' has no clear meaning") to another assumption justified by a particular experiment. He asks: "how is it possible to infer from the subjective world of experience the existence of an objective external world?" and continues: "actually, this inference is innate and so natural that to doubt it seems rather absurd. But the doubt exists, and all attempts at a solution, whether of the type of Kant's 'thing in itself' or of Lenin's dogma are unsatisfactory because they violate the principle of decidability."

The logic of "physical thinking" leads Born from an impossible experiment (the transfer of sensory perception between different individuals) to an experiment that can be performed, namely, the transfer to another individual of the result of my *comparison* of two of my sensory impressions received through the same sensory organ, say, the comparison of two colors, two tones, two temperatures, two quantities, and so on.

Born supposes that, having exposed this possibility of transferring two of "my perceptions" to another person, he has made a discovery that was lacking in previous and in existing philosophical systems, and which provides a solution to the epistemological problem.

After this, Born's thoughts run along the following lines: if I can transfer to another person some information about a perception (comparison) common to us, then we should be in a position to leave behind the subjective world and replace it by a world of symbols which can then be used as the means of communication between individuals. "Symbols are the carriers of communication between individuals and thus decisive for the possibility of objective knowledge."[3] These symbols can be used in various operations and can be associated with sense impressions. Born gives several examples of this association between impressions and symbols. Words can be associated with objects, letters with sounds, chemical symbols with elements, the length of the mercury column with the sensation of heat, groups of numbers (coordinates) with points in space, and so on, and so on. In fact, "in every field of experience this correspondence of sense impressions with symbols has been established. It suffices for the needs of ordinary life: the words and sentences of a language, whether spoken or written, corresponding to perception, emotions, etc., are learned and used without being further analyzed (naive realism)."

The situation in science and, especially, in natural science is quite different. "There, mathematical symbols are used, and they have a particularity: they reveal structures." Born explains: "mathematics is just the detection and investigation of structures of thinking which lie hidden in the mathematical symbols." These mathematical structures change their form with time. Since the time of Newton, they have had a "direct connection with experiences about ordinary things in daily life." Eventually, however, "very slowly and against violent opposition, the opinion spread that models were not only unnecessary, but even an obstruction to progress..." Nowadays, "we try to find the mathematics appropriate to a domain of experience, then we investigate its structure and regard it as representing physical reality, whether it conforms to accustomed things or not." Born does not define the epistemological position of "domain of experience," but it is clear from his account that this domain is still within the limits of sensations.

Perceptive readers of Born's epistemological credo could not but note that his entire account of physical methods of thinking is confined to an attempt to explain the origin of the means of communication between people, such as language, writing, and scientific method. The problem of the development of the means of communication is itself scientifically important, but specialists would probably say that the development of means of communication such as language, writing, art, and science cannot be regarded from the standpoint of physical methods alone: this point of view is too restrictive, and the development of means of communication must be discussed in the light of the historical transformation of homo sapiens into a social human being. However, we shall confine our attention to the much narrower range of purely epistemological problems.

In this context, we must note the following feature of Born's argument. Whereas, in the so-called naive

[3]Born emphasizes that only rough, i.e., topological, correspondence between symbols is sufficient for communication between individuals.

realism, the existence of reality outside Man developed on the basis of direct sensory perception, the situation in modern physics is quite different. The search for mathematical structures of thinking plays an important role in this area and, notes Born, the researcher enters the sphere of abstract concepts. "Here, the question cannot be eluded whether there is an objective world, independent of the observer, behind the phenomena."

Thus, according to Born, the question of the existence of an objective world naturally arises only when the researcher enters the sphere of mathematical abstraction. It appears that Born is beginning to be worried by the question: how can one evaluate the development of an abstraction?

However, none of the logical schemes developed so far (i.e., the transition from the subjectivity of sense impressions to the objectivity of experience, the association of symbols with sensory perceptions, and the transition from these to mathematical structures of thinking) can provide an answer to this question. Born himself, with the candor of a great scientist, confesses that he does not "believe that this question can be answered categorically by logical thinking." This is true: the question of the existence of an objective world cannot be resolved by logical thinking separately from the process of the acquisition of knowledge, which includes the practical activity of Man.

Nevertheless, as a major natural philosopher developing his own philosophical position, Born is forced to seek an answer to this question. An answer, moreover, that would not be in conflict with natural philosophy. In the end, he concludes that an answer to the question can be obtained. The problem is—how? Here, Born again discovers in modern physics a key to the solution of the basic epistemological problem, i.e., whether an objective world exists or not. He finds this key in the probability laws described by him in the section "Probability" of the chapter "Methods of Thinking in Physics."

Thus, the answer can be obtained if "we make use of the freedom to regard an extremely improbable statement as wrong. The assumption that the coincidence of structures revealed by using different sense organs and communicable from one individual to the other is accidental, is improbable to the highest degree."

By rejecting events of low probability, Born is thus led to the conclusion that "objective structures" have a chance of existing. He even challenges possible opponents and partly returns to Kant's terminology ("thing in itself"). His motivation for this is so interesting that we quote in full from Born's text:

"I am not afraid of identifying such well defined structures with Kant's 'thing in itself.' The objections quoted before in the formulation of Bertrand Russell have no validity from our point of view. They consist in the following: the existence of the 'thing in itself' is postulated because one needs an external cause to understand why different individuals experience 'the same' phenomena; but the category of causality has a meaning only within the domain of phenomena. However, the concept of causality is a residue of former ways of thinking and is replaced today by the process of coordination as described before. This procedure leads to structures which are communicable, controllable, hence objective. It is justified to call these by the old term "thing in itself." They are of pure form, void of all sensual qualities. That is all we can wish and expect."

Having taken exception to the Hegel critique of Kant's "thing in itself," which Hegel regards as a "perfect abstractum, the complete emptiness, just something from a world beyond," Born concludes that the "thing in itself" is, of course, an abstraction, but it can hardly be regarded as being from a world beyond since it must be remembered that practical use can be made of it in the production of things like engines, aeroplanes, nuclear reactors, and other earthly objects.

In his theory of knowledge, Born finds a place for the "Bohr principle of complementarity," which must also be looked upon as "another new method thinking." Born does not give a thorough discussion of the meaning and significance of this principle because this would lead him "beyond the frame of these considerations." However, he uses it in his epistemology. The point is that physicists must return from the world of abstractions to the world of images because they "are bound to describe the content of their abstract formulas as far as possible in terms of ordinary language with concepts based on intuition... Bohr has shown that it is possible to describe atomic processes with the "classical" concepts, provided one desists from investigating all properties of a physical system simultaneously. Different, mutually exclusive but complementary experimental arrangements are needed."

Having emphasized the necessity for a "return to images" from abstract structures ("thing in itself"), Born returns to the problem of subjectivity. He writes that the subjective element cannot be eliminated altogether, and produces two arguments for this. Firstly, it cannot be eliminated because the choice between the mutually exclusive experimental arrangements (and, consequently, between the concepts in terms of which abstract formulas are described) is made by the experimenter himself. Secondly, it cannot be eliminated because of the probability laws which are universal and overriding: "another *loss of objectivity* is due to the fact that the theory makes only probability predictions, which produce *graded expectations*. From our standpoint, *where subjectivity is primary* and the possibility of objective knowledge problematic, it is not surprising that the rigorous separation of subject and object is not possible if one tries to express the mathematical formalism with the aid of images" (our emphasis).

This completes the circle in Born's theory of knowledge. Subjectivity appears in this theory not only as the primary but as the overriding category. The "thing in itself" is revealed only in mathematical structures.

The only thing that remains unclear is how these abstract structures which are "pure forms" (of thinking?)

can be used to fabricate aeroplanes and other earthly objects. We shall return to a critique of Born's theory. For the moment, we conclude that the objective world has not, in fact, been directly and unambiguously acknowledged by Born in epistemology, the primary purpose of which is to substantiate the possibility of communication.

3. Difference between the basic positions in the two epistemologies: the method of philosophization, the nature of perception, and the concept of objectivity

We have considered the completed theory of knowledge of a major physicist, which is allegedly directly based on the most recent achievements of physics, and is "superior" to materialism and positivism. We are now in a position to consider precisely what this "third" philosophy amounts to. We shall base our analysis on the philosophy of dialectical materialism, a philosophy which Born peremptorily but unjustifiably dismisses.

We note, to begin with, that the difference between the initial positions of these philosophical systems reflects the difference between the methods of philosophization. Although Born states that his philosophy is founded on physical methods of thinking, his own method of philosophization is not distinguished by particular novelty. Berkeley considered questions such as: I perceive green but can this perception resemble anything but the perception of green? Consequently, since perceptions are my sources of knowledge, the entire world consists of perceptions and is limited to them. In his search for a basic philosophical position, Descartes adopts the same method but in another formulation: I think, therefore I am. The mind is the foundation of existence. In Born's theory, the source of knowledge is sensation, but sensations are not communicable and, therefore, are subjective, so that it is necessary to find communicable symbols, and this transition is justified by the principle of decidability used in physics.

This is the *formal-logical* method in which the foundations of philosophy are laid down by *thinking* about how *I* think, how *I* perceive, and so on.

Dialectical materialism, on the other hand, is based on the *historical-logical* method. It starts with the assumed existence of not only *I* as an individual thinking about philosophy, but also as a biological type that has existed for many thousands of years not only as a biological type with an extensive developmental history, but also as a type that develops in certain definite social forms producing a definite level of civilization, i.e., science, technology, and world outlook. Mankind not only thinks logically about the laws of thinking and about cognition, but it also *acts* on the basis of acquired knowledge, and does so purposely and successfully. The results of this can be seen at all levels of its existence and knowledge (since, otherwise, the type would not survive, nor would there be any progress of civilization, and these are undisputable). The science developed by mankind, which it must accept as real (since, initially, it was simply an accumulation of everyday experience transmitted from generation to generation, and subsequently became the basis of its civilization), has revealed to us a very extensive world, a world which existed before Man appeared on the scene and, in this sense, has always been independent of him. Archeology has demonstrated the reality of previous generations that lived under more primitive cultures; Pre-Cambrian geology deals with periods during which the earth's mantle was involved in the development and accumulation of enormous amounts of oil and gas, well before the emergence of Man, and, in our own time, Man has learned, on the basis of the results of this science, to *predict* the position of these deposits in the earth's interior, and actually find and extract them. Astronomy and astrophysics have described the development of solar systems and the different physical conditions on celestial bodies (with the essential help of physics), whilst biology has determined the necessary conditions (presence of oxygen, water, shielding from radiation, temperature and pressure excursions, and so on) under which Man can exist and which have not always prevailed. All this suggests that the earth (i.e., nature or the external world) existed before the emergence of Man and independently of him. Man emerged only when suitable conditions appeared for his existence, and these conditions are known to science. V. I. Lenin put forward these scientific conclusions as an irrefutable argument in favor of dialectical materialism.

It is precisely these conclusions that are generalized in dialectical materialism in the form of the proposition that nature (material world) is primary and consciousness is secondary. One cannot say, therefore, that the basic position of dialectic materialism is adopted as a dogma, without proof. This proof can, in fact, be seen in the entire history of development of Man, of his civilization, in the science developed by him, and in the many scientific disciplines, the conclusions of which are not only mutually consistent, but are confirmed by the practical *activity* of Man. How could a major modern natural philosopher bypass all this evidence?

Born concludes that most people have only naive views about the existence of the external world: "naive realism is a natural attitude which corresponds to the biological situation of the human race, just as that of the animal world. A bee recognizes flowers by their color or scent and needs no philosophy." But what is the consequence of all this? True enough, most people are not engaged in philosophization in the usual sense of this word. But their "philosophy" contains a basic element, namely, the acknowledgment of the existence of an external objective world. They do not give proofs of this, but these proofs reside in the results that have been achieved by mankind over many thousands of years, starting with these naive ideas. Therefore, whilst, in order to accelerate the further and deliberate development of mankind, it has been necessary to justify the possibility and to investigate the very process of cognition in relation to nature and social formations, philosophical thinking has, in fact, made use of this particular experience of mankind. "The naive beliefs of mankind," wrote Lenin, "are *deliberately* laid down by ma-

terialism as the foundation for its theory of knowledge."[4] It is precisely this step that has resulted in the logical clarity and effectiveness of the theory.

This is the essence of the historical-logical method of dialectical materialism, which contrasts with the formal-logical method adopted by Born.

However, this method obliges us to go further and to construct a theory of knowledge of the objective world in a way different from that used by Born and, above all, to interpret the source of knowledge in a different way.

There is no doubt, and this is a trivial thing to say, that sensations play an important role in the cognitive process. However, this role is understood in different ways in different philosophical systems.

In Born's epistemology, sensation is the primary, initial, and unquestioned starting point, and his entire epistemological system is constructed so that, initially, nothing is known about the external world, and the concept of this world arises at a later stage in the development of the theory. Sensation therefore appears as absolutely subjective, and this is, indeed, acknowledged by Born. But this unavoidably leads to the next step: if a physicist who has adopted this concept nevertheless does not wish to become a member of the league of solipsists (for whom science is a nonsense), then he must seek ways of communicating with the other "*I*'s" and, in this way, he develops the concept of objectivity which is then interpreted in a different way, i.e., not as the acknowledgment of the existence of an external world, but as *collective experience* or *universal significance*.

This is how objectivity is interpreted in Born's epistemology. The "epistemological discovery" which he made (the fact that the results of comparison can be communicated between individuals) does not take us outside the framework of sense impressions. Collective experience does not in itself mean the acknowledgment of the existence of an objective world outside Man. We have seen that, in his account of the positivist standpoint, Born notes in this connection that "all these theories are relying on the same assumption that the world of sensory perception is 'the same' for different objects." But this means that the concept of objectivity interpreted as the synonymity of the sensory perceptions of different individuals is logically compatible with positivism. Objectivity of *this kind* is assumed by positivists as self-evident and needing no justification, whereas Born elevates this concept to the rank of an epistemological category, and attempts to justify it by "physical methods." It is only by the answer to this cardinal question that the two approaches differ.

The interpretation of objectivity as collective experience of a number of individuals is not new. It is characteristic of all the positivist positions in philosophy, which substitute this interpretation for the materialist view of objective reality (nature existed before Man).

H. Poincaré, who was one of the protagonists of the idea of conventionalism in science regarded science as a system of ordering "the facts of perception," constructed on the basis of an agreed convention; he acknowledged, however, that this necessarily led to the question "If that is so, then what is the value of science?" His answer was: in achieving a *harmony of perceptions* among different people, at first among scientists and, ideally, among everyone. He saw conventionalism as an instrument for achieving this harmony. It is readily seen that the phrase "harmony of perceptions," and the value of science lies in the continuing tendency to achieve it, is, according to Poincaré, of the same order as the phrases "collective experience" and "universal significance of sensations."[5]

Niels Bohr devoted considerable attention to the analysis of the process of observation in atomic physics and all its properties, and was concerned, above all, with the conditions under which the description of observations by one researcher could be communicated to another.[6] In this communicability of descriptions, he saw the significance of objectivity, and the final point of his investigations, without trying to find a way to objective reality. Positivists have made excellent use of this approach to objectivity as an argument in favor of their ideas, whereas Bohr, who tended towards positivism and frequently appeared in company with its supporters in published collections of papers on the foundations of quantum mechanics, did not protest this situation.

At the beginning of this century, attempts were made to develop this idea of treating objectivity as collective experience by some theoreticians who were, at one time, in agreement with Lenin. Having reinterpreted the idea of objectivity, they tried to "modernize" Marxist philosophy. Thus, A. Bogdanov, in his "Empiriomonism" (1906) maintained that "objectivity of

[4]V. I. Lenin, Complete Works Vol. 18, p. 66 (in Russian).

[5]Incidentally, Poincaré's views on objectivity are clearly expressed. In the book, The Value of Science (1905), he wrote: "The sensations of another individual will always be a closed world to us. We have no way of establishing whether the sensation which I describe by the word 'red' is the same as that which is associated with the same word by someone else... On the other hand, we can establish whether both for him and for me the words 'cherry' and 'poppy flower' refer to the *same* sensation since we both give the same name to the sensations experienced in this case... . Thus, sensations cannot be transferred... . However, the same cannot be said about relationships between sensations... . We must admit that only entities that can be transferred are objective and, consequently, only relationships between sensations can have objective value." [H. Poincaré, The Value of Science, Dover Publications, New York (1958)]. Thus, 60 years before Born, well before the appearance of his "physical methods of thinking," Poincaré anticipated his ideas about sensation and objectivity.

[6]Niels Bohr, Selected Scientific Papers, Vol. II, pp. 282, 406, 483, 509, 528, 531, and elsewhere (Russian translation); see also Usp. Fiz. Nauk **76**, 21 (1962) [Address to Int. Congress on Pharm. Science, Copenhagen, 1960].

the physical series is its *universal significance*" (Book III, p. 25). Again: "The objectivity of the physical bodies we encounter in our experience is established in the last analysis by the mutual verification and coordination of the utterances of various people. In general, the physical world is socially coordinated, socially harmonized, in a word, *socially-organized experience.*" (*ibid.*, p. 36, Bogdanov's emphasis).[7]

However, collective experience or even "socially-organized experience" cannot in itself take us outside the framework of subjectivity and lead us to the objective world. In connection with Bogdanov's attempts to "modernize" Marxism, V. I. Lenin notes with irony that religion, which rejects objective reality, is also "universally significant" and "socially organized"; the source of Bogdanov's views is in fact the teaching of positivists such as Mach and Avenarius.

Scientific materialist philosophy cannot interpret sensation as anything but a link between the external objective world and the man perceiving it, i.e., as a result of the action of the external world on the receptors in the corresponding sense organs. Consequently, sensations are the sources of information about the external world. This means that the sensations that carry information about the external world are both *subjective* and *objective*. They are subjective because the receptors and the brain that analyzes their signals are part of a common physiological system in which the process of cognition takes place. They are objective because they carry the information from the external world. Positivists of all kinds and periods have put forward the subjective aspect as the only starting point of the theory of knowledge, whereas materialists emphasize the objective aspects of sensations without rejecting their subjective component. In "Materialism and Empiriocriticism," which is directed against positivism, V. I. Lenin pays very considerable attention to the objective aspect of sensations. "For every scientist," wrote Lenin, "who has not been led astray by professorial philosophy, as well as for every materialist, sensation is indeed the direct competition between consciousness and the external world; it is the transformation of the energy of external excitation into the fact of consciousness. This transformation has been, and is, observed by each of us a million times on every hand. The sophism of idealist philosophy consists in the fact that it regards sensation not as being the connection with the external world, but a fence, a wall, separating consciousness from the external world—not an image of the external phenomenon corresponding to the sensation, but as the sole entity."[8]

Of course, information from the external world passes through sensations but not in the form of a predication of, say, *green*, the subjectivity of which was emphasized by Born (and by Berkeley and Poincaré in the eighteenth and beginning of the twentieth centuries). It is the generalized forms of logical relationships that are transferred through sensations. These relations are of the type more-less, same-different, confirm-reject, appear-disappear, combine-separate, increase-reduce, and so on, and so on. The comprehension of this logic of the objective world is connected with the activities of Man and with the results that are important to him in his daily life. This is, of course, only the first step in the comprehension of the logical relationships of reality. Higher order logical relationships in the objective world are comprehended gradually, and the evolving character of the cognitive process eventually includes thinking and consciously purpose-oriented activity of Man. Nevertheless, the elementary logical relations in the external world are transmitted through sensations.[9]

It seems to us that ordinary daily experience clearly shows this connective role of sensations. The blind, deaf, and dumb Ol'ga Ivanovna Skorokhodova has no knowledge of the sensation of green or of the sound of music of which Born wrote with such emotion. Since her very early days, her channels of communication with the external world have been restricted to the sensations of smell, touch, and taste. Through these extremely restricted channels of communication, she has been able to learn about logical connections in the objective world: she has received higher education, is fully familiar with the structure of our society and its problems, with the achievements of science and culture, has written books and articles, is a Candidate of Pedagogic Sciences, and takes part in very considerable teaching and social activities.[10] Her logical connections with the external world are now much more complicated.

The necessary condition for achieving this very impressive result in a single lifetime was, of course, the presence of a normally functioning brain at a current level of biological development, and the help of specialist teachers who, in this case, included Professor I. A. Sokolyanskiĭ. In the history of mankind, this corresponds to the slow evolution of the brain, and the constant fight for survival replaces the didactic component. It is readily seen from the foregoing that the formal-logical approach to the analysis of the process of cognition immediately led Born to the positivist error in his interpretation of the nature of sensations, even though Born personally did not accept the positivist philosophy.[11]

4. Difference in the interpretation of epistemological problems

We thus have to face two different ways of interpreting objectivity, and epistemological problems are

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[7] V. I. Lenin, Complete Works, Vol. 18, p. 125 (in Russian).

[8] *Ibid.*, p. 46.

[9] Ludwig Feuerbach, the German materialist philosopher, understood this connection between sensations and objective logic. In the appendices to his work on Leibnitz, which dates from 1847, he wrote that reason was based in its conclusions on the evidence supplied by sense organs which gave the information about the properties of external things, their existence, identity, difference, and so on.

[10] She was awarded the Order of Red Labor Banner in 1974.

treated in accordance with this distinction. In Born's theory, the problem is how to achieve collective experience for all individuals. Essentially, the "physical methods of thinking" are used to resolve this problem; they include the comparability of sensations, the introduction of symbols, the association between symbols and sensations, and abstract structures of thinking. The principle of complementarity as a means of returning from abstractions to commonly accepted images is discussed as part of the same plan. If the question of "reality lying behind phenomena" arises in the course of all this, it appears not as the initial point and the final aim of cognition defining its pathways, but as a "thing in itself"—the name of an abstract structure; and although it is admitted that it is used to manufacture earthly things, it does appear as a subjective expectation, thus losing its objective status, and cognition again returns to sensory imagery.

The problem facing the epistemology of dialectic materialism is different. This is precisely because this theory is founded on the acknowledgment of the existence of an external world, and the problem is to establish a satisfactory picture of this world on the basis of the interactions with it at the different stages of the process of cognition, and the different levels of understanding of the nature of things.

Of course, we cannot give here a detailed exposition of the theory of knowledge of dialectical materialism, but we must, nevertheless, note at least some of its features and the problems which it solves. This will help us to elucidate the difference between the formulations of problems in the two theories that we are considering.

The philosophy of dialectical materialism looks upon cognition as an infinite *process* of deepening our knowledge of *objective nature*, a process of transition toward increasingly profound knowledge of reality. In this process, knowledge passes through a series of successive *cycles*, each of which begins with the establishment of a set of experimentally justified relations in which the as yet unexposed essence is *manifested*. The set of such relations appears as a set of *phenomena* in relation to the essence which is still to be exposed. Each cycle involves its own phenomena and, correspondingly, transitions to its essence. The sequence of essences of different order is a reflection of the increasingly profound relations involving a given object. Each phenomenon is the *result of the interaction* between the given object and some other object (which can be a "physical arrangment"); it exposes the object to some extent, but not as one whole and only in some particular respect. The object under investigation therefore appears to the researcher not as some "object in itself" with "pure properties in itself," but through the set of interactions with other objects (through the set of phenomena). It is precisely this that is responsible for the complexity of the path to the object, and for the abstract character of the resulting image of the object.

All phenomena at a given level of knowledge (at the beginning of the epistemological cycle) are formulated in terms of the concepts of the *existing* level of knowledge, which are *definitely not adequate* for the new and more profound level of essence. The transition from phenomena to essence is accomplished through a synthesis of a set of "most essential" phenomena, and this involves a *search for the conditions of logical compatibility of a set of phenomena of different kinds*. The formulation of these conditions of logical compatibility of phenomena is then the *theory* which is the *image* of the essence under investigation. The epistemological cycle terminates with a verification of the adequacy of the resulting theory. The *criterion of adequacy*, according to the materialist theory of knowledge, is the *practical activity* of Man based on the knowledge formulated in the theory.

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[11]We are bound to note that we cannot agree with the evaluation of Born's treatment of the nature of sensations, given in the name of Marxist epistemology by Professor Heinrich Vogel of Rostock University (German Democratic Republic). In his book on Max Born, he devotes a chapter to Born's paper which we have been discussing here, and writes as follows: "The interesting and striking ideas developed here are not in conflict with the views of dialectical materialism on these problems. On the contrary! Marxist epistemology starts with the fact that *sensations are subjective and have no true content* (und ihren kein Wahrheitsgehalt zukommt). Only the pronouncements of the corresponding theory (as a system of pronouncements) can be true or false. And they reflect the state of things. Nothing can be said about a single sensation. *Nothing can be derived from it.* The objective content of sensory perception is brought out by thought only in the course of comparison; it is then freed from subjectivity and is made objective in language. *This is, in fact, the epistemological foundation and justification of the fundamental philosophical conclusions about the existence of objective reality* which subsequently finds its specific expression in dialectical materialism as the abstract concept of matter. It is precisely this basic theoretical-epistemological position which states that *objective knowledge can be obtained from a large number of sensory perceptions* that was repeatedly emphasized and defended by Lenin (in "Materialism and Empiriocriticism"—S. S.)" (see: Heinrich Vogel, Physik und Philosophie bei Max Born, VEB Deutscher Verlag der Wissenschaften, 1968, p. 103; our emphasis). It is clear from our own discussion in the main text that the interpretation of the nature of sensations given by Lenin is quite different from that given by Born and by Vogel. "The epistemological foundation and justification" of the existence of objective reality does not lie in the comparison with the "content of sensory perception" as stated by Born and Vogel. It is clear from the above quotation and from the text following it (for example, from the identification of the concept of "symbol" in the case of Born with "image" in Marxist philosophy) that Heinrich Vogel completely accepts the philosophical position of Max Born and recommends it allegedly in the name of Marxist philosophy. In actual fact, Marxist philosophy gains nothing from this unjustified attempt to associate it with the eminent scientist. As far as Born himself is concerned, he had already publicly protested against the analogous attempt by Heinrich Vogel in other cases [cf. Max Born, Die Physik und die Ismen, Gespräch mit M. Born und H. Vogel, Phys. Bl. **7**, 341 (1961)]. When the present author was asked to write a postscript to the Soviet edition of a collection of papers by Max Born [Physics in My Generation (1963)], Born was very concerned that he should not be presented in this postscript as a follower of dialectical materialism. There was, in fact, no objective foundation for this concern.

Even this relatively schematic comparison of the two theories shows how different are the two directions of evolution of knowledge.

For Born, this is a return, with the aid of the principle of complementarity, to familiar images expressed in classical terms as applied to the readings of macro-instruments. Born regards this return as the great achievement of the principle of complementarity. But the images of what is observed in macro-instruments are illusory and do not have the same significance for all; they also form an abstraction, but at a different level, and Born frequently noted this fact in many of his papers. Moreover, Born's theory is essentially closed in that it does not indicate ways of further extension of knowledge, or ways of return of knowledge from still more profound abstractions (when essence of higher order has been exposed) to the images of classical physics, since it does not indicate how the principle of complementarity would operate in this case.

The advance of knowledge is presented in a different way in the epistemology of dialectical materialism. It is directed toward discovering the image of an object, and is accomplished in cycles in each of which the essence of a particular order is discovered, and adequate theories confirmed in practice are developed. Of course, the adequacy of a theory is a relative concept; it signifies a correspondence between the theory and the objective essence of a given level. When a set of new phenomena has accumulated, and a transition to the essence of a more profound level becomes necessary, these theories (concepts, images) turn out to be inadequate for the new essence. However, the advance of knowledge overcomes this inadequacy. It penetrates inward, and the process of the evolution of knowledge never ends but is directed toward a continuous improvement of the image of objective reality.

By discovering the laws governing the extension of knowledge and by overcoming the associated contradictions, we are, in fact, formulating a theory of knowledge, discovering the "mechanism" that ensures the adequacy of knowledge, and finding the answer to a number of topical epistemological problems that arise in the very development of natural philosophy.

II.

Particularly acute epistemological problems arise in science whenever it undergoes a transition from one level of knowledge to another, more profound level. Such periods are characterized by a growth in the number of "anomalies" and "paradoxes," epistemological crises arise, and problems of cognition are actively discussed. We shall consider some of these problems. This will enable us to obtain a clearer picture of the difference between the methods and the solutions in the two epistemologies which we are discussing.

5. Discussions with Einstein. Principle of complementarity

The physics of the middle nineteen-twenties had to face the acute problem of describing the complicated and totally nonclassical character of microparticles which had both discrete and wave properties. There were many well-known attempts to picture this complicated character in terms of only discrete or only wave structure. But although such attempts were undertaken even by major physicists (for example, E. Schrödinger), they were always unsuccessful.

Bohr tried to find the solution to this problem by concentrating his attention on the process of *observation* which he considered a major problem for the theoretician. The process of observation of quantum phenomena, he noted, always took place under definite experimental conditions created by a classical experimental arrangement. Descriptions of these arrangements always involved only classical concepts which, incidentally, created the necessary conditions for communicability. The discrete and wave pictures, pointed out Bohr, were realized in experimental arrangements that belonged to two mutually exclusive classes which were never encountered together. However, both pictures had to be taken into account in a complete description of microphenomena, so that they appeared not only as mutually exclusive but also as mutually complementary. This is the principle of complementarity.

Bohr used the principle of complementarity in his argument with Einstein who tried to refute the principle of uncertainty which forbade the simultaneous precise determination of both the momentum and position of a microparticle. Einstein devised thought experiments designed to measure by indirect methods the simultaneous values of p and q, which he regarded as classical quantities. Bohr then analyzed the proposed experiments and, in each case, showed that the principle of complementarity helped to resolve the problem: if, for example, the position of the point of collision between a microparticle and a stationary part of an instrument is determined, the momentum transferred to the support becomes uncontrollable.[12] Any attempt to control the momentum in the course of the collision (which would require the use of a mobile part of the instrument as the target) leads to lack of control of the position of the point of collision. Einstein then devised a new thought experiment and Bohr again analyzed the situation and again determined which of the two conjugate quantities became uncontrollable.

The discussion did not satisfy Einstein. It was not logically complete because it was empirical in character. Both sides proceeded as if a quantum particle *possessed* classical momentum and coordinates, but only Bohr considered that the mutually exclusive nature

[12] Describing the case where the "spatial reference system" in which the collision of the microparticle has been defined, Bohr wrote: "The momentum transferred by the particle to the slit and to other parts of the instrument will then be taken up by their common support. Thus, in this case, we deliberately abandon any possibility of taking into account the reaction of the particle on the individual parts of the instrument, or of including these reactions in our predictions....." [N. Bohr, Selected Scientific Papers, Vol. II, p. 183 (Russian translation)].

of the experimental devices was such that it was impossible to establish simultaneously (in a given experiment) both the momentum and position, whereas Einstein did not consider this exclusion to be absolute and tried to find ways of obviating it, for example by indirect measurement.

The fact that the discussion of this problem proceeded in the language of classical concepts, and that it was precisely in this way that all physicists understood it, will be confirmed by two further examples.

In his article "Symbol and Reality," Born looked upon the principle of complementarity as a method permitting a return from abstract mathematical structures to the world of images. This return to the world of images was regarded by Born as essential. However, classical concepts operate in this "world of images," and so the return to this world involves precisely the return to these concepts. The application of the principle of complementarity which dissects the complicated quantum picture of the phenomenon and reduces it to classical pictures is, in fact, a basis for believing that, in the collision of a microparticle, we are, in fact, dealing with classical momenta and coordinates and not with some more complicated categories.

Another piece of evidence can be found in the critical remarks of V. A. Fock. In his paper published in 1955 Fock wrote: "Bohr states that, when the coordinate x can be well controlled, the momentum p is uncontrollable ('the balance of momentum cannot be controlled because the momentum is taken up by the support'). This mode of expression may be an echo of the old point of view in which x and p 'basically' always have definite values but, as a result of some quirk of nature (uncontrollable interactions, and so on), cannot be observed simultaneously.... Thus, the concept of 'fundamental uncontrollability' must be regarded as incorrect."[13]

Thus, "the momentum is taken up by the support", and the process of collision of the microparticles occurs at the classical level. It is clear that V. A. Fock also concludes that these ideas are present in Bohr's arguments.

Naturally, Einstein, who argued in the same key, had his own justification for his searches for ways of realizing control of the momentum taken up by the support. It is important to note that Bohr did not abandon the idea of uncontrollability even after his discussion with V. A. Fock whom he met personally in 1957.[14]

He unreservedly retained the concept of complementarity which, as before, contained the classical concepts in their separated form, so that the loss of control of one of the conjugate quantities remained unavoidable.[15]

The principle of complementarity can be contrasted with the fruitless attempts to reduce the description of quantum phenomena to some single picture. In this respect, it has played a positive role. From the epistemological point of view, it is undoubtedly superior to the principle of reduction because it implies, although in a very restricted sense, the synthesis of two phenomena, an approach which is entirely excluded by the concept of reduction. However, it was put forward as an empirical rule, external to the complete epistemological theory without which many problems remain unresolved, including the problem of the trransformation of concepts, so that the dispute with Einstein also remained unresolved.

We must now consider this dispute in the light of materialist epistemology and, as a preliminary, we shall show how this epistemology resolves the problem of the advance of knowledge, the transition from the old to the new.

6. The problem of new knowledge. Ways of transforming concepts

The discovery of the laws of atomic physics led to the following acute problem: how is it possible to acquire new knowledge if the instruments of this acquisition are concepts formulated in the analysis of the old and, therefore, inadequate for the new? The inadequacy of the concepts of classical physics in the atomic field was accepted by Bohr and Heisenberg. Let us recall their views.

In "The Unity of Human Knowledge" (1955), Bohr wrote: "The most important point that one must be clear about is that any new knowledge appears to us in the envelope of old concepts adapted for the explanation of previous experience, and that any such envelope may turn out to be too narrow for the inclusion of new experience."[16]

However, this hardly troubled Bohr. He concentrated his epistemological analysis exclusively on the processes of observation. This process is always realized with the aid of classical instruments, and its results are described in classical concepts. Reviewing his discussion with Einstein in 1949, Bohr wrote: "However far the phenomena depart from the framework of classical

[13]V. A. Fock, "A Critique of Bohr's Views of Quantum Mechanics," Czech. J. Phys. 5, 4 (1955). V. A. Fock published this paper again in 1958 in: Filosofskie voprosy sovremennoĭ fiziki (Philosophical Problems of Modern Physics), Gozpolitizdat, Moscow. This time, the paper included a note stating that it contained the opinion of the author about Bohr's views as indicated in his papers up to 1948, inclusive. However, this reservation does not affect our discussion.

[14]In his "Reminiscences of the Founder of Nuclear Science," which appeared in 1961, Bohr again indicates that the application of the "general conservation laws of momentum and energy" is limited because "any experimental arrangement... implies a transfer, uncontrollable in principle, of momentum and energy to the fixed scales and regulated clocks." N. Bohr, Selected Scientific Papers, Vol. II, p. 578 (Russian translation).

[15]In a paper published in 1955, Fock wrote that the "Bohr concept of complementarity taken as a whole is unacceptable and must be rejected"; however, after his meeting with Bohr, he admitted it, but continued to argue against the idea of uncontrollability."

[16]N. Bohr, Selected Scientific Papers, Vol. II, p. 481 (Russian translation).

physical explanation, all the experimental data must be described with the aid of classical concepts."[17] These views are in agreement with his treatment of the idea of complementarity.

The idea that knowledge is restricted to classical concepts was expressed more sharply by Heisenberg. In his lectures, "Physics and Philosophy," delivered in 1955–1956, he maintained that "the Copenhagen interpretation of quantum theory begins with a paradox. Every physical experiment, whether it refers to phenomena in everyday life or to phenomena in atomic physics, must be described in terms of the concepts of classical physics. The concepts of classical physics form a language which we use to describe our experiments and results. *We cannot replace these concepts by other concepts* and their applicability is restricted by the uncertainty principle. We must bear in mind the restricted applicability of classical concepts *instead of trying to go outside the framework of this limitation.*[18]

Heisenberg's description clearly expresses the permanence of this situation. We can operate only with classical concepts which remain unaltered. This is a consequence of two influences. On the one hand, cognition reduces entirely to the process and the result of *observation* which is accomplished with the aid of classical instruments. On the other hand, the view of the process of cognition established in physics demands that, before a theory is developed, a rigorous definition must be given of the concepts deployed in the theory. Operationalism even requires that each concept must be associated with some precise experimental operation. Concepts defined in this way must, of course, become rigidly constant in all operations involving them. Such concepts would, in fact, create much too narrow a framework and would not be capable of imaging a new area of knowledge.

However, the real process of cognition through observations of instrumental readings does not end but merely begins, unavoidably passing through the entire epistemological cycle. In this process, which is accomplished dialectically, the narrow framework of initial concepts is disrupted, and the concepts not only do not remain unaltered but are actually *transformed*. This process of transformation of concepts is realized *in the course of development of the theory*, and proceeds without consciously directed action.

In point of fact, in the development of quantum mechanics in its matrix form, Heisenberg made use of the classical concepts of coordinates and momenta, the same concepts that were involved in the experimental situations and in classical Hamiltonian equations. All the operations which he himself (and, subsequently, in collaboration with Born and Jordan) carried out were confined to the classical framework, except that a quantum condition was imposed upon them. All the concepts continued as if they were the initial, i.e., classical, concepts.

However, having analyzed the resulting mathematical apparatus of the theory, Born was surprised to see "the strange formula $pq - qp = h/2\pi i$," i.e., a commutation relation," which lay outside the framework of classical physics. Instead of the numerical values of p and q, there were now the more complicated formations for which the *order* in which they were written was important, and which were called *operators*. It is, however, important to note that they are genetically related to the original categories. A class of new categories—the operators—thus appeared in quantum mechanics.

The transformation of concepts was unexpected, but the reasons for it are readily understood. The process of development of a theory involves the search for and formulation of the conditions of logical compatibility for a set of certain experimentally confirmed relations. These initial relations are, of course, formulated at the level of *existing* knowledge, and this formulation involves the use of concepts connected with this level. Other concepts do not exist at this stage, so that it is not necessary to associate this fact with the use of classical instruments. When, however, these relations are linked logically, this unavoidably involves a transformation of the content of the concepts. The realization of the requirement that the initial relations be taken together—and this means the development of a theory of the phenomena—coordinates all the concepts into a common system, relates them, and thereby adapts their content independently of whether or not this is realized by the theoreticians.

At this point, it is useful to emphasize the epistemological significance of theory. It is well known that positivists of all kinds maintain that theory is merely a method of ordering the "facts of sensation" and that it does not yield anything new insofar as knowledge is concerned. It merely provides us with a mnemonic, an "economical" method of recording these "facts of sensation" (Mach), or it is an ordered "catalog" which facilitates the use of the "library" of facts but adds nothing new to it (Poincaré).

In point of fact, theory is an important stage in the process of cognition. It does not catalog the facts, but actively exposes profound relations between phenomena that are not immediately obvious, and transforms the content of concepts. The development of a theory is a complicated process which consists not in the adaptation of new discoveries to existing ideas but in the discovery and formulation of the conditions of logical compatibility of a set of experimentally verified relations, the result of which is a radical transformation of the previous ideas.[19]

[17] *Ibid.*, p. 406.

[18] W. Heisenberg, Physics and Philosophy, Harper & Row, New York, 1958 (Russ. transl., M., 1963).

[19] It is appropriate to remind the reader how insistent V. I. Lenin was on the importance of evaluating all experience together, avoiding the use of special hypotheses in order to ensure agreement between a particular experiment and existing ideas [see V. I. Lenin, Collected Works, Vol. 29, pp. 191–192 (in Russian)]. These writings of V. I. Lenin are considered in a paper by the present author, entitled 'Lenin's theory of knowledge and physics,' Usp. Fiz. Nauk **100**, 537 (1970).

It is clear that the theory itself develops in the course of this process and emerges as a logical interrelationship between the transformed concepts. It becomes the starting point for new theoretical representations. Thus, in quantum physics, theory appears not as a relation between numerical values of physical quantities, but as a relation between definite physical operations. It is thus raised to a higher level of abstraction, and begins to develop the operator calculus in which the wave function itself is given the significance of an operator.

Concepts are thus transformed in the very process of development of the theory because the latter evolves as a condition for the logical compatibility of the original and experimentally verified postulates. All this is, of course, valid only provided the reality of the theory has been demonstrated, i.e., the fact that it provides an adequate description of the external world.

All this leads to two conclusions. One is quite general: the researcher is not confined to a circle of permanent classical concepts which enter at some initial stage of the process of cognition as initial and restricted. The development of science does not cease so long as there is a continuing expansion of the relation between Man and nature. Contrary to Heisenberg's statement, science overcomes the limiting character of the initial concepts and thus extends the scope of knowledge.[20)]

The other conclusion is concerned with Einstein's position in his discussion with Bohr.

One cannot operate with the concepts of momentum and position of a microparticle as if they were classical concepts, and then devise thought experiments designed to measure them at a given time, because the interpretation of the symbols p and q in quantum theory is different. Einstein's position would be more correct if he were to argue against experiments which lie at the basis of quantum theory, by indicating their inconsistency and by looking for errors in the course of development of the conditions for the logical compatibility of the results of these experiments. However, he clearly recognized that this could not be done; the method used by him, on the other hand, conflicted with the scientific theory of knowledge.

Einstein's critique can be refuted by a method based on the theory of knowledge, which is uniquely valid but can be used only with a correct understanding of the entire process of cognition, including, in particular, an understanding of the relation between concepts and theory. We have already noted that Born had a kind of intuitive understanding of the epistemological role of theory. Thus, in his Nobel Prize lecture (1954), he stated: "If the theory is correct, and we have sufficient grounds for believing this, then the obstacle to the simultaneous measurement of position and of motion[21)] (and of other similar pairs of the so-called conjugate quantities) must lie in the laws of quantum mechanics itself. This is undoubtedly so, but this fact is not so obvious."[22)] Unfortunately, Born did not develop this idea. He did not place it in relation to the entire process of cognition and, having noted that "this fact is not so obvious," he immediately proceeded to an exposition of Bohr's argument about mutually exclusive experimental arrangements. We know, however, that these arguments provided Einstein with a basis for his search for other solutions.

7. Epistemological cycle as a key concept in cognition

We have already stated that the epistemology of dialectical materialism exposes the fact that the advance of knowledge is achieved in cycles. It is extremely important to take this into account if we are to understand the relations between the different epistemological categories. We cannot discuss this in detail here and will confine our attention to the most important points.

The essential point is that each epistemological cycle is completed through practical activity based on received knowledge—by checking the adequacy of knowledge. This removes the contradictions that unavoidably arise in the acquisition of knowledge, and results in a relative state of completion of knowledge that is reflected in a closed system of concepts, a theory. An adequate theory exposes the image of the object, its relative essence. However, further advance of knowledge violates this relative completeness, generates new contradictions, and the entire epistemological cycle is repeated at a new and more profound level. "Man's thought becomes infinitely more profound between phe-

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[20)] In later years, W. Heisenberg frequently discussed the question of the "development of concepts in twentieth-century physics" [see, for example, the Russian translation of his 1973 paper in Voprosy Filosofii No. 1 (1975)]. However, here, we are concerned with a different aspect of this problem. Noting the undoubted fact that physics is becoming increasingly abstract, that the idea of finite constitutive elements of matter is collapsing, and that ideas such as "fundamental symmetries," invariance, and so on are becoming more popular, Heisenberg tends to the view that the development of physics has "turned away from the philosophy of Democritus and toward the philosophy of Plato," and that "in the final analysis, we shall arrive not at some very small particles but at mathematical objects defined in terms of their symmetry. The particles of modern physics, on the other hand, are mathematical abstractions of fundamental symmetries."

The questions discussed by Heisenberg require separate analysis, especially because his historical parallels are extremely tendentious since Democritus is known in the history of philosophy as a materialist and Plato as an idealist. We cannot discuss these questions in the present paper. It will be sufficient to note that, in the same paper, Heisenberg maintains that, in the new situation, physicists have abandoned searches for some new generalized logic: "Over a period of many years, physicists have become used to the restricted application of old concepts such as waves, particles, positions, velocities, and so on, and clearly recognize that this terminology has a restricted sphere of applicability. These limitations are imposed by the uncertainty relationship" (see also *ibid.*, p. 84). These are, in effect, the same ideas that are discussed in our main text.

[21)] Both the German and English texts state this; this is probably an error: what is meant is *momentum*.

[22)] Max Born, Physics in My Generation, Springer-Verlag, New York (1969) (Russ. transl., IL, M., 1963 p. 313).

nomena and essence, between the essence of, so to speak, first order and the essence of the second order, and so on without end."[23]

It follows from this proposition of the epistemology of dialectical materialism that knowledge of an object is expressed in a series of theories, the successive members of which generalize instead of refuting the preceding members. As a matter of fact, the geometry of the nineteenth century and the physics of the twentieth have shown that the generalized theory reverts to the theory reflecting the preceding level of knowledge of the object for certain limiting values of characteristic parameters.[24]

It is essential to emphasize the role of the epistemological cycle as the *only path* toward the image of objective reality. It is particularly important to recognize this function of the cycle in those areas of knowledge in which objective reality is manifested only in very intermediate fashion and is described in terms of extremely abstract forms (for example, in microphysics and political economy).

To demonstrate this, let us return to Einstein's critique of quantum mechanics. In a well-known paper published in 1935, Einstein and his co-authors gave the following definition of the completeness of physical theory: "... It seems to us that any complete theory must satisfy the following requirement: each element of physical reality must be reflected in the physical theory. We shall refer to this as the condition of completeness."[25] If we regard this as a statement that the theory of an object and the object itself must correspond to one another in all their elements, then no objection can be raised against it. There is, however, the unavoidable question as to how this correspondence can be established, i.e., whether the theory is constructed on the basis of known elements of the object or whether an adequate theory is used to judge the image of the object. This question is of fundamental epistemological importance. Einstein and his co-authors used this condition as a basis for their conclusion that quantum mechanics did not satisfy the condition of completeness since it did not allow one to establish the simultaneous values of momentum and position of a micro-object which could, in principle, be measured (although indirectly), and for these reasons, they considered that physical theory must be constructed in accordance with the elements of the objects. This looks like being in the spirit of materialism: theory is regarded not as a voluntary creation of the theoretician, who organizes the world in accordance with his ideas, but a direct copy of external things.

The question is, however, where do they get their ideas about the definite structure of the micro-object prior to the creation of the theory referring to it and without an analysis of all the experimental relations characterizing its interactions? There is only one source: it is the result of the transfer of those ideas about the macro-object that were created at the preceding level of knowledge.

It is precisely the notion of an object developed at the level of macroscopic physics that led Einstein to his futile searches for simultaneous and mutually independent values of classical coordinates and momenta for the micro-object. In precisely the same way, the notion of idealized abstract determinism, formed in classical physics and excluding objective randomness, was interpreted by him as a universal and unambiguous form of relationship that was valid even in the world of microparticles.

These are some of the most prominent and widely known examples. The history of physics includes quite a number of such unjustifiable transfers of notions taken from an old field of knowledge to a new field in which they are no longer valid in their existing form. Such transfers impede the development of new theories, especially if they originate from influential scientists who have made considerable contributions to the development of science. They are based on ignorance or disregard of the scientifically based theory of knowledge and on intellectual conservatism from which even major scientists can suffer.

In general, an object (microparticle) does not face the theoretician in the way that a model poses in front of a sculptor. There is no real possibility of establishing its elements prior to the formulation of the theory. The interrelation between the structure of the object and the structure of the theory cannot be understood without analyzing the very process of formation of the theory, and the path to the structure of the object lies in this process. The theory is, in fact, developed gradually by investigating the interactions between the as yet unexposed object and other objects (instruments), and by establishing the conditions of logical compatibility for the results of these interactions. Any lack of correspondence between the structure of the theory developed in this way and the structure of the object is then taken as evidence for the inadequacy of the theory in a particular respect, so that a more precise formulation of the conditions of logical compatibility of the set of experimental assumptions of the theory has to be established, this set is then improved and extended, and so on, i.e., the entire process leading to the formulation of the theory must be re-examined, improved, and corrected. The final result of this process is the emergence of an adequate (for the given level of knowledge) theory which is then justifiably referred to as having a structure that corresponds to the structure

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[23] V. I. Lenin, "Philosophical notebooks," Complete Works, Vol. 29, p. 227 (in Russian).

[24] Physicists have felt their way toward these theoretical relations in an empirical fashion by looking for ways of solving problems in quantum mechanics, and formulated these relations in the form of the correspondence principle. The relation between this principle and the epistemology of dialectical materialism was first discussed by the Soviet philosopher, I. V. Kuznetsov, in his book Printsip sootvetstviya v sovremennoĭ fizike i ego filosofskoe znachenie (The Principle of Correspondence in Modern Physics and Its Philosophical Significance), 1948.

[25] "Can the quantum-mechanical description of physical reality be regarded as complete?" Albert Einstein, Collected Scientific Papers, (Russian translation, Vol. 3, p. 604).

of the object.

The fact that there is no way of knowing the object of modern physics independently of theory was subtly noted by Born and was used by him in his own way. This is clear from his remarks about a paper by the present author.[26] Born called attention to the statement in that paper that "in Marxist philosophy, theory can equally well be regarded as an image of objective reality." Born praised the paper as a whole (he read it in English in the American edition of the present journal) but, nevertheless, noted, not without a measure of malice, that "one can speak about the image if there is some knowledge of the so-called object that is independent of the image (i.e., of the theory—S. S.). This is why I think that the Marxist view is quite groundless" (letter to the present author dated November 18, 1966).

In his interpretation of theory as an image of objective reality, Born searches for some weak points in order to demonstrate that the Marxist view is groundless. To this end, he suggests to us that theory can be thought of as an image, and that it can be developed by a method similar to that used by a sculptor to produce a portrait of a model in front of him. However, we interpret the development of a theory as a complicated process of cognition passing through a number of stages—the epistemological cycle—and it is only after the completion of this process that an adequate theory emerges and can be justifiably called the image of objective reality. Born's argument becomes meaningless when the development of theory is understood in this way.

The above examples illustrate the essential role of the epistemological cycle as a complete process that includes the advance of cognition from phenomenon to essence, in which the investigation begins with the establishment of the results of interaction of the still unexposed object (formulated in terms of concepts of the language corresponding to the preceding level of knowledge), and the search for the logical compatibility of these results (in which the concepts are transformed). The theory obtained in this way is then checked for adequacy (through practical activity) and, if found to be satisfactory, it expresses the adequate image of objective reality.

Each stage of the process and its completion right up to the image of reality are important, and this means that the epistemological cycle is the complete process of cognition, the key concept of cognition.

8. Permanence in epistemology and new problems

The twentieth century has seen a transition of physics to a new level of knowledge, in accordance with the transition from the macro- to the microworld. It is now clear that its further development will involve other transitions that will be accompanied by the transformation of conceptual systems. Such transitions are very painful, as has been well demonstrated by the development of physics up to the present time. It is also clear that scientific epistemology can only play its role as a theory of knowledge during such troubled periods of transformation of science if it provides researchers with clear guidelines for their thinking at all stages of the process of cognition, which are generalized and, therefore, adequate for all transitions, both those that have already been completed and those still to come. It is useful to emphasize once again this permanent generalized method of scientific epistemology.

Firstly, we note that "... recognition of the external world and the reflection of it in the human mind form the basis of the theory of knowledge of dialectical materialism."[27] Whatever the development of science and however abstract the forms adopted by physical theory, this proposition will always be the point of departure of genuinely scientific epistemology. It is a summary, a generalization, of the development of the human thought, and is thus a historically justifiable *premise* of scientific epistemology (and not a probabiltistic assumption). In this proposition, V. I. Lenin briefly formulated (1908) the essence of materialism, having directed this formulation against the revision of Marxist philosophy that was being carried out under the banner of empiriomonism, a variety of Machist philosophy. We note, by the way, that it is clear from this proposition how simplified is the exposition of the essence of materialism given by Born, who describes Lenin as being concerned with making sure that Marxist philosophy is made to correspond to the results of modern physics and interprets the old term, "matter" in "such a general way that nothing of its meaning is preserved" (see p. 643). However, neither Marx nor Lenin ever tied down the essence and fate of materialism to particular notions about the structure of physical reality.

Secondly, the recognition of the external world and its reality are confirmed through a process which we have called the epistemological cycle and which includes a number of stages. The advance of this recognition from the perception of the external world to the determination of the laws of physical reality (from phenomena to essence) has been exposed in its logical aspect by scientific materialist epistemology, and this method retains its significance for all the transitions from one level of knowledge to another, both those that have already been completed and those still to come. It is this that has been achieved by thought and is an inalienable part of scientific epistemology.

The universality and completeness of the epistemology of dialectical materialism are of enormous importance. Many eminent scientists have made pronouncements of epistemological character—on the value of theory, on its confirmation by experiment, and many other topics. These can and should be accepted as compelling evidence for the living process of cognition. But they are fre-

[26] S. G. Suvorov, "Einstein's philosophical views; their relation to his physical viewpoints," Usp. Fiz. Nauk 86, 537 (1965) [Sov. Phys.-Usp. 8, 578 (1966)].

[27] V. I. Lenin, "Ten questions to a lecturer," Complete Works, Vol. 18, p. 5 (in Russian).

quently fragmentary and mutually unrelated, and are not intended as part of a systematic theory of knowledge. The fragmentary and occasionally contradictory character of these pronouncements is, of course, quite natural because epistemology is a particular area of knowledge requiring at least as much preparation and expenditure of energy as any other science. The influence of bourgeois ideology is also found to impede its mastery.

Physicists have been forced to consider epistemological problems to gain some understanding of new phenomena, and have analyzed them as problems that arose in the course of the transition from macro- to microphysics, i.e., in the light of the encounter of two adjacent levels. Hence, the "principles" enunciated by them have an empirical ring. For example, in situations in which the principle of complementarity is used, a complex *microprocess* is resolved into two mutually complementary pictures that can be described in the language of *classical* concepts. There is no shortage of announcements about the possibility of extending this principle to biology, psychology, and other sciences, but it is still not clear whether this principle can be used and, if so, how this can be done in the analysis of the transition from the microworld to the submicroworld.

It is only the scientific (i.e., dialectical-materialist) theory of knowledge, taken as a whole, and not the fragmented solutions of particular problems, that throws light on the *path* of the advancement of knowledge, and it is precisely this path, and not the solutions of particular problems in the structure of the material world, that lies within the scope of physical sciences.

The foregoing remarks about the universality of the materialist basis and the epistemological cycle in the scientific theory of knowledge are not in any way intended to suggest that all the problems of cognition have been solved in this theory. On the contrary, there are existing and continuously emerging new epistemological problems that require further investigation, of course, on the basis of the original propositions of the dialectical-materialist epistemology.

Here we have space to mention only some of these problems. One is the problem of the relation between the *form* and the *content* of knowledge. In Marxist theory, the solution of this problem in a general form seems clear: the form of knowledge is determined by the internal structure of the content and is subordinate to it. Only this solution is compatible with the main problem of natural philosophy, namely, the problem of representing the properties of an objective natural process. However, the literature still frequently emphasizes the role of the subjective factor in cognition, the conventional character of the basic propositions of the theory, and the freely chosen forms of description of phenomena. The conventionalism of Poincaré dies hard. It is well known that Poincaré discussed the problem of the relationship between geometry and physics. He regarded geometry as the form of the representation of physical phenomena. He regarded this as a matter of agreement, and gave preference to Euclidean geometry as being the simplest and most convenient. Poincaré was thus essentially concerned with our problem, i.e., the relationship between form and content. He solved this question through the conservation of form, i.e., its independence of content: whatever the levels of knowledge of nature reflected by physics, the most convenient metric is the simplest, Euclidean, metric. Born's theory of knowledge, which adopts the idea of complementarity, incorporates the idea of the unavoidable return to images and thus to classical concepts. Here again, the form in which the imaging of phenomena is considered remains constant. In contrast to the Poincaré example, here the constancy of form is justified by the classical character of the instruments employed. However, this does not remove the problem as to whether the conservation of the form of knowledge is possible during the advance of knowledge—the transition from the micro- to the submicroworld—and whether this constant return to the initial form does not have to be paid for by a complication in the formulation of physical laws. These problems are still to be resolved.

Since the discovery of the different forms of quantum theory, epistemology has had to face the important theoretical phenomenon of isomorphism of two or even several theories reflecting the same range of physical phenomena. Why isomorphic theories are possible, how their equivalence can be established, do any of these theories have particular advantages despite their equivalence, and what are these advantages—these and other problems connected with the isomorphism of theories require further investigation.

There are also certain other problems. They include the question of the conditions that are necessary and sufficient for a transition to a new system of concepts and the development of theories on the basis of new initial propositions. The process of cognition is contradictory if only because, in practice, it is not realized in accordance with some predetermined scheme. Each new discovery facing the researcher as a *single* anomaly is at first interpreted by him in terms of existing ideas with the addition of certain new hypotheses, so that the anomalous fact no longer appears as such, at least for a period of time.

The accumulation of new anomalies in the end explodes the existing system of concepts. The question then is—when does a set of new anomalies become "explosive" and results in the reconstruction of the entire theoretical system? Which concepts will remain in the course of this reconstruction in a transformed form and which will be lost altogether? How is the process of development of generalizing theories accomplished (theories of transformation, invariance, multidimensional geometries, and so on, and so on), and what is their relation to objective reality?

Epistemological problems of this kind are always found to arise in the course of cognition and should be the subject of investigation and generalization.

Born's epistemology has no room for such problems because it is based on different initial propositions and has other aims.

III.

In this section, we shall examine critically the evolution of Born's views on certain epistemological problems. The logical system developed by Born has unfortunately frequently led him to positions that were different from those he adopted before in his role as a major scientific intellectual, in fact, well before he attempted to "formulate philosophical principles that can be derived from science," or, more precisely, from physics.[28]

9. Content of sensations. External world

As far back as the 1940's and the beginning of the 1950's, Born saw an objective content in sensations. For example, in his book, Natural Philosophy of Cause and Chance (1949), he wrote: "... Our sense impressions are not a permanent hallucination, but the indications of, or signals from, an external world which exists independently of us."[29] In almost identical words, he expressed the same thought in his article, "Physics and Metaphysics" (1950). The scientist "should see in his sensory impressions something more than hallucination, namely, information from the real external world."[30]

As we have seen, in his article "Symbol and Reality" (1965), Born departs from the position that sensations carry information about the real world, and regards them as purely subjective. This is a significant departure from his previously correct treatment, and we have already noted its positivist character.

In precisely the same way, Born changes his position in relation to the acknowledgment of the existence of a real world. In the article "Physical Reality" (1953), Born sharply attacks positivists such as Dingle and others (who deny the existence of a real world), and frequently maintains that a real world does exist outside Man. In all great discoveries, he writes, scientists have used "models which for them were not products of phantasy but representatives of real things." The concept of reality can be abandoned only by "those people who live in isolated castles in the sky, well away from any experiment." Having noted the change in our views regarding the regularity of nature, he maintains that it calls us to "a new way of describing the physical world but not to the abandonment of its reality." Pointing to the role of the instrument and the observer in the description of experiments, he writes that "we can obtain certain restricted but well-defined information which is independent of the observer and of his instrument.... The process whereby we acquire this knowledge is undoubtedly also due to the observing individual but this does not mean, however, that the results have no reality.... It is true that the boundary between the action of the individual and the reaction of the object is not clear but this does not prevent us from applying these concepts in a reasonable fashion."

In the article, "Symbol and Reality", Born's views have undergone a radical change. He accuses dialectical materialism of adopting the existence of an objective world as an axiom. He maintains that, from his standpoint, "where subjectivity is primary and the possibility of objective knowledge problematic, it is not surprising that the rigorous separation of object and subject is not possible...."

As regards Born's discussion in the above article, the aim of which was to justify the idea that there exist objective structures (which he was "not afraid of identifying" with Kant's "thing in itself"), this is incorrect in a number of respects. Firstly, we must consider what is meant by "object" and by the "coincidence of structures revealed by using different sense organs and communicable from one individual to the other." However, even positivists admit this coincidence of structures (we recall that they admit the existence of "things" by which they understand "stable complexes of sensations" obtained from different sense organs) and the communicability of sensations although, as noted by Born, without justification.

Secondly, Born attempts to solve the problem of whether an objective world exists behind the "coincidence of structures" with the aid of the probability method applied to...the analysis of human sensations. The disproportion between the problem and the means proposed for its solution is quite striking. The use of probability method in this example is essentially incorrect: in physics, the methods of which Born wishes to employ, the probability method is applied to systems which, under certain definite external conditions, can be assigned a function representing the distribution of some particular parameters characterizing its elements or its possible states. An important feature of this is that the system must exist as a complete set of specifically related possibilities. It is only in this case that there exists an objective measure—a distribution function—and it is possible to predict the probability of a particular event which, under certain definite conditions, may turn out to be a certainty. For example, meteorology is concerned with the search for the as yet unknown interrelation between all the physical factors but, for us, these factors do not as yet appear as the components of a complete system, and, therefore, weather forecasts are not very reliable. In the epistemological example to which Born applies the "physical method of thinking," there is no system that could be characterized by a distribution function and in which the category of probability could be applied.

Although the role of statistical regularity in science and, therefore, of the method of the calculus of probabilities has justifiably increased, there are phenomena to which probabilistic logic cannot be applied and unambiguous determinism must be used. This, in fact, is the logic of substantiation of accomplished facts. It is sometimes very important to be able to establish whether a particular fact has occurred. For example,

[28] See M. Born, My Life and My Views, Scribner, New York, 1968 (Russl. transl. Progress, M., 1973).

[29] Max Born, Natural Philosophy of Cause and Chance, Oxford, 1949, p. 103.

[30] Max Born, Physics in My Generation, Springer-Verlag, New York, 1969 (Russ. transl. IL., M., 1963).

the fate of a defendant depends on the answer to the question, "Guilty or not guilty?" Soviet criminal legislation demands that the court must establish unambiguously the fact of an offence. Basing itself on the scientific theory of knowledge, it does not admit as lawful the establishment of some high degree of probability that the defendant is guilty, and demands that the true facts of the case be established. This approach is even more valid in the case of the question of existence of an external world. The solution of this problem in dialectical materialism has already been discussed.

Finally, Born bases his conclusions on two propositions: 1) an extremely improbable statement can be regarded as wrong and 2) probability predictions "produce only graded *expectations*" which Born interprets from the subjective standpoint. However, the theory of probability does not provide us with a basis for identifying low-probability statements as *wrong*. And the distribution of probabilities for the realization of any particular parameters in a system expresses not the subjective expectation but the objective properties of the system under consideration.

Born's incorrect reasoning leads to the fact that, while the world of the "thing in itself" does appear in his theory behind mathematical structure, it emerges only as a subjective expectation, and Born himself admits that this means a "loss of objectivity."

10. Causality. Predictability

Up to a certain point in time, Born's discussion of causality continued to develop in a realistic spirit. In his book, 'Natural Philosophy of Cause and Chance" (1949), he gave an analysis of determinism and causality. He totally rejected determinism on the grounds that it was impossible to establish in nature an unambiguous link between two states at different times. With regard to causality, he wrote that, in physics, it was not "causality, properly understood, that is eliminated, but only a traditional interpretation of it, consisting in its identification with determinism" (pp. 101–102 of the English edition). The relation of modern physics to causality is even more clearly formulated in the introduction to this book: "The statement, frequently made, that modern physics has given up causality is entirely unfounded. Modern physics, it is true, has given up or modified many traditional ideas; but it would cease to be a science if it were to give up the search for the causes of phenomena" (pp. 3–4 of the English edition). Materialists readily supported these views on the organic link between science and the search for causal connections.

However, during the last ten years of his life, Max Born gradually revised his view of causality which he replaced with randomness. Even in the book cited above, he indicated that "chance is a more fundamental concept than cause." This is not a transient opinion but a manifestation of a definite tendency toward reducing the role of causality; this tendency has become enhanced in the course of time. The author of the probabilistic interpretation of the modulus of the wave function in quantum mechanics, who laid the foundations for the broad utilization of stochastic methods in atomic physics, expended much effort in trying to extend these methods far beyond the limits of atomic physics. In particular, he showed that statistics was encountered in the problems of classical mechanics because the initial state parameters could be measured only approximately, with a certain spread of their values (the initial phase region of the values); this ensured that the phase region of the parameters of states gradually spread out during the motion, and predictions of the values of the parameters became uncertain after a certain critical instant of time. Born considered that the teaching of classical mechanics should be carried out in the language of statistics right from the very outset.[31)]

Born gradually tried to introduce probabilistic methods at the basis of his new view of the world. We have already seen how they were used in establishing the conclusion that, behind the abstract mathematical structures, there is probably the "thing in itself." In the final analysis, he used them as an argument against the category of cause which he replaced by an absolutist concept of chance. It seems to us that he was led to this extreme position for certain particular reasons which we shall discuss below.

It is well known that, over a period of 25 years, Born actively campaigned against atomic warfare. Among the many "unresolved contradictions" which could lead to a global war, he could see hardly anything more important than the fact that there "exist the opposing ideologies of capitalism and communism." He frequently stated that the entire evil lay in the fact that both opposing camps insisted that there existed only one truth and that this truth was in their possession. In Born's view, it is precisely this ideological confrontation that is maintained by the successors of historical materialism, who have elevated to the status of science their conclusion that society inevitably evolves from capitalism to socialism and communism.

It is clear that Max Born, a "convinced Western democrat," as he frequently referred to himself, could not accept this prospect. Against it, he directed his arguments based on... his treatment of physical laws. His reasoning was as follows. Having classified as "evil" the proposition of Marxist philosophy that "in society there operate objective and specific for the given society economic laws that are independent of people's recognition of them," Born concluded that "this principle of historical materialism was the present root of the conflict between East and West. The fanatic belief of Marxists that the world will reach communism by itself, and unavoidably, is based upon this principle. In actual fact, this faith is the outcome of physical determinism which follows from Newtonian mech-

[31)]See, for example, Max Born, "Is prediction possible in classical mechanics?" Usp. Fiz. Nauk 69, 173 (1959) [Z. Physik, 153, 372 (1958)]. The question of how a given target of motion is achieved despite the fact that the initial values lie in a finite phase region is discussed in the postscript by the present author to the Russian translation of Born's book, "Physics in My Generation" (pp. 516–521, 1963).

anics."[32] Referring next to the fact that he had already demonstrated that the deterministic interpretation was an erroneous conclusion for both classical and quantum physics, he concludes that, "thereby, the idea of determinism loses its meaning altogether. The application of this idea to historical processes is something that lies in the realm of phantasy." In accordance with his treatment of determinism and predictability, Born began to interpret any event in the life of a society as an unpredictable chance event. Thus, he maintains that: Marx predicted that the social revolution will occur in the most industrialized country whereas, in fact, it occurred in backward Russia; India received its independence not as a result of internal development and struggle but through the humanitarian decision of the British Government; the evolution of society and of civilization is determined by the unpredictable discoveries of great scientists and inventors, and this means that history is unpredictable; it is through these chance events, difficult decisions, and unpredictable discoveries that history advances. This was Born's allegation.

From the theoretical standpoint, Born's ideas are very vulnerable. First and foremost, one cannot associate predictability exclusively with the Laplace determinism and remove both from science.[33] Science depends on predictability for, without it, it would be meaningless. Predictability is founded on the existence of objective regularities that are realized under certain definite conditions. Random processes can occur in a system and do not exclude but, on the contrary, presuppose definite tendencies when a permanently acting potential is imposed on the random processes. We have already indicated that this is nothing new in physics. If a temperature difference appears between the ends of a rod, i.e., a temperature field is produced with a definite gradient, then although the oscillations of each molecule are random, the process of equalization of temperatures breaks through these random motions. In precisely the same way, despite the statistical character of molecular processes in Brownian motion, the situation is characterized by a definite tendency, namely, an increase in entropy. There is no doubt that random processes occur in an electronic computer, but this does not prevent us from using it to solve a particular problem with enormous accuracy, although one must remember that conditions may arise under which the machine will not give us the correct answer. Insofar as the conclusions of historical materialism about the final fate of capitalist society are concerned, these conclusions are based on a profound study of economical and social processes occurring in the society.

Marx carefully analyzed the economic and social processes in the capitalist formation. He demonstrated the role of random processes in the natural kingdom of market forces in which each capitalist realized his own wishes and, at the same time, the value of the "imposed potential" characteristic for this formation (means of production in the hands of private corporations; organization of production for private profit and contrary to the interests of society; presence of exploitation which divides society into classes). This "potential" is generated by the historical course of development and produces a number of economic and political tendencies (for example, the tendency toward technological perfection of production, an increase in the organic strength of capital, a reduction in the rate of profit and a concentration of capital, a migration of capital from one branch of industry to another and from one country to another, an increase in the rate of exploitation, and an enhancement of colonialist politics). The accumulation of all these tendencies leads to social consequences, namely, class struggle and national liberation movements, and, in the final analysis, to a revolutionary transformation of society.

These tendencies are objective and operate in society so long as it remains a capitalist society. However slow and self-contradictory they may be, in the final analysis they find a way. This is the conclusion of historical materialism.

How far all this seems from Born's naive idea that Marxists base themselves on the fatalistic philosophy of Laplace determinism rather than on the study of the objective laws of development of society!

Nevertheless, we must pay tribute to Born's steadfast fight against the danger of atomic war, which he carried on after his return from emigration to Western Germany during the difficult time when the authorities increasingly pursued a reckless revanchism and applied direct pressure on the ageing scientist. We place a high value on his peace initiatives, his participation in the Pugwash movement, and his many appeals against the threat of war and the resurgence of fascism. But we are bound to say that we cannot agree with his explanation of the reasons for the military confrontations or his attempt to supply a "scientific and physical" basis for the arguments against the conclusions of historical materialism with regard to the development of society. At the present stage of the fight for a reduction in tension, and for the security and collaboration between countries with different social systems (and it is generally accepted that the Soviet Union and the Socialist alliance play a leading role in this), it is quite obvious that opposition to *detente* comes from major armament-manufacturing and finance corporations and from colonialists who accumulate enormous profits by robbing economically backward countries of their resources. Quite naturally, the Soviet Union is striving for a reduction in tension, right up to disarmament.

As far as our defence of the conclusions of historical materialism is concerned, we merely note the existence of objective laws that are realized independently of whether or not anyone acknowledges their existence. Nevertheless, Marxists are convinced that, as the laws governing the development of society become more ac-

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[32] Max Born, Der Realitätsbegriff in der Physik, West-deutscher Verlag, Cologne and Opladen, 1958, pp. 21–22.

[33] We leave on one side the question as to whether Laplace determinism, even in Born's interpretation, appears as a limiting case in which the spread in the initial values of measured parameters contracts to a point, and the critical time tends to infinity.

curately known, the revolutionary transformation of society will occupy a shorter period and will be less painful.

It follows from the foregoing that the scientific truth that emerges from the analysis of special (in the present example—social) phenomena is, in fact, unique, and this is why, while we strive for a reduction in tension and for security, we do not abandon the ideological fight for the establishment of the validity of objective truth.

Born's interpretation of social processes, and his attitude to them, undoubtedly influenced his interpretation of chance. His increasing tendency, which we noted in 1963, toward ever greater absolutization of chance in contrast to cause did, in fact, continue. In the paper, "Symbol and Reality," Born finally stated that, "the concept of causality is a residue of former ways of thinking and is replaced today by the process of coordination as described before."[34]

One would like to think that, in this case, Born was referring to some special, perhaps Kantian, interpretation of the concept of cause. But there is no indication of this and it is clear that, in his theory of knowledge, Born tried to free himself from the concept of causality altogether.

Moreover, causality and the "process of coordination" are categories of different order. Whereas the category of causality reflects an objective connection between natural phenomena, the procedure of coordination is a volitional device for designating matter or process. This device is, of course, absolutely necessary to enable Man to find his bearings in nature and for communication. Born correctly noted the formation of language as an example of this procedure. However, although verbal symbolism (coordination of word and object) is due to the historical development of a particular ethnic group, it is not, nevertheless, connected in a necessary fashion with the nature of the object or process to which a particular designation has been attached. In particular, this explains the existence of a large number of languages with different vocabulary and different grammatical structure. The foregoing should be sufficient to show that the coordination procedure described by Born does not replace the objective causal links in nature.

Natural sciences cannot avoid the use of the category of causality since they deal first and foremost with a set of diverse phenomena and seek the reasons for them. Science proceeds from phenomena to essence, exposing the regularities inherent in the latter. The path from phenomena to essence is, in fact, the search for the cause of phenomena. In his discussion of the problem of causality, Lenin emphasizes precisely this point: "On the one hand, knowledge of matter must be deepened to knowledge (to the concept) of substance in order to find the causes of phenomena. On the other hand the actual cognition of the cause is the deepening of knowledge from the externality of phenomena to the substance."[35]

Thus, true knowledge of cause is a *deepening* of our knowledge that all *phenomena are external*... The use of the term "substance" seems to us to be an indication that phenomena should lead to their objective basis, and it is their essence that emerges in this capacity.[36]

How then can one explain the readiness of thinking scientists such as Born to replace one set of philosophical categories by others? It appears that the answer must be that they know only the old, metaphysical, definitions of these categories. Thus, in determinism, they see only a single-valued fatalist connection between states; in chance, they see absolute lack of cause; and in causality, they see a single-valued connection between one phenomenon and another, a connection located on some one-dimensional infinite series of phenomena. This view is, of course, in conflict with the results of modern science because no science proceeds along an infinite series of phenomena but, on the contrary, all sciences investigate the connection between phenomena and essence—the regularity in the essence of the given phenomena.[37] This is why some philosophizing scientist banish some categories (for example, causality) and replace them by other, just as one-sided, categories (for example, chance). However, when the philosophical categories are treated dialectically, they reflect different aspects of objective reality, namely, aspects of interrelations between phenomena and essence, and the relationships between parts and wholes in particular systems. Thus, statistical regularities are not founded on absolute chance; they are regularities, the elucidation of which is an essential part of the analysis of relationships realized in the structures of particular systems. They cannot, therefore, be contrasted either with causality in its deeper sense or with the regular appearance of directed tendencies in systems.

It is precisely toward the development of this deeper and integrated understanding of dialectical relationships between all categories (causality, chance, statistical relationships, tendencies of development, and so on) that the research of Marxist philosophers has been directed in recent years.

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[34] Der Begriff der Ursache ist ein Überbleibsel aus älteren Denkformen und wird heute ersetzt durch das Verfahren der Zuordnung, das ich beschrieben habe." Symbol und Wirklichkeit, Reprint from Phys. Blätter, p. 14.

[35] V. I. Lenin, "Philosophical notebooks," Complete Works, Vol. 29, pp. 142–143 (in Russian).

[36] The fact that Lenin interpreted "essence" and "substance" as categories of the same order can be seen, for example, from the following statement: "Man's knowledge, his science ("der Begriff"), reflects the essence, the substance of nature" (V. I. Lenin, *ibid.*, p. 170).

[37] Infinity does, in fact, enter here not as an infinite chain of connections between phenomena but in a different way, i.e., in the transition from the essence of one order to the essence of a deeper order, and in relation to the connection between a given system and a system of which it, in turn, is a component. It is precisely in this way that a single world process is realized.

Let us now briefly summarize our discussion. Max Born contrasted his theory of knowledge with the epistemology of dialectical materialism. The present author took up the challenge and tried to outline, if only briefly, the various problems that actually arose in the process of cognition and were solved by the epistemology of dialectical materialism. This was essential. The process of cognition is complicated and contradictory. It starts with sensations and ends with theory, but it also includes subjective forms of cognition as well as the effects of the external objective world. Materialist epistemology shows how the subjective form of knowledge is transformed in the process of cognition, and how it eventually results in the knowledge of the objective laws of nature. Its task is to study, in the making, the image of objective reality, starting with the creation of new knowledge in the envelope of old concepts, going on to the disruption of this envelope, the transformation of these concepts, the departure from obsolete definitions, and the emergence of dialectical mobility. It exposes the conflict between the influence of existing knowledge which serves both as a *basis* for new knowledge and as a *source of conservative ideas* that cannot be used in the new field, and points to ways of resolving this conflict through the correct application of the epistemological cycle.

All these and many other problems in the theory of cognition turn out to be outside the framework of Born's epistemology because, having rejected scientific materialism right at the outset, he used his epistemology not to investigate ways of achieving genuine objectivity—the laws of nature—but to achieve the communicability of knowledge. It goes without saying that communicability problems such as, for example, the development of language, must be investigated. But this is not the problem that is posed and solved by scientific epistemology. We have already noted that it should be solved not in the physical context but in the light of an analysis of the historical development of society, involving the participation of particular sciences.

Born's attempt to develop an integrated theory of knowledge did not succeed. His theory does not even analyze the contradictions which emerge and are overcome in the course of cognition, and it does not indicate ways of examining the image of objective reality. By contrasting his method with that of scientific materialism, Born immediately fell into the error of treating sensations as purely subjective and objectivity as experience. After this, his epistemology proceeded along a direction which objectively brought it closer to positivism. It was not an accident in that he abandoned his previous, naturally materialist, views about sensations, objective reality, and causality.

We applauded Born when he opposed the positivist, Dingle, and maintained that the chair upon which he stood was a thing outside. But this is the naive side of the dispute. Firstly, for the purposes of ordinary life, positivists acknowledge the existence of every-day things, and reject the objective world only in the theory of knowledge. Secondly, positivism can be refuted theoretically, as a philosophical direction, only by raising the analysis to the level of dialectical-materialist epistemology adopted in its entirety. It is precisely for this reason that, in his philosophical work, V. I. Lenin attached enormous importance to the foundation, protection against distortion, further development, and propagation of the epistemology of dialectical materialism. No other epistemology is capable of breaking the envelope of subjectivist constructions. In fact, this is illustrated by Born's attempt to develop his own theory of knowledge based on "physical methods of thinking."

Translated by S. Chomet