PREFACE TO ARTICLES BY A. EINSTEIN AND J.J. THOMSON

BORIS HESSEN

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Abstract. The following is a translation of Boris Hessen's «Предисловие к статьям А. Эйнштейна и Дж. Дж. Томсона», which was published in the Soviet Journal, *Под знаменем марксизма*.[1] The paper was an introduction to the Russian translations of Albert Einstein's „Newtons Mechanik und ihr Einfluß auf die Gestaltung der theoretischen Physik",[2] J.J. Thomson's "Newton's Work in Physics"[3] and Horace Lamb's "Newton's Work in Mechanics", all of which were written in commemoration of the bicentennial of Sir Isaac Newton's death.[4] Hessen maintains that the resurgent interest in Newton in the early 20th century was not only due to the bicentennial, but to the unwillingness of many theorists to accept the significance of the ensuing crisis within physics. He contends that this crisis was the sign that the Newtonian paradigm was breaking down and giving way to something new. Quantum mechanics, for Hessen, marked one aspect of the way forward as it made a qualitative break from Newtonian physics in the same way that the latter had been from Scholastic Aristotelian physics some centuries before. He also argues that quantum mechanics alone could not solve every aspect of the crisis as it required a supplement in Marxist dialectical/historical materialism. This paper is a marked contrast to Hessen's later, and better-known, work on Newton, "The Social and Economic Roots of Newton's *Principia*" from 1931. Where in 1927, he appears to defend a position more akin to the so-called 'internalist' approach to the historiography of natural science, in 1931, he is generally considered to have defended an 'externalist' approach.[5] We hope that this new translation will stimulate discussion about the overall consistency of Hessen's thought as well as encourage new assessments of his contribution to the historiography of natural science.

Keywords: Boris Hessen, Isaac Newton, René Descartes, history of natural science, classical mechanics, quantum mechanics, Marxism, Soviet philosophy

The bicentennial of Newton's death was celebrated all over the world with a series of celebrations, speeches, reports and articles. Newton's works and thoughts have been acquiring a renewed interest in the context of the revolution currently taking place in modern, natural science. Many of his ideas, above all those in the

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Opticks, are once again acquiring significance and attracting interest. At the same time, however, in the context of the crisis in modern physics, the weaknesses of his "*Natural Philosophy*" are beginning to appear with a particular clarity. The basic methodological concepts and foundations of the system of Newtonian physics must be reassessed. The need for such a revision is the result of the course of the development of the theoretical knowledge of nature. How should the revision and further development of Newtonian physics be carried out? How do new concepts which have been advanced as a result of the development of physics over the last twenty years relate to Newtonian physics and is there any connection between them at all?

Of course, all of these questions inevitably arise without any connection to the 200th-year anniversary, but it has, nevertheless, greatly stimulated the formulation of such questions.

The articles published below by Einstein, J.J. Thomson and H. Lamb each offer a different approach to the question of Newton's role and significance as well as to the evaluation of his works.

Commemorations of Newton in England were particularly noteworthy for their pomp. The most prominent members of the Royal Society, also among the most prominent physicists in England, dedicated speeches to Newton's works. Thomson, Jeans, Lamb, Glazebrook and many others sketched a picture of Newton's accomplishments in the fields of physics, mechanics, astronomy and mathematics.

But in these speeches, which were often brilliant in form, there are almost no generalizations. Almost no attempts are made to question Newton's methodology and philosophy in connection to modern physics. In most cases, the articles provide interesting accounts of Newton's works in a particular field, but often without any attempt to raise the question of the connections between his works. The birthplace of classical empiricism makes itself felt here.

J.J. Thomson's speech, at least, provides deeper content than the others, but it still does not raise basic questions about the nature of fundamental principles. The speech perhaps most concerned with generalizations and the nature of fundamental principles and which seeks to link Newton's work with the revolution taking place in modern physics, was that by . . . the Lord Bishop of Birmingham and member of the Royal Society, Dr. E.W. Barnes.

In a lengthy speech, the Lord Bishop tries to prove that

> [although] [t]he Thirty-nine Articles of our Church . . . belong to the pre-Copernican period of knowledge . . . ., [although i]ts theology seems to be associated with crude beliefs as to the history and structure of the universe,[6]

theology does also follow the times. "[I]ts theology has been continuously re-shaped by its leading divines, and the process has not yet ended."[7] Theology must build upon and use all of the achievements of science, both past and present. Newton's name is, therefore, as dear to the church as it is to science.

Having presided over the memorial service for Newton that ended the celebration at the request of the Yorkshire Mathematical Society, in his closing remarks, the bishop summed up all of the previous speeches and noted the unity of science and religion with satisfaction, even stressing that the decision to end the celebration with a religious service came from a group of leading scientists. Here, English empiricism has not strayed from its traditions.

In contrast to the English spirit, Einstein's article precisely poses the most general, fundamental questions concerning the influence of Newton's ideas on the development of theoretical physics and the relationship of these ideas with modern, scientific methodology.

Therefore, it would be appropriate to say a few words regarding some of the main points that Einstein puts forward.

The 17th century is a turning point in the history of the development of physics: beginning with Galileo, the struggle against Scholastic Aristotelian physics was successfully completed by the beginning of the 18th century. 'Hidden qualities', the *horror vacui* [horror of the void] are forever banished from physics. The general laws of terrestrial and celestial mechanics are established. Gassendi and Boyle clearly formulated the principles of atomism.

The basic tools for the study of nature (i.e., the telescope, microscope, thermometer) are being developed and improved.

Strong foundations are being laid for a quantitative, mathematically-based study of nature.

The reaction against Scholastic physics is fueled by two sources: Bacon's empiricism and the mechanistic principles of Descartes's physics.

The most consistent and principled opponent of Scholastic Aristotlelian physics, the physics of hidden qualities, was Descartes.

Aristotle identified hidden qualities as those properties of objects that cannot be directly perceived by our senses, but which are nevertheless the causes of the actions of the objects that we observe: a magnet attracts because it possesses the magnetic force to pull. This force is a hidden quality, a *qualitas occulta*.

Clearly, such a methodology could not serve as an instrument of scientific research and Descartes strongly opposes it.

"I freely acknowledge," he states,

> that I recognize no matter in corporeal things apart from that which the geometers call quantity, and take as the object of their demonstrations, i.e. that to which every kind of division, shape and motion is applicable. Moreover, my consideration of such matter involves *absolutely nothing* apart from these divisions, shapes and motions; and even with regard to these, I will admit as true only what has been deduced from indubitable common notions so evidently that it is fit to be considered as a mathematical demonstration. And since all natural phenomena can be explained in this way, as will become clear in what follows, I do not think that any other principles are either admissible or desirable in physics.[8]

The mechanistic principle of explaining nature became not only a slogan in the struggle against Scholasticism, but also a basic methodology.

"[T]rue Philosophy," says Huygens, "conceives the causes of all natural effects in terms of mechanical motions. This, in my opinion, we must necessarily do, or else renounce all hopes of ever comprehending anything in Physics."[9]

But the mechanical principle is only one component of Descartes's physics.

The main question of the era was the question of the general method of scientific research. If Bacon chose experience as the primary starting point, then according to Descartes, the only true path to knowledge is deduction. Descartes's physics is a remarkable example of the application of rationalism, coupled with the mechanical principle of explaining nature. This is its advantage as well as its disadvantage. Thanks to this synthesis, Descartes managed to create that majestic picture of the world, which in many respects, has not only not lost its value, but is even attracting special interest today.

"The greatness of Descartes's plan and the courage with which he executed it stimulated scientific thought in an unrivaled way. From the wreckage of his system, later scientists created the most stable theories that have retained their significance to the present day."[10]

On the basis of a mechanical worldview, the basic task of Descartes's physics was to provide an exhaustive picture of all natural phenomena:

> [in] physics . . . after discovering the true principles of material things, we examine the general composition of the entire universe and then, in particular, the nature of this earth and all the bodies which are most commonly found upon it, such as air, water, fire, magnetic ore and other minerals. Next we need to examine individually the nature of plants, of animals and, above all, of man so that we may be capable later on of discovering the other sciences which are beneficial to man.[11]

Having established the concepts of matter and motion, Descartes builds his entire system of physics according to the plan outlined above.

But his physics is not an encyclopedic summary of modern knowledge. Physics, as a science, did not yet exist then. From the time of Galileo, it had been undergoing a period of accumulating factual knowledge about nature, which is now gathered not only by observation, but also by experimentation. Therefore, Descartes builds his physics into a complete, rationalistic system, sometimes even at odds with the known facts of the time (i.e., the collision of bodies).

Newton's tasks in the field of physics were different.

For Descartes, the main question was that of method. Once this method was discovered, the scientific system could be built. Conducting a merciless struggle against the Aristotelian physics of hidden qualities, Descartes formulated the basic principles of the mechanistic worldview as general methodological prerequisites for the study of nature.

Consistently applying this principle, Descartes did not stop at reducing mass to extension (i.e., volume). For him, any other conception of mass was already a 'hidden quality'. Phenomena must only be explained by 'figure and movement'.

Newton's physics, as a system of mathematical phenomenology, is opposed to this unified and complete construction of the edifice of physics, which is based on the unity of the mechanistic outlook and rationalistic method.

"[G]eneral phenomenology," Boltzmann says,

> seeks to describe every other group of facts by enumeration and by an account of the natural history of all phenomena that belong to that area, without restriction as to means employed except that it renounces any uniform conception of nature, any mechanical explanation or other rational foundation.[12]

In fact, although Newton's main work is entitled *The Mathematical Principles of Natural Philosophy*, within it, we do not find a philosophically grounded and consistently conducted natural-scientific worldview.

Newton's methodology is that of empiricism, which is wrapped in a mathematical form.

The struggle between Newtonian and Cartesian physics is a struggle between empiricism and rationalism in the study of natural science. And it should be noted that Newtonian physics by no means wins out because it is a synthesis of these approaches, but, rather, because it is a form of mathematical phenomenology.

Therefore, it is only possible to correctly understand and evaluate Newton's historical significance and place by comparing it with that of Descartes.

In this respect, J.J. Thompson is absolutely correct when he, in his speech about Newton's work in the field of physics, pays tribute to Descartes. It is interesting to note that he points precisely to those general, methodological principles that Descartes introduced into physics, but he does not stress the fact that the theory of vortices and the ether are consequences of those same methodological principles.

Both Descartes's theory of vortices and the ether are closely related to his poignant statement about the question of discontinuity and continuity. The issue of long-range and short-range interaction is essentially a question of discontinuity and continuity. Classical atomism, which accepts atoms and empty space and considers any action to not be action at a distance, but a jolt, an 'action from behind' (*vis a tergo*), essentially does not explain anything, because the transmission of an impulse by a jolt is as methodologically incomprehensible as action at a distance.

Maxwell's extremely clever experiment showed that when one body pushes another, it does not touch it.[13]

Descartes perfectly understood these difficulties and hence, in his theory of vortices and the ether, wanted to provide a synthesis of atomism and the theory of continuous matter.

The problem of continuity and discontinuity is the central problem of modern physics and, hence, why Descartes's methodological studies are fresh and interesting today.

Newton approached these questions from the point of view of pure phenomenology.

Of course, it cannot be said that Newton did not pose any of these fundamental questions, but the fact of the matter is that Newton's methodological reasoning does not constitute a whole system and does not serve as the starting point for his constructions.

In this sense, Newton and Descartes can and must be opposed, the latter for whom method and basic methodological prerequisites constitute the foundation and the soul of physics.

It is very well known[14] that Newton's empiricism and phenomenology are sharpened and turned into a systematic worldview by Cotes. But it would be completely wrong and un-Marxist to argue on this basis that there is, effectively, no opposition between Newton and Descartes.

We have Newton's physics as an integral and historically necessary system of physical views. Newton the person, who allowed Cotes to amend the *Principia*, is not of interest to us, but rather, the whole system of Newton's views, since it was expressed in the character and direction of his concrete research.

Any transitional epoch must be considered in the whole variety of its contradictory trends.

The figure of Luther is incomplete and incomprehensible without the figure of Müntzer.

The sample of Engels's Marxist analysis in "*The Peasant War*" should be applied to the era of the struggle between Newton and Descartes that we are here considering. Just as "the anticipation of communism in fantasy became in reality an anticipation of modern bourgeois conditions,"[15] so is Descartes's physics a grandiose anticipation of the methodological problems that, after two centuries, have received their due importance based on accumulated, factual material.

But Newton's physics, like any methodology, is a necessary stage in the development of natural science; one whose subsequent development more and more reveals the insufficiency and unsatisfactory nature of its methodological premises.

This value of Newton's physics, as a stage of physical research, was greatly appreciated by Maxwell:

> it was most essential that Newton's method should be extended to every branch of science to which it was applicable---that we should investigate the forces with which bodies act on each other in the first place, before attempting to explain *how* that force is transmitted. No men could be better fitted to apply themselves exclusively to the first part of the problem, than those who considered the second part quite unnecessary.[16]

Modern natural science owes its independence to its liberation from teleology. It recognizes only the causal consideration of nature.

One of the battle slogans of the Renaissance was: "to know truly is to know by causes"---"*vere scire [esse] per causas scire*."[17]

Bacon emphasized that the teleological view is one of the most dangerous of *idola* [idols]. The true connection of things is mechanical causality. "Nature knows only mechanical causality; all of our forces must be directed to the investigation of the latter."[18]

The mechanistic worldview necessarily leads to the mechanical concept of causality. Descartes establishes the principle of causality (*ex nihilo nihil fit*) as an 'eternal truth'.

On English soil, mechanical determinism is generally recognized, but it is often intertwined with religious dogma (i.e., the "Christian necessitarian" sect to which Priestley belonged). This is a peculiar combination, which is characteristic of English thinkers and, which is also what we find in Newton.

The universal recognition that the principle of mechanical causality is the sole and basic principle of the scientific study of nature is due to the powerful development of mechanics itself. Newton's "*Principia*" is a grand extension of this principle to our planetary system. "The old teleology has gone to the devil,"[19] but so far, only in the field of inorganic nature, in the fields of earthly and celestial mechanics.

The main idea of the "*Principia*" is to present the motion of the planets as a consequence of the combination of two forces: "a composition of a Descent towards the sun, & an imprest motion."[20] Newton attributed this initial impetus to God, but he "forbade Him any further interference in his solar system."[21]

This peculiar 'division of labor' between God and causality in the oversight of the universe, the intertwining of religious dogma and the materialistic principle of mechanistic causality, which Plekhanov also identifies, was characteristic of English historians.[22]

The recognition of the modality of motion, the negation of matter in motion as a *causa sui*, inevitably led Newton to the concept of an initial impulse.[23] From this point of view, the idea of a deity in Newton's system is not accidental, but organically linked with his views on matter and motion, not to mention his views on space, which follow from Henry More, who was highly influential on Newton.

At this point, the entire weakness of Newton's general, philosophical worldview is revealed. The principle of pure mechanical causality leads to the concept of the divine principle. The 'bad infinity' of the universal chain of mechanical determinism ends with the initial impulse and together with it, the door to teleology is opened.

But God, having created the world and having provided the initial impulse to matter, leaves the world to the dominion of mechanical causality. The world in which the law of gravitation is enacted exists independently.

In this respect, as Einstein emphasizes in his article, Newton's system is truly a complete system of physical causality.

Newton gave the law of causality a mathematical form and endowed it with a form that theoretical physics now considers the only possible formulation of the principle of causality in physics.

Just as the development of natural science led to a revolution in the concepts of space and time, the study of microcosmic and intra-atomic processes and the accumulation of new experimental data led to a revision of the concept of causality in the context of physical research.

Newton's physics is molar (macroscopic) physics *par excellence*. It is absolutely clear that with the transition to the study of the microcosm, a new approach to the study of phenomena is required.

The question of the law of causality is now at the center of attention in modern physics and, hence, why Einstein raises the question of the concept of causality along with those of space and time. The concept of mechanical causality is essentially a spatio-temporal structure. Naturally, then, the negation of the law of causality raises the question of the very possibility of a spatio-temporal conception of phenomena. Not for nothing, therefore, the question of the law of causality is the bane of contemporary physics.

The development of the foundations of Newtonian mechanics inevitably led to the abandonment of the concept of absolute space and time. Is it worth the modern development of the physics of atomic processes to abandon the need for the law of causality?

Einstein ends his article by pointing out that hardly anyone would dare to resolve the question as to whether the law of causality should be abandoned. Nevertheless, we will try to approach the consideration of this issue from the point of view of dialectical materialism.

The question of chance and necessity or, as is customary to say in physics, the question of statistical and dynamic regularity was raised simultaneously with the development of the kinetic theory of matter. For the first time, the formulation of this question in the form of a general principle was provided by Maxwell. The dualism between statistical and dynamic regularity, as Planck rightly notes, is closely connected with the dualism between the macrocosm and the microcosm.

The regularities of Newtonian physics are of a dynamic nature precisely because they are macrocosmic regularities.

Dynamic regularity refers to that regularity of phenomena in which the state of the system at a given time determines its future and past state. If the position and speed of a planet at a given time are determined, then its very behavior in the past and future is completely determined.

In Newtonian mechanics, there is no place for probability. Each subsequent state is uniquely determined by the previous state. In this sense, Einstein calls Newton's system a complete system of physical causality. That is why Newton's laws are given in the form of differential equations; i.e., in the form of a relationship between the infinitesimal elements of the quantities input into an equation. Thereby, the law of continuous mathematical causality appears as a mathematical formulation, since specifying the state of a system in an infinitely small element of time determines its subsequent state, and the transition from one state to another takes place continuously. Thus, the need for a causal study of nature receives its preliminary completion with Newton.

When physics departs from a purely phenomenological point of view to delve deep into the phenomena of the microcosm, however, the old methods become insufficient.

First of all, the dynamic consideration of phenomena turns out to be inadequate.

The study of phenomena, which consists of the study of molecular processes, is no longer a study of the behavior of singular individuals, but a study of the behavior of a collective.

Therefore, in modern physics, the concept of chance and probability begins to play an important role.

When a certain arrangement of the planets of the solar system is specified, the subsequent arrangement necessarily follows from it. If two bodies of different temperatures are given, then the transfer of heat from a more-heated body to a less-heated body is more likely, but a reverse transition from a less-heated body to a more-heated one is possible, although such a transition is far less likely.

The study of thermodynamic phenomena from a purely phenomenological point of view led to the establishment of an impassable chasm between reversible and irreversible phenomena. Only the introduction of the concept of statistical regularity allowed Boltzmann to eliminate this chasm and to prove the relativity of the concept of irreversibility. At the same time, however, the question arose as to the very essence of dynamic and statistical regularity. Which of the two should be recognized as fundamental and, so to speak, absolute? Is it necessary to try to reduce any statistical regularity to a dynamic one, or are they both full-fledged methods for studying phenomena? These questions are relevant for the present, since one of the main tasks of modern physics is the study of atomic processes.

Above, we have already noted the connection between dynamic regularity and phenomenology.

The difference in the approach to the study of microcosmic phenomena in classical and modern physics, according to Born, is that

> [t]he classical theory introduces the microscopic coordinates which determine the individual process, only to eliminate them because of ignorance by averaging over their values; whereas the new theory gets the same results without introducing them at all.[24]

We do not have the means, Born argues, to observe the behavior of each individual atom or electron when we perform a complex experiment.

At best, we can observe the final and initial state. What happens in the interval between these two states, how the electron behaves at a given time, is unknown to us. The initial and final states are not connected by an unambiguous chain of causal states, as is the case in the dynamic regularities of classical, Newtonian physics. Therefore, the initial state does not determine the final state absolutely, but only probabilistically. Knowing the position of the earth, we can unambiguously and accurately determine the position that it will occupy after a certain period of time; knowing the state of a given set of atoms, however, we can only determine its subsequent state with a certain degree of probability.

Researchers are questioning determinism for other reasons as well. With the transition from classical physics to quantum theory, we enter the domain of discontinuous processes.

> Physical quantities are *not* continuously propagated through space; physical motions are not invariably continuous. . . . What remains of determinism is not necessarily more than statistical. If we work with a great many similar atoms, or repeat very often experiments with a few, then we always get a result in agreement with the principle of determinism.

But these results possess a significantly different nature from the results given by classical physics. "The classical calculation gives us information about our specific system of planets. The quantum theoretical calculation does not, in general, tell us anything about a single atom, but only about the mean properties of an assembly of similar atoms."[25]

Thus, the statistical regularity of quantum processes is also due to their discontinuous nature.

Classical physics was mainly concerned with the study of the sequence of individual states, the very course of the process. Born stresses how in the new quantum mechanics, conversely, "the question of the course of phenomena practically disappeared from [this circle of study]."[26]

Regularities in the new mechanics are essentially statistical regularities. But since we are not considering a sequence of phenomena, but only finite, observable states, is it possible to say that atomic processes are univocally defined along their entire length? Is it possible to speak of a causal investigation of phenomena if the final state can only be probabilistically determined from the initial state: does such a concept of the connection between phenomena raise the question of the causal sequence of phenomena as such?

These are the questions that arise with the development of the new, quantum mechanics; this is the sense in which Einstein says that when confronted by the difficulties posed by the development of modern physics, the law of causality refuses to waver.[27]

This rejection of the causal study of phenomena, as we have seen in modern physics, is understood as a rejection of the establishment of a continuous connection between the initial and final state and its replacement by the distribution of the probability of a given state.

Since modern quantum, unlike classical, mechanics does not even introduce microscopic coordinates, but is limited to observable values, as we saw above, it is clear that "it does not provide the means for determining particles in space and time."[28]

In the place of dynamic description there arises a kind of statistical phenomenology. It is in this sense that one can speak of the rejection of the spatio-temporal description.

The question of whether the modern development of physics gives rise to the rejection of the law of causality and of the spatio-temporal description can only be resolved if the question of the relationship between statistical and dynamic regularities is correctly posed; that is, the question of necessity and contingency.

Abandoning the law of causality can only come about if one metaphysically opposes the significance of chance.

Indeed, if we consider dynamic regularities to be the only expression of physical causality, to the exclusion of chance, and contrast these regularities with statistical regularities based only on the concept of probability, then it is natural to consider such regularities as the antithesis of causality, favoring total determinism.

Engels was the first to attest to the significance of the concept of chance in theoretical natural science. He explained that the metaphysical opposition between chance and necessity cannot be sufficient for the development of research; that bare, mechanical determinism cannot serve as a sufficient research tool. Accident is an objective category.

> Common sense, and with it the majority of natural scientists, treats necessity and chance as determinations that exclude each other once and for all. . . . And then it is declared that the necessary is the sole thing of scientific interest and that the accidental is a matter of indifference to science.
> . . . That is to say: what can be brought under general laws is regarded as necessary, and what cannot be so brought as accidental.
> . . . In opposition to this view there is determinism, which passed from French materialism into natural science, and which tries to dispose of chance by denying it altogether. According to this conception only simple, direct necessity prevails in nature.
> . . . With this kind of necessity we likewise do not get away from the theological conception of nature.
> . . . Hence chance is not here explained by necessity, but rather necessity is degraded to the production of what is merely accidental. If the fact that a particular pea-pod contains six peas, and not five or seven, is of the same order as the law of motion of the solar system, or the law of the transformation of energy, then as a matter of fact chance is not elevated into necessity, but rather necessity degraded into chance.
> . . . In contrast to both conceptions, Hegel came forward with the hitherto quite unheard-of propositions that the accidental has a cause because it is accidental, and just as much also has no cause because it is accidental; that the accidental is necessary, that necessity determines itself as chance, and, on the other hand, this chance is rather absolute necessity (*Logik*, II, Book III, 2: 'Die Wirklichkeit'). Natural science has simply ignored these propositions as paradoxical trifling, as self-contradictory nonsense, and, as regards theory, has persisted on the one hand in the barrenness of thought of Wolffian metaphysics, according to which a thing is *either* accidental *or* necessary, but not both

> at once; or, on the other hand, in the hardly less thoughtless mechanical determinism which in words denies chance in general only to recognize it in practice in each particular case.[29]

The rejection of fatalistic determinism does not mean the rejection of the law of causality.

The recognition of chance as a real, objective category, and not just a consequence of our failure to determine causal connections, does not at all mean identifying chance with groundlessness, the introduction of cause-lessness, as some additional 'postulate'.[30]

But such an interpretation of chance also means a different approach to the question of statistical regularity.

In fact, statistical regularity is based on the concept of the probability of phenomena and the concept of probability is based on the concept of contingency.

Thus, if we abandon the fatalistic concept of determinism, on one hand, and recognize contingency not just as a result of our ignorance, but as an objective category, the opposition between dynamic and statistical regularity will be eliminated. They do not exclude, but imply each other. They are both legitimate and necessary. Statistical regularity is not a consequence of our inadequate knowledge of processes, but an objective, necessary method of research, rooted in the characteristic features of the phenomena being studied. Engels's concept of chance and necessity provides us with the key to solving the problem not through the abandonment of causality, but through a correct synthesis of necessity and chance, and, consequently, of dynamic and statistical regularity. Since chance is not necessity that we cannot observe, but an objective, and not a subjective category, the task of this particular science is to decide what is contingent for this process and, therefore, to decide which regularity is more applicable to the studies of this group of phenomena, statistical or dynamic. But these two regularities cannot be regarded as mutually exclusive. If, in statistical regularity, the initial and the final states are not connected by a continuous sequence of states, then this only shows that for a given phenomenon, at this stage of research, a certain number of intermediate states are contingent. The final state is always a necessary consequence of the elementary processes, its components, but which are accidental with respect to the whole process, taken as a whole, in this connection of phenomena.

Engels's methodological views were confirmed in a very interesting work by Smoluchowski, entitled „Über den Begriff des Zufalls und den Ursprung der Wahrscheinlichkeitsgesetze in der Physik."[31]

Smoluchowski considers the commonly-accepted concept of chance and probability in physics to be unsatisfactory.

"My main thought," he says, "is that the *objectivity* of the notion of probability, which has not been fully paid attention to before, should be presented in its proper light."[32]

"The law of probability is subject to those phenomena, the occurrence of which depends on chance."[33]

"If we consider contingency, as is commonly done in popular theories, to be a negation of regularity, then we will be faced with insoluble contradictions."[34]

"As for its application in theoretical physics, all probability theories that consider contingency to be an unknown, partial cause must be declared unsatisfactory in advance."[35]

"The physical probability of events only depends on the conditions affecting its outcome, but not on the degree of our knowledge!"[36]

But if, in contrast to mechanical determinism, we pay attention to the objective side of probability and chance, if we stop to consider contingency to be unknown necessity, then we must change our view about the significance of statistical regularities. Therefore, having established the limits of the old concepts of chance and probability, Smoluchowski takes a different approach to the issue of statistical regularities.

"I am fully aware," he says

> that this concept of chance stands in conflict with the usual definition of chance, which considers partial ignorance of the causes to be its most significant aspect, so I will note the following in confirmation of my view: the application of the theory of probability in the kinetic theory of gases would retain its significance and would be fully justified even if we knew exactly the structure of the molecules and their initial positions and were able to accurately mathematically describe the motion of each in time.[37]

Thus, statistical regularity and statistical laws, i.e., laws based on the concept of chance, are not simply a consequence of our lack of knowledge, but represent an equal method of studying nature. In this respect, the general concept of determinism is not in the least disturbed. But, determinism will no longer be limited to mechanical determinism. Determinism and statistical regularity, necessity and chance cannot be regarded as mutually exclusive. This is what Smoluchowski emphasizes.

"It seems to me," he says,

> that it is very important for a philosopher that, at least in a narrow field of physics, it can be shown that the concept of probability, in the usual sense of a regular sequence of contingent phenomena, has a strictly objective meaning and that the concept and origin of chance can be accurately determined, remaining strictly on the basis of determinism all the time.[38]

With these brief remarks, of course, we have by no means exhausted the problems of the nature of the laws of physics. In any case, however, it can be said with confidence that the development of modern physics does not give the slightest reason to question the causal connection between phenomena and the concept of space-time. Just as the development of our knowledge has necessitated changing the Newtonian concepts of absolute space and time, the development of quantum theory raises the question of the insufficiency of the concept of continuous, mechanical determinism. And in essence, the question of abandoning determinism is only evidence of the insufficiency of the metaphysical concept of causality.

In 1873, that is, during the time when the kinetic theory of gases had just appeared, Maxwell[39], out of his unique ingenuity, raised the question as to whether the modern development of physics provides any arguments against determinism.

He responds as follows:

> [i]f . . . cultivators of physical science . . . are led in pursuit of the arcane of science to the study of singularities and instabilities, rather than the continuities and stabilities of things, the promotion of natural knowledge may tend to remove that prejudice in favour of determinism which seems to arise from assuming that the physical science of the future is a mere magnified image of that of the past.[40]

The development of science is not a simple, quantitative and incremental accumulation of content. It is inextricably linked with the development and change of basic methodological concepts. Science inevitably grows in its development from the framework of old concepts and notions. This process of growth is necessarily associated with various idealistic vacillations. But these vacillations, for the most part, signal intractable difficulties in the framework of the old worldview.

We see the same picture in the question of the role and significance of causality in modern physics.

But for us, one thing is certain:

> [i]t is mainly because the physicists did not know dialectics that the new physics strayed into idealism. . . . The basic materialist spirit of physics, as of all modern science, will overcome all crises, but only by the indispensable replacement of metaphysical materialism by dialectical materialism.[41]

Here, we tried to show that by replacing the metaphysical opposition of necessity and chance with the dialectical concept of causality, pointed out by Engels, there is a way out of the crisis that would otherwise lead to the rejection of the causal and spatio-temporal conception of phenomena.[42]

References

[1] Гессен, Б., «Предисловие к статьям А. Эйнштейна и Дж. Дж. Томсона [Predisloviye k stat'yam A. Eynshteyna i Dzh. Dzh. Tomsona]», *Под знаменем марксизма* [*Pod Znamenem Marksizma*; *Under the Banner of Marxism*] 4 (1927): 152–165.

[2] Эйнштейн, А., «Механика Ньютона и ее влияние на развитие теоретической физики», *Под знаменем марксизма* 4 (1927): 166–173. See also Einstein, A., „Newtons Mechanik und ihr Einfluß auf die Gestaltung der theoretischen Physik," *Die Naturwissenschaften* [*The Natural Sciences*] 15 (1927): 273–276; Einstein, A., "The Mechanics of Newton and Their Influence on the Development of Theoretical Physics," in *Ideas and Opinions*, ed. C. Seeling, et al. and trans. S. Bargmann (New York: Crown Publishers, Inc., 1954), 253–261.

[3] Томсон, Дж. Дж., «Работы Ньютона в области физики», *Под знаменем марксизма* 4 (1927): 174–181. See also Thomson, J.J., "Newton's Work in Physics," *Nature* 119 (1927): 36–40.
[4] Ламб, Г., «Работы Ньютона в области механики», *Под знаменем марксизма* 4 (1927): 182–185. See also Lamb, H., "Newton's Work in Mechanics," *Nature* 119 (1927): 33.
[5] Schäfer, W., "Boris Hessen and the Politics of the Sociology of Science," *Thesis Eleven* 21 (1988): 114.
[6] Barnes, E.W., "The Bicentenary of Newton's Death," *Nature* 119 (1927): 21. Where possible, Hessen's original references have been substituted by contemporary, English translations, but where such translations were not available, the originals have been left in. In cases where Hessen quotes a text, but does not himself provide a citation, reference to that text has been provided by the translator [Translator's Note, hereafter 'TN'].
[7] Barnes, E.W., (1927): 21 [TN].
[8] Descartes, R., *Principles of Philosophy*, in *The Philosophical Writings of Descartes, vol. 1*, ed. and trans. J. Cottingham, R. Stoothoff and D. Murdoch (Cambridge: Cambridge University Press, 1985), 247.
[9] Huygens, C., *Treatise on Light*, trans. S.P. Thompson (London: Macmillan and Co., Limited, 1912), 3.
[10] Whittaker, E.T., *A History of the Theories of Aether and Electricity: From the Age of Descartes to the Close of the Nineteenth Century* (New York/Bombay/Calcutta: Longmans, Green, and Co., 1910), 3.
[11] Descartes, R., (1985), 186 [TN].
[12] Boltzmann, L., "On the Development of the Methods of Theoretical Physics in Recent Times," in *Theoretical Physics and Philosophical Problems*, ed. B. McGuinness and trans. P. Foulkes (Dordrecht/Boston: D. Reidel Publishing Company, 1974), 95.
[13] Maxwell, J.C., "On Action at a Distance," in *The Scientific Papers of James Clerk Maxwell, vol. 2*, ed. W.D. Niven, M.A., F.R.S. (Mineola: Dover Publications, Inc., 1890), 314.
[14] "The doctrine of direct action at a distance cannot claim for its author the discoverer of universal gravitation. It was first asserted by Roger Cotes, in his preface to the *Principia*, which he edited during Newton's life. According to Cotes, it is by experience that we learn that all bodies gravitate. We do not learn in any other way that they are extended, movable, or solid. Gravitation, therefore, has as much right to be considered an essential property of matter as extension, mobility, or impenetrability. And when the Newtonian philosophy gained ground in Europe, it was the opinion of Cotes rather than that of Newton that became most prevalent." Maxwell, J.C., (1890),316.
[15] Engels, F., *The Peasant War in Germany*, in *Marx & Engels: Collected Works, vol. 10 – Marx and Engels 1849–51*, ed. A. Vladimirova and L. Zubrilova and trans. G. Benton, et al. (London: Lawrence & Wishart, 2010a), 415.
[16] Maxwell, J.C., (1890), 317 [TN].
[17] Bacon, F., *The New Organon*, ed. L. Jardine and M. Silverthorne (Cambridge: Cambridge University Press, 2000), 102 [TN].
[18] Деборин, А.М. [Deborin, A.M.], *Введение в философию диалектического материализма* [*Vvedeniye v filosofiyu dialekticheskogo materializma*; *Introduction to the Philosophy of Dialectical Materialism*] (Москва [Moskva; Moscow]: Государственное издательство [Gosudarstvennoye izdatel'stvo; State Publishing House], 1922), 49 [TN].
[19] Engels, F., *Dialectics of Nature*, in *Marx & Engels: Collected Works, vol. 25 – Engels*, ed. V. Smirnova and trans. C. Dutt (London: Lawrence & Wishart, 2010b), 475 [TN].
[20] Halley, E., "Halley to Newton (29 June 1686)," in *The Correspondence of Isaac Newton, vol. 2 – 1676–1687*, ed. H.W. Turnbull, F.R.S. (Cambridge: Cambridge University Press, 1960), 441.
[21] Engels, F., (2010b), 480. [TN]

[22] Plekhanov, G., *The Role of the Individual in History*, trans. unknown (New York: International Publishers, 1940), 11n1. To what "English historians" Hessen sees Plekhanov as referring here is unclear. Perhaps Hessen means Plekhanov's references to "English historical figures" such as Priestley, etc. [TN].
[23] The initial impulse is the tangential component for which Engels blames Newton. See Engels, F., (2010b), 480.
[24] Born, M., "Physical Aspects of Quantum Mechanics," in *Physics in My Generation: A Selection of Papers*, trans. R. Oppenheimer (London/New York: Pergamon Press, 1956), 11.
[25] Jordan, P., "Philosophical Foundations of Quantum Theory," trans. R. Oppenheimer, *Nature* 119 (1927): 567.
[26] Born, M., (1956), 6.
[27] The issue of causality and statistical regularity has recently become particularly relevant after Schrödinger's theory, which seemed to return to the dynamic concept of molecular phenomena, received a purely statistical interpretation. Born, M., (1956), 566–569.
[28] Born, M., (1956), 566–569.
[29] Engels, F., (2010b), 498–501 [TN].
[30] See also Деборин, А.М., «Наши разногласия [Nashi raznoglasiya; Our Differences]», in *Летописи марксизма* [*Letopisi marksizma*; *Chronicles of Marxism*] II, 9–11.
[31] Smoluchowski, M., „Über den Begriff des Zufalls und den Ursprung der Wahrscheinlichkeitsgesetze in der Physik [On the Concept of Contingency and the Origin of the Laws of Probability in Physics]," *Die Naturwissenschaften* 6 (1918): 253–263.
[32] Smoluchowski, M., (1918):253 [TN].
[33] Smoluchowski, M., (1918):253 [TN].
[34] Smoluchowski, M., (1918):253 [TN].
[35] Smoluchowski, M., (1918):254 [TN].
[36] Smoluchowski, M., (1918):254 [TN].
[37] Smoluchowski, M., (1918):254 [TN].
[38] Smoluchowski, M., (1918):262 [TN].
[39] Maxwell examines the question of necessity and contingency applied to physics in a short article published by Campbell and Garnett, namely, Maxwell's report presented at the Cambridge Philosophical Circle (Club of Seniors). The article is Maxwell, J.C., "Does the progress of Physical Science tend to give any advantage to the opinion of Necessity (or Determinism) over that of the Contingency of Events and the Freedom of the Will?" in *The Life of James Clerk Maxwell with a Selection from his Correspondence and Occasional Writings and a Sketch of His Contributions to Science*, ed. L. Campbell, M.A., LL.D. and W. Garnett, M.A. (London: Macmillan and Co., 1882), 434–444.
[40] Maxwell, J.C., (1882),444. [TN].
[41] Lenin, V.I., *Materialism and Empirio-Criticism: Critical Comments on A Reactionary Philosophy*, in *V.I. Lenin – Collected Works, Vol. 14; 1908*, ed. C. Dutt and trans. A. Fineberg (Moscow: Progress Publishers, 1977 [1962, 1968, 1972]), 262, 306.
[42] Thank you to Olga Bashkina and two anonymous reviewers for their assistance in rendering this translation, and special thanks to one reviewer who tracked down a missing reference. I would also like to extend my gratitude to the School of Philosophy at the National Research University – Higher School of Economics for providing the context in which this translation work could be completed [TN].