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HISTORICAL DOCUMENT

Marian Smoluchowski[1] (On the tenth anniversary of his death)[2]

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[144] September of the current year (1927) marked tenth anniversary of the death of Marian Smoluchowski.[3] Smoluchowski's works are of outstanding importance not only for the physicist. They are also of extremely high methodological value.

Atomism, which thanks to the work of Clausius, Maxwell and Boltzmann, flourished in the second half of the nineteenth century, by the end of the nineteenth century began to fall into disfavor among physicists. The reality of atoms began to be questioned, accompanied by a strengthened impulse to "overcome natural scientific materialism."[4]

In 1898, in the preface to his classic work on the kinetic theory of gases, Boltzmann wrote regretfully that "it would be a great tragedy for science if the theory of gases were temporarily thrown into oblivion because of a momentary hostile attitude toward it, as it happened for example to the wave theory because of Newton's authority" (Boltzmann 1898, v–vi; Boltzmann 1995, 192 [TN]). Smoluchowski's works on the theory of Brownian motion[5] provided a brilliant new proof of the reality of atoms. Since that time, as Einstein remarks, due in large part to Smoluchowski's work, universal recognition of the kinetic theory has been established and confidence in the reality of atoms has begun to spread among physicists.

This, however, by no means exhausts the significance of Smoluchowski's works. Boltzmann, with his own work, eliminated the metaphysical gap between reversible and irreversible processes. He showed that "the world clock does not need to be wound up."

[1]The following is a translation of Gessen 1927b: 144–148. Hessen's original references have been replaced by references to English translations where possible. References to texts not cited by Hessen have been provided by the translator. This translation was completed with the aid of translation software [Translator's Note; hereafter, 'TN'].

[2]An overall assessment of Smoluchowski's work has been provided in Einstein 1917, 107–108; Sommerfeld 1927, 533–539.

[3]Marian Smoluchowski (1872–1917) was a Polish physicist, who was chair of theoretical physics at Lvov University and chair of experimental physics at Jagellonian University. He is best known for his work on Brownian motion and statistical physics. His work also marked a major contribution to the confirmation of atomic theory (Fuliński 1998: 1523–1525) [TN].

[4]Here, Hessen is referring to a tendency common in physics at the time to consider matter as either a mental construct or as reducible to energy. This is exemplified in such tendencies as Machism, according to which atoms are "artificial hypothetical" constructs, as well as energetics, according to which mind and matter are reducible to energy. Regarding the former, Ernst Mach writes in his *Contribution to the Analysis of the Sensations* that "if ordinary 'matter' must be regarded as a highly natural, unconsciously constructed mental symbol for a complex of sensuous elements, much more must this be the case with the artificial hypothetical atoms and molecules of physics and chemistry" (Mach 1897, 152). Regarding the latter, German mathematician and physicist Georg Helm writes in his *Die Lehre von der Energie* that "energy is the true element of the world, for everything that we know of the world we know about energy" (Helm 1887, 56–57. See also Deletete 2005, 140–162). Likewise, Latvian chemist and philosopher Wilhelm Ostwald suggests, in his *Lectures on Natural Philosophy,* "unit[ing] the concepts matter and mind by subordinating both to the concept of energy" (Ostwald 1902, viii. See Lenin 1977, 258–273, 346–356) [TN].

[5]Brownian Motion refers to the random motion of particles in a medium. The concept originated in the work of R. Brown with his observation under a microscope of irregularities in the motion of pollen grains in a drop of water (Brown 1827. See also Schilling & Partzsch 2014, 1) [TN].

Thanks to Smoluchowski, Boltzmann's concept received brilliant experimental confirmation and a final theoretical completion. Quite obviously, the elimination of the metaphysical distinction between reversible and irreversible processes is of great methodological importance. If you hold to Clausius's view, as Engels remarks with ingenious foresight,

> *Clausius'[s] second law*, etc., however it may be interpreted, shows energy as lost, qualitatively if not quantitatively. *Entropy cannot be destroyed by natural means but it can certainly be created*. The world clock has to be wound up, then it goes on running until it [145] arrives at a state of equilibrium from which only a miracle can set it going again. The energy expended in winding has disappeared, at least qualitatively, and can only be restored by an *impulse from outside*. Hence, an impulse from outside was necessary at the beginning also, hence, the quantity of motion, or energy, existing in the universe was not always the same, hence, energy must have been created, i.e., it must be creatable, and therefore destructible. (Engels 2010, 563 [TN])

Boltzmann succeeded in eliminating this gap and in providing a dialectical interpretation of natural processes due to a statistical approach to molecular processes. What was previously considered irreversible is in principle reversible from Boltzmann's point of view, but the *probability* of the reversibility of those processes considered practically irreversible is vanishingly small (though not equal to zero!).

If we put a pot of water on a primus stove, the heat passes from the flame to the water and the water boils. We constantly observe this in everyday life: heat transfers from a body with a higher temperature to a body with a lower temperature. We have never observed the opposite in human practice and this is where the conviction arises that there are fundamentally irreversible processes: the transfer of heat from a warmer body to a less heated one.

However, if heat is nothing other than the movement of molecules, it is completely incomprehensible why a set of molecules, where each acts according to a fundamentally reversible movement, results in such an irreversible process as the transfer of heat from a more heated body to a less heated one.

Boltzmann's accomplishment is that, based on the kinetic theory of heat, instead of the impossibility to reverse the process, he introduced the concept of the *probability* that the process flowed in a certain direction. If we put the pot on the stove, the probability that the water in the pot will boil is so great that we practically do not distinguish it from necessity; however, it is quite possible that the water in it will freeze, i.e., that heat will move from the pan to the stove; and this is not impossible, only very unlikely.

As in the Copernican revolution, nothing changes in our practice, but a complete revolution has occurred in our theoretical views.

This revolution could only be carried out thanks to the development of the kinetic theory of matter. But the kinetic theory of matter, which treats each body as a combination of an enormous quantity of atoms, forced physicists to broadly apply methods that are best suited to the study of the collective: statistical methods. Since atomic and intra-atomic processes underlie all natural phenomena, statistical method is increasingly becoming one of the most important tools of physics. The brilliant results obtained by Boltzmann are closely linked to the central role of statistical method in his works.

Smoluchowski, as Sommerfeld[6] justly remarks, is the direct heir and successor of Boltzmann's path. [146] "Statistics was necessary for him, like air" (Sommerfeld 1927, 537).

[6]Arnold J.W. Sommerfeld (1868–1951) was a German professor of theoretical physics, who held positions at the University of Göttingen and University of Munich throughout his career. He is best known for his contributions to atomic theory and quantum mechanics, exemplified in his *Atomic Structure and Spectral Lines* - once considered the "Bible of atomic physics" - along with his six-volume *Lectures on Theoretical Physics* (Eckert 2013, xi–xiv) [TN].

In recent years, the statistical concept has been increasingly affirmed and disseminated throughout physics. To every physicist, it really has become necessary "like air."

But if the dynamic concept of the laws of nature is methodologically simpler and clearer, the statistical concept poses a number of deep methodological problems, above all, the problem of causality and chance.[7]

The statistical method necessitates a more in-depth development of the laws of causality. The mathematical apparatus of statistical method is probability theory. Therefore, the study of the methodological foundations of statistical method necessarily leads to the study of the foundations of probability theory. However, the concept of probability is closely related to the concept of chance. Therefore, the wide dissemination of statistical method highlights the need to bring to the fore the questions of causality, necessity, and chance.

The understanding that had been invested in these concepts by classical physics has become insufficient.

The ambiguity and confusion of these basic concepts leads to the abandonment of the law of causality, to the revival of teleological views, etc.

What is the essence of chance? What are the importance and the limits of application of statistical method in physics? These questions are impossible to avoid in the current state of physics.

We have all recently witnessed the fiercest attacks on the dialecticians for daring to advance the idea that chance is not a subjective category, not a consequence of our ignorance, but a real, objective category.

It is clear how important one or another solution of this question is for physics. Indeed, if chance is the result of the limitations of our knowledge, then statistical method would take on a subjective hue. It would become a temporary crutch for our ignorance. It would be impossible to provide an objective criterion for the conditions and limits of its application. Like our ignorance, all such criteria would take on a subjective hue. The Smoluchowski article printed below is especially valuable for us in that it not only fully confirms the views of Hegel and Engels defended by dialecticians on chance as an *objective* category,[8] but also provides concrete illustrations of this concept by using physical examples.

This article is Smoluchowski's last work, which was published after his death. It provides an analysis of those basic concepts without which a correct understanding and assessment of statistical method would be impossible. This article is Smoluchowski's[9] only purely methodological [147] work, and his choice of topic shows which conceptions he considers the most important to analyze.

The main idea that Smoluchowski highlights is the objective aspect of the concepts of probability and chance.

"All probability theories," he asserts, "that consider chance to be an unknown, partial cause must be declared unsatisfactory in advance. The physical probability of events only depends

[7]For more on statistical and dynamic concepts with respect to the formulation of the problem of causality in contemporary physics, see Hessen 1927a, 152–165.

[8]Here, Hessen is referring to a passage from Friedrich Engels' *Dialectics of Nature*, in which Engels elaborates G.W.F. Hegel's conception of chance and necessity. According to Engels, "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" (Engels 2010, 500–501). See also Hegel 2010, 482–485; Hessen 2019, 97–98. [TN].

[9]Smoluchowski provides a remarkable overview of his physical works in Smoluchowski, 1913, 261; Smoluchowski 1916, 557.

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on the conditions affecting its outcome, but not on the degree of our knowledge" (Smoluchowski 1918, 254; Smolukhovskiy 1927, 151 [TN]).

But, if chance is an objective category, then it is necessary to provide an objective definition of its essence, to show the conditions when it is possible and necessary to apply probability theory, i.e., statistical method of analysis. Smoluchowski's article is devoted to clarifying these questions. Based on a detailed analysis of simple examples that serve as "models of random phenomena," he provides a methodological analysis of the concept of chance.

Furthermore, the typical interpretation of chance contrasts it with the concept of necessity: a phenomenon is either by necessity or by chance. One excludes the other. Chance is the antithesis of necessity and regularity. But if we stand on such a metaphysical opposition of chance and necessity, and of regularity, then we inevitably come to a contradiction, which Smoluchowski formulates as follows. If we adopt the point of view of absolute, metaphysical determinism, how can an accident occur at all? How can regular causes result in random actions? If we try to answer this question by calling chance a subjective category, a consequence of our partial ignorance, the following difficulty immediately arises: there is no such thing as objective chance. Everything that happens is strictly and uniquely determined. However, in our practical activities and in science, we are engaged in calculating the results of chance (albeit as a subjective category). The activity of any insurance company will serve as a sufficient example. How, then, does it become possible to calculate the result of chance? How do *accidental* causes result in regular outcomes? Indeed, even though we abstractly assume that an accident is unknown necessity, in each particular case we do not know this necessary connection and we do not even try to establish it; and yet, the result of calculating accidents provides a consistent pattern. "If we consider chance, according to a popular expression, to be a negation of regularity," Smoluchowski states, "then we will be faced with an insoluble contradiction" (Smoluchowski 1918, 253; Smolukhovskiy 1927, 150 [TN]).

But it is necessary to resolve this contradiction, and Smoluchowski shows how these contradictions are resolved if we abandon the metaphysical opposition of chance and necessity [148] (laws) and recognize chance as an objective category.

In his work, *The Role of the Individual in History*, Plekhanov[10] provides brilliant examples of the concretization of the dialectical concept of chance as applied to social processes, based on the recognition of chance as an objective category and of the dialectical synthesis of the concepts of chance and necessity (Plekhanov 1940 [TN]). Smoluchowski's article provides a concrete definition of the dialectical concept of chance as applied to physical phenomena.

This is clear proof of the fruitfulness of the dialectical concept of chance and of its special interest for the Marxist.

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[10]Georgi V. Plekhanov (1856–1918) was a Russian revolutionary and philosopher of Marxist theory. One of the founders of the social-democratic movement in Russia, he is best known as the "father of Russian Marxism" and for having coined, or at least popularized, the term "dialectical materialism" in his *The Materialist Conception of History*. He was a member of the Menshevik wing of the Russian Social-Democratic Labor Party and an outspoken opponent of Lenin and the Bolsheviks (Graham 1987, 25; Sheehan 1985, 114, 115n; Wetter 1964, 100–109) [TN].

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