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Book Review: *Creating Modern Probability*

Creating Modern Probability. Its Mathematics, Physics and Philosophy in Historical Perspective, Jan von Plato, Cambridge University Press, Cambridge, 1994.

Jan von Plato, a philosopher at the University of Helsinki, presents a thorough but readable account of the events leading to the definitive formulation of "modern probability theory" by the Russian mathematician Andrei Kolmogorov in 1933. Kolmogorov's theory uses the concept of the "measure" of a set of points, so the historical background of his theory necessarily involves a discussion of the development of measure theory by Émile Borel and Henri Lebesgue. But a substantial part of this book deals with physics rather than pure mathematics; the author argues that the 20th-century mathematician's concept of probability has been strongly influenced by the success of statistical theories in physics, and in particular by quantum mechanics. At the same time the book pushes physicists to think more carefully about the statistical concepts commonly used in their theories.

Classical probability theory was developed to deal with situations involving sequences of repetitions of a trial, whose possible outcomes could be described in terms of elementary events. In a symmetrical situation each elementary event could be postulated to have equal probability; thus the calculation of the probability of finite combinations of events, and of sequences of these events, was reduced to combinatorial analysis.

With the development of the kinetic theory of gases by Rudolph Clausius, James Clerk Maxwell, and Ludwig Boltzmann in the last half of the 19th century, the resources of classical probability were pushed to their limits. In a system with huge numbers of rapidly colliding molecules it seemed plausible to regard the positions and velocities of the molecules as random variables. Yet the instantaneous values of these variables, regarded as elementary events, would be infinitesimal points in a continuous multidimensional space; how could a finite combinatorics be applied? Worse,

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the time variable also had to be continuous. On the other hand, as long as physicists believed that molecular motions were governed by a deterministic mechanics, they could not fully accept the idea that molecular events were intrinsically random—that probability was "objective" rather than "epistemic" (depending on the knowledge of the theorist).

Contrary to the views of some mathematicians who have written on this subject, von Plato sees Boltzmann rather than Gibbs as having the most satisfactory approach to the use of probability in physics. He argues that "Boltzmann's is a rather sophisticated view of the relation between the mechanical assumptions of the molecular theory and its probabilistic character" (p. 79), while he dismisses Gibbsian ensembles as insignificant heuristic devices, subsequently made obsolete by measure theory. Other mathematical techniques introduced by physicists, such as Planck's partition function and the Darwin–Fowler method, are not even mentioned.

Surprisingly, von Plato accepts the traditional view that Max Planck introduced the quantum theory with his radiation law in 1900. Thomas Kuhn's thesis, that Planck used finite energy elements for mathematical convenience without assuming physical quantization, would seem to fit better with von Plato's general approach (see T. Kuhn, *Black-Body Theory and the Quantum Discontinuity: 1894–1912*, Oxford University Press, Oxford, 1978).

A crucial step toward modern probability, according to von Plato, was the invention of quantum mechanics in the 1920s. In this context one should not simply invoke what physicists call "the probability interpretation" of quantum mechanics—on the contrary, "probability itself is a mathematical notion in need of interpretation" (p. 153). Once the physicists had overthrown determinism, the mathematicians were free to use objective probability, and the road to Kolmogorov's theory was open.

But von Plato immediately points out that matters are not quite so simple. "Before the recent popularity of chaos theory, it was common to make a twofold classification of physics into deterministic classical physics and indeterministic quantum physics. Similarly, probabilities were classified into epistemic and objective" (p. 166). It was assumed that epistemic probability had to be associated with determinism and objective with indeterminism. But, just as chaos theory has linked determinism with objective probability (as Maxwell suggested in 1873), the Italian mathematician Bruno de Finetti linked indeterminism with epistemic probability—or rather with a "subjective probability" which "remains totally noncommittal" on whether probability is inherent in nature or is imposed by us (p. 166). The last chapter of the book is devoted to de Finetti's theory, which von Plato considers a viable alternative to Kolmogorov's.

I strongly recommend *Creating Modern Probability* to all teachers and advanced students of statistical physics. Parts of the exposition assume some familiarity with modern mathematics, but only to the extent that I would assume to be now an essential prerequisite for doing respectable research in theoretical physics. Going against current fashion in the historiography of science, von Plato has little to say about the social context of research; Paul Forman's provocative claim, that German physicists and mathematicians accepted indeterminism in response to cultural critiques of science, is barely mentioned in a footnote. But von Plato achieves a more important goal: uncovering and explicating the intellectual connections between two major domains of 20th century mathematics and physics.

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