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REFLECTIONS ON REVOLUTIONS

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The Probabilistic Revolution. **Lorenz Krüger, Lorraine Daston, and Michael Heidelberger, Eds.** ***Volume 1: Ideas in History.*** **Lorenz Krüger, Gerd Gigerenzer, and Mary S. Morgan, Eds.** ***Volume 2: Ideas in the Sciences.*** Cambridge: MIT Press, 1987. Volume 1, 449 pp. Volume 2, 459 pp. $32.50 (cloth) each volume

Despite the controversy that often surrounds scientific revolutions, such as the Copernican revolution in astronomy or the Freudian revolution in psychology, one usually finds a general consensus among historians about certain basic issues concerning them; there is rarely any dispute about the principal individuals involved, or the specific discipline undergoing change, or the relevant period of time during which that change took place. None of these hold true, however, of the so-called probabilistic revolution that is the subject of this two-volume collection of papers: this is a proposed revolution that is difficult to attribute to any one group of individuals, affected a wide range of fields rather than just one, and took the better part of a century before it was in place.

Often an important aspect of a scientific revolution is its impact on the way we view the world. Such far-reaching shifts often have far humbler origins: they are the natural if unintended result of major theoretical changes within a science, adopted initially because they provide new ways of dealing with old problems. The impact of Copernicus, Johannes Kepler, and Isaac Newton on the thought of their time was profound, but they were largely motivated by specific technical questions of a much more limited character. What is perhaps unique about the probabilistic revolution, however, is that the methodological changes one observes appear to be not so much the cause as the result of external changes in scientific philosophy.

The rise of quantitative genetics provides a striking example. The story of how Gregor Mendel's paper of 1866 was ignored until 1900, when it was simultaneously rediscovered by Hugo de Vries, Carl Correns, and Erich von Tschermak, is too familiar to require recounting here.[1] Viewed in isolation, Mendel's story seems a mere curiosity. On reflection, however, it is tempting to interpret the initial neglect of Mendel's work, coupled with its subsequent rediscovery, as symptomatic of a much more basic change that was taking place beneath the surface; as a shift in perspective that had taken place in biology, a change from old ways of thought in which Mendel's approach was not even thinkable, to a new way of thinking in which it became natural and inevitable.[2] This was after all the period that saw the birth of the English school of biometrics; the work of that eccentric Victorian genius Francis Galton; the founding of the journal *Biometrika;* and also such developments as Alphonse Bertillon's method of criminal identification by numerical measurements.[3]

This change was not limited to the biological sciences; similar transformations also took place in many of the other natural sciences. The same decade in which Mendel wrote his paper also saw the first papers of James Clerk Maxwell and Ludwig Boltzmann on statistical mechanics, an entirely novel mode of physical explanation based on the average behavior of a large system of particles, rather than the deterministic evolution of a small number.[4] Even more revoluntionary was the later quantum mechanics of Erwin Schrödinger and Werner Heisenberg, which actually built indeterminism into its very model of nature, making it an attribute of the world rather than a reflection of limited knowledge on the part of the observer.

Nor was this trend toward stochastic modes of explanations restricted to the natural sciences. In psychology, Gustav Fechner introduced the use of probability models and experimental design in his *Elemente der Psychophysik* (1860), Charles Sanders Peirce and Joseph Jastrow advanced Fechner's methodology by advocating the use of randomization, and Hermann Ebbinghaus went a step further when he quantified the experimental uncertainty inherent in the measurement of psychophysical constants.[5] In sociology, despite initial and—often strident—opposition from Destutt de Tracy, Louis Poinsot, Auguste Comte, and many others, statistical methods and models later became not merely a respectable component, but an integral part of the subject. In economics, many of the early pioneers in its mathematical development—F. Y. Edgeworth, W. E. Johnson, John Maynard Keynes, and F. P. Ramsey—had a deep interest in statistics and the philosophical foundations of probability.

What was responsible for this "probabilistic revolution" that began in the latter half of the nineteenth century? Writing of the earlier scientific revolution, C. S. Lewis argued that

> What proved important . . . about the new astronomy was not the mere alteration in our map of space but the methodological revolution which verified it. This is not sufficiently described as a change from dogmatism to empiricism. Mere empiricists like Telesius or Bacon achieved nothing. What was fruitful in the thought of the new scientists was the bold use of mathematics in the construction of hypotheses, tested not by observation simply but by controlled observation of phenomena that could be precisely measured. On the practical side it was this that delivered Nature into our hands.[6]

This perceptive observation succinctly captures not only the essence of the earlier scientific revolution, but also the allure of using statistical methods in the behavioral and social sciences. The use of mathematics had become to many the *sine qua non* of a true science as a result of its spectacular successes in physics and astronomy; it thus became seductively attractive to try to mathematize the sciences of human behavior as well.[7] Given the variability inherent in the subject matter, however, the use of statistical methods, models, and explanations was inavoidable. This had been a dream of M. J. A. N. Condorcet's in the eighteenth century, but it required the passage of a hundred years before it began to become a reality.[8]

When one begins to look for other examples of this growing embrace of the statistical, it is remarkable how ubiquitous it appears, not only in the theoretical development of various disciplines, but also in the resort to randomization in areas as diverse as scientific sampling, clinical trials, and numerical analysis. Although the mathematics necessary for the development of sampling methodology existed well before the turn of the century, its widespread use ranging from public opinion surveys to financial audits only began in the 1920s.[9] Similarly, both the use of the randomized clinical trial in medicine and the implementation of Monte Carlo methods in numerical analysis are essentially twentieth-century developments (occasional earlier anticipations aside). In both cases the technical mathematical machinery necessary had existed much earlier, but what was necessary in addition was a particular type of mind-set, a willingness absent earlier to think and frame answers in statistical terms. Clinical medicine provides a particularly striking example of this: early discussions about the use of statistical methods in diagnosis were often punctuated by angry debates about the uniqueness of the individual and the irrelevance of aggregate behavior.

The powerful tool of randomization was not the invention of the twentieth century, but the uses it was now being put to were novel: where previously methods of random allocation had been used solely to disorder and disguise pending outcomes, that is, to *suppress* information – for example, in games of chance, jury selection, and impartial allocation – now randomization was being employed to *obtain* information. This has become so natural a part of our current scientific culture that it is easy to overlook the paradox it contains; the conundrum that order can emerge from the deliberate imposition of chaos.

One might have expected this twentieth-century theoretical and methodological revolution to have attracted no small share of attention by historians of science. In fact, however, the history of probability and statistics has always been a relatively unmined field. It does have a literature, but nothing to rival the massive output to be found in Greek mathematics, mathematical astronomy, classical physics, or the biological sciences. It has no towering figures such as Otto Neugebauer, Thomas Heath, or Joseph Needham who have chronicled its past. And not only has the history of the subject been largely neglected, but what does exist usually stops just at or before the nineteenth century, when this great transition began to take place.[10]

It is tempting to speculate on the reasons why so few of these accounts go beyond the era of Pierre Simon de Laplace. Laplace admittedly does represent a natural stopping point in the history of the subject. He displays a combination of mathematical technique and breath of application going well beyond that of any of his predecessors. This must have been inhibiting for at least two reasons: understanding the technical aspects of Laplace's work requires substantial mathematical prerequisites; and for those willing to undertake the task, assessing what went on after him is a daunting prospect, precisely because so many new vistas had been opened up to investigation.

Ironically, Isaac Todhunter's epic *History of the Mathematical Theory of Probability,* the one true classic history of the subject, may have only reinforced this tendency.[11] More a work of reference than a book to be read from cover to cover, it provides a careful survey of virtually all serious work on probability up to and including Laplace. Keynes's comment that Todhunter's "[bibliography], commentary and analysis, are complete and exact, – a work of true learning, beyond criticism," is, rhetorical hyperbole aside, not far of the mark.[12] Discuss anything up to Laplace and you had at your fingertips the major references, their interconnections, and in outline what they said; discuss anything after and you faced an uncharted morass.

But now, at last, this neglect has begun to wane. Two new books on the development of statistics in the nineteenth century have recently appeared (by Theodore Porter and Stephen Stigler), as well as two on probability: Lorraine Daston's *Classical Probability in the Enlightenment* and *The Probabilistic Revolution,* the subject of the present review.[13]

The Probabilistic Revolution is the spin-off of a year-long meeting held during 1982-1983 at the Zentrum für interdisziplinäre Forschung at the University of Bielefeld in West Germany; its two volumes contain thirty-five papers contributed by many of the participants in that seminar. *Volume 1: Ideas in History* focuses on "general conceptual, philosophical, and historical issues" and is largely nineteenth century in its coverage; *Volume 2: Ideas in the Sciences* is devoted to specific areas of application, and covers both the nineteenth and twentieth centuries.[14]

The range of contibutors is impressive: it includes such names as Thomas Kuhn and I. Bernard Cohen, well known for their work in other areas of the history of science; Ian Hacking, Stephen Stigler, and Ivo Schneider, well known for their work on the history of probability and statistics; and others, such as Anthony Oberschall, who have explored the historical background of fields (in Oberschall's case sociology) that draw heavily on statistics. But many other names are relatively new, evidence of growing interest in the subject.

As one finds in many such collections, there is a great deal of variability in the papers offered. Some, like those of Kuhn, Cohen, and Hacking, are quite general, dealing with broad issues such as the nature of scientific revolutions, and in what sense a genuine revolution in probability can be said to have taken place during the nineteenth century. Others, such as those of Andreas Kamlah, Gérard Jorland, and Schneider, are more narrowly focused, dealing with topics such as the German philosophical tradition in probability, the history of the St. Petersburg paradox, and the evolution of French textbooks on mathematical probability after Laplace. Some of the papers are quite long; others, such as those of Daston and Stigler, are briefer, summarizing arguments and research published elsewhere.

The result is a very useful set of materials for those interested in the history of this period. Several of the papers fill serious gaps in the literature. Kamlah's article on Carl Stumpf, Johannes von Kries, and Alexius Meinong, for example, is virtually the only serious discussion of von Kries to appear in English since Keynes's *Treatise on Probability* was published in 1921. Of necessity many of the articles in *The Probabilistic Revolution* can only begin to scratch the surface of their subject. William Coleman's discussion of nineteenth-century German clinical trials, for example, is an excellent survey of the subject, but one could write an entire article pursuing the references given in his footnote 57 (concerning the literature that sprang up in response to the work of Jules Gavarret).

Whatever their field, most readers are likely to find a number of articles in the collection to be of interest to them, but many of the contributions will be of only limited interest to the nonspecialist, and by design no general survey of the subject is attempted. For that, one can now turn with gratitude to the recently published books of Daston, Porter, and Stigler mentioned earlier. *The Probabilistic Revolution* is, however, a collection that any serious university library should possess.

Notes

1. Recent scholarly accounts include Robert C. Olby, *Origins of Mendelism* (London: Constable, 1966; 2nd ed., Chicago: University of Chicago Press. 1985); William B. Provine, *The Origins of Theoretical Population Genetics* (Chicago: University of Chicago Press, 1971).

2. Thus Sturtevant notes, "The question has often been raised: Would any biologist have appreciated Mendel's work if he had seen Mendel's paper before 1900?" (A. H. Sturtevant, *A History of Genetics* [New York: Harper and Row], p. 22); the one candidate suggested by Sturtevant is, not surprisingly, Francis Galton (in part because of the latter's "mathematical turn of mind").

3. See, for example, D. W. Forrest, *Francis Galton: The Life and Work of a Victorian Genius* (New York: Taplinger, 1974); H. T. F. Rhodes, *Alphonse Bertillon* (London: Harrap, 1956). *Biometrika* was founded in 1901 by Galton, Karl Pearson, and W. F. R. Weldon after the Royal Society refused to accept papers combining mathematics and biology.

4. Earlier work on the kinetic theory of gases by Daniel Bernoulli, William Herapath, J. J. Waterston, and others, written in less receptive times, had been for the most part ignored. Indeed Waterston suffered a fate worse than Mendel's: his paper of 1845 was rejected for publication by the Royal Society and lay mouldering in its archives for nearly half a century until discovered and published by Lord Rayleigh in 1891.

5. See generally Stephen Stigler, *The History of Statistics: The Measurement of Uncertainty Before 1900* (Cambridge: Harvard University Press, 1986), Chapter 7.

6. C. S. Lewis, *English Literature in the 16th Century* (Oxford: Oxford University Press, 1964), p. 3.

7. Thus Laplace argued, "Let us apply to the political and moral sciences the method founded upon observation and upon calculus, the method which has served us so well in the natural sciences" (P. S. Laplace, *Essai philosophique sur les probabilités* [Paris: Courcier, 1814]; translated as *A Philosophical Essay on Probabilities*, F. W. Truscott and P. L. Emory [1902]; translation reprinted [New York: Dover Publications, 1951, pp. 107-108].

8. For Condorcet, see Keith Michael Baker's outstanding *Condorcet: From Natural Philosophy to Social Mathematics* (Chicago: University of Chicago Press, 1975).

9. See W. Kruskal and F. Mosteller, "Representative Sampling IV: The History of the Concept in Statistics, 1895-1939," *International Statistical Review* 48 (1980): 169-195.

10. Examples include F. N. David's *Games, Gods and Gambling* (New York: Hafner, 1962), and Ian Hacking's *The Emergence of Probability* (Cambridge: Cambridge University Press, 1975); both accounts begin in antiquity but stop in the mid-eighteenth century. Writing towards the end of his career, the great English biometrician Karl Pearson was uniquely situated to describe the revolutionary changes that had occurred during his lifetime, but the title of his survey is *The History of Statistics in the 17th and 18th Centuries*, ed., E. S. Pearson (New York: Macmillan, 1978). The one major exception, L. E. Maistrov's *Probability Theory: A Historical Sketch* (New York: Academic Press, 1974), does go as far as the early twentieth century, primarily in order to discuss later Russian contributions.

11. Isaac Todhunter, *A History of the Mathematical Theory of Probability from the Time of Pascal to that of Laplace* (London: Macmillan, 1865).

12. John Maynard Keynes, *A Treatise on Probability* (London: Macmillan, 1921), p. 432.

13. Theodore M. Porter, *The Rise of Statistical Thinking: 1820-1900.* (Princeton, NJ: Princeton University Press, 1986); Stigler, *History of Statistics*, n. 5; Lorraine Daston, *Classical Probability in the Enlightenment.* (Princeton, N.J.: Princeton University Press, 1988). In addition to these general histories, a variety of more specialized monographs have appeared during the last twenty years: these include D. V. Glass, *Numbering the People* (Farnborough, England: Saxon House, 1973); N. L. Rabinovitch, *Probability and Statistical Inference in Ancient and Medieval Jewish Literature* (Toronto: University of Toronto Press, 1973); C. C. Heyde and E. Seneta, *I. J. Bienaymé: Statistical Theory Anticipated* (New York: Springer-Verlag, 1977); Kh. O. Ondar, ed., *The Correspondence Between A. A. Markov and A. A. Chuprov on the Theory of Probability and Mathematical Statistics* (New York: Springer-Verlag, 1981); A. W. F. Edwards, *Pascal's Arithmetical Triangle* (New York: Oxford University Press, 1987). Recently biographies of major twentieth-century statisticians have also begun to appear: Joan Fisher Box's *R. A. Fisher: The Life of a Scientist* (New York: Wiley, 1978), and Constance Reid's *Neyman—From Life* (New York: Springer-Verlag, 1982).

14. The fields discussed include psychology, sociology, economics, physiology, evolutionary biology, and physics.

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Yuji Ichioka. *The Issei: The World of the First Generation Japanese Immigrants, 1885-1924.* New York: The Free Press, 1988. 317 pp. $22.95 (cloth) (Reviewed by Roger Daniels)

Yuji Ichioka has long since established himself as our finest historian of the Issei generation. American-born but with a command of Japanese-language sources, he has been producing lapidary articles of high quality on this or that aspect of the immigrant generation's experience since the early 1970s. He was also one of the editor-compilers of an inventory of the Japanese American Research Project Collection at UCLA, the premier repository for materials about the immigrant generation.[1] This book is, in large part, an organization of ten of his articles into a narrative. It is good to have them so compiled, and this book is an important milestone in the development of Japanese-