The Empire of Chance

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The Empire of Chance

How probability changed science and everyday life

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To the memory of Bill Coleman,
who helped sow the seeds for this book

CONTENTS

Acknowledgments

Our first debt is to the Zentrum für interdisziplinäre Forschung (ZiF) of the University of Bielefeld and to the Stiftung Volkswagenwerk for sponsoring in 1982–83 a year of research on the probabilistic revolution, of which this book is one outcome. We are grateful to all our colleagues in the ZiF project for much stimulating conversation and for advice on this project. Our collaboration was enormously assisted by two families who provided accommodations for us to meet, to plan, and to edit the various chapters in 1986 and 1987. We heartily thank the Wolfs of Freiburg im Breisgau, and the Dastons of Cheverly, Maryland, for their generous hospitality. Much of the typing and word-processor translation was done – with admirable efficiency – by Bonnie Blackwell, Lottie McCauley, Kathleen Miller, Elizabeth Stovall, and Ella Wood of the History Department, University of Virginia.

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Introduction

Fortuna, the fickle, wheel-toting goddess of chance, has never been a favorite of philosophy and the sciences. In that touchstone of medieval learning, Boethius' *Consolations of Philosophy*, sober Dame Philosophy warns that only when Fortuna "shows herself unstable and changeable, is she truthful," and preaches against the very existence of chance, conceived as "an event produced by random motion and without any sequence of causes." Dame Philosophy had illustrious allies. Despite the upheavals in science in the over two millennia separating the Athens of Aristotle from the Paris of Claude Bernard, they shared at least one article of faith: science was about causes, not chance.

Yet even as Bernard sought to banish chance and indeterminism from physiology, Fortuna already ruled a large and growing empire in the sciences. The laws of the realm were probability theory and statistics. By "taming chance," in Ian Hacking's evocative phrase, probability and statistics had reconciled Scientia to her arch-rival Fortuna. From its beginnings in the mid-seventeenth century, probability theory spread in the eighteenth century from gambling problems to jurisprudence, data analysis, inductive inference, and insurance, and from there to sociology, to physics, to biology, and to psychology in the nineteenth, and on to agronomy, polling, medical testing, baseball, and innumerable other practical (and not so practical) matters in the twentieth. But this triumphal march was emphatically not the simple accumulation of applications by a mathematical theory. Perhaps more than any other part of mathematics, probability theory has had a relationship of intimacy bordering upon identity with its applications. Indeed, there was arguably no "pure" theory of mathematical probability until 1933 (see 3.6), and until the early nine-

teenth century, the failure of an application threatened the theory itself (see 1.5). For much of its history, probability theory *was* its applications.

This means that probability theory was as much modified by its conquests as the disciplines it invaded. When, for example, probability became a tool for evaluating compilations of numbers about births, deaths, crimes, barometric fluctuations, dead letters, and other kinds of statistics, the very meaning of probability changed, from a degree of certainty in the mind to a ratio of events counted in the world (see 2.2). When the British polymath Francis Galton invented a way of measuring how much offspring peas deviated from their parent stock, he launched the analysis of correlations (see 2.5; 4.4). Factor analysis has its roots in educational psychology, analysis of variance in eugenics and agronomy, and so on.

It was in fact the rule for probabilistic ideas and techniques to originate in highly specific contexts, and to advance on the strength of vivid analogies. The normal or bell-shaped curve at first represented the probability of observational error in astronomy, then of nature's "errors" from *l'homme moyen* in sociology, then of anarchic individual gas molecules exhibiting orderly collective properties (see 2.5; 5.6). Eventually the normal curve came to represent the distribution of almost everything, from intelligence quotients to agricultural yields, and shed the particular interpretations derived from its early applications (see 8.1). But for almost a century such concrete analogies were the bridges over which it and other probabilistic notions passed from one discipline to another.

This book is about the applications of probability and statistics to science and life, where "application" is understood in this special sense: the mathematical tool shaped, but was also shaped by, its objects. The mathematical development of probability and statistics has been admirably treated in the work of such scholars as Isaac Todhunter, L. A. Maistrov, O. B. Sheynin, Stephen Stigler, and Ivo Schneider. Our primary concern, however, is not theirs. We analyze how probability and statistics transformed our ideas of nature, mind, and society. These transformations have been profound and wide-ranging, changing the structure of power as well as of knowledge. They have shaped modern bureaucracy as well as the modern sciences. The extraordinary range and significance of these transformations has rarely been appreciated, perhaps because the influence of probability on the various sciences has until now been studied only piecemeal. Also, the domain of probability and statistics was less often expanded by decisive conquest and revolution than by infiltration and alliance. In this book, we view these transformations synop-

tically, as a single historical movement – one whose influence on modern thought and life is second to no other area of scientific endeavor.

These encounters of probability and statistics with science have in no case been neutral – mere translations of extant ideas and methods into the language of mathematical probability. Even when probability has entered at the level of methods rather than of theories, the ultimate impact has transcended technique. When psychologists adopted inference statistics as a tool of the trade, they also came to view the same techniques as models of the mind (see 6.4). When biometricians warred with Mendelians over the proper approach to genetics, the view of biological inheritance implied by Pearsonian statistics was at issue (see 4.4). When physicians opposed the use of randomized clinical trials, they doubted not only the relevance of the results but also the ethics of the therapy (see 2.3; 4.2; 7.3). Whatever they touch, probability and statistics transform, and are themselves often transformed in the process. This book is a study in the interactive effects of quantification.

Not all important notions of chance, however, can be set to numbers – even in the sciences. Some of the most important influences of probabilistic ideas have involved qualitative ideas. Consider, for example, the extent to which discussions of chance permeate philosophy, raising issues of determinism, free will, causality, explanation, evidence, and inference. These strands are braided together with scientific themes in this book. The Belgian statistician Adolphe Quetelet and the British physicist James Clerk Maxwell grappled with the issue of free will in their work (see 2.6; 5.6); the probabilists Jakob Bernoulli and Laplace gave us our most lapidary statements of determinism (see 1.5; 8.3); chance as "absence of design" played a seminal role in evolutionary biology (see 4.3). This book documents how supple the bonds linking philosophical and probabilistic notions could be, depending on the context: statistics in nineteenth-century sociology, for example, was paired with the most inexorable brand of determinism, but in twentieth-century physics it implies the strictest indeterminism.

The empire of chance is too vast for us to map in its entirety in the compass of a single volume. We aim at a comprehensive, but not an exhaustive tour of its domains. We begin with two historical chapters that describe the origins and development of probability and statistics from the mid-seventeenth to the end of the nineteenth century. Here we introduce changing interpretations of the probability calculus, changing attitudes towards determinism, changing conceptions of averages and errors – all, again, in the context of changing applications. In each of the subse-

quent four chapters, we focus on one area of broad application: experimental methodology, biology, physics, and psychology. Our objective is not simply to list the points at which probability has entered these fields, but to examine the historical circumstances and conceptual consequences attendant to key applications. With chapter 7, we leave the sciences to assess the impact of probability and statistics on daily life, from weather reports to mammography. Again, we lay no claim to an exhaustive study of such applications – to catalogue them alone would require volumes. Rather, we have selected instances that show how deeply, if quietly, these applications have altered our values and assumptions about matters as diverse as legal fairness or human intelligence. Finally, we survey, from something like the victorious general's hilltop, the territory we have covered.

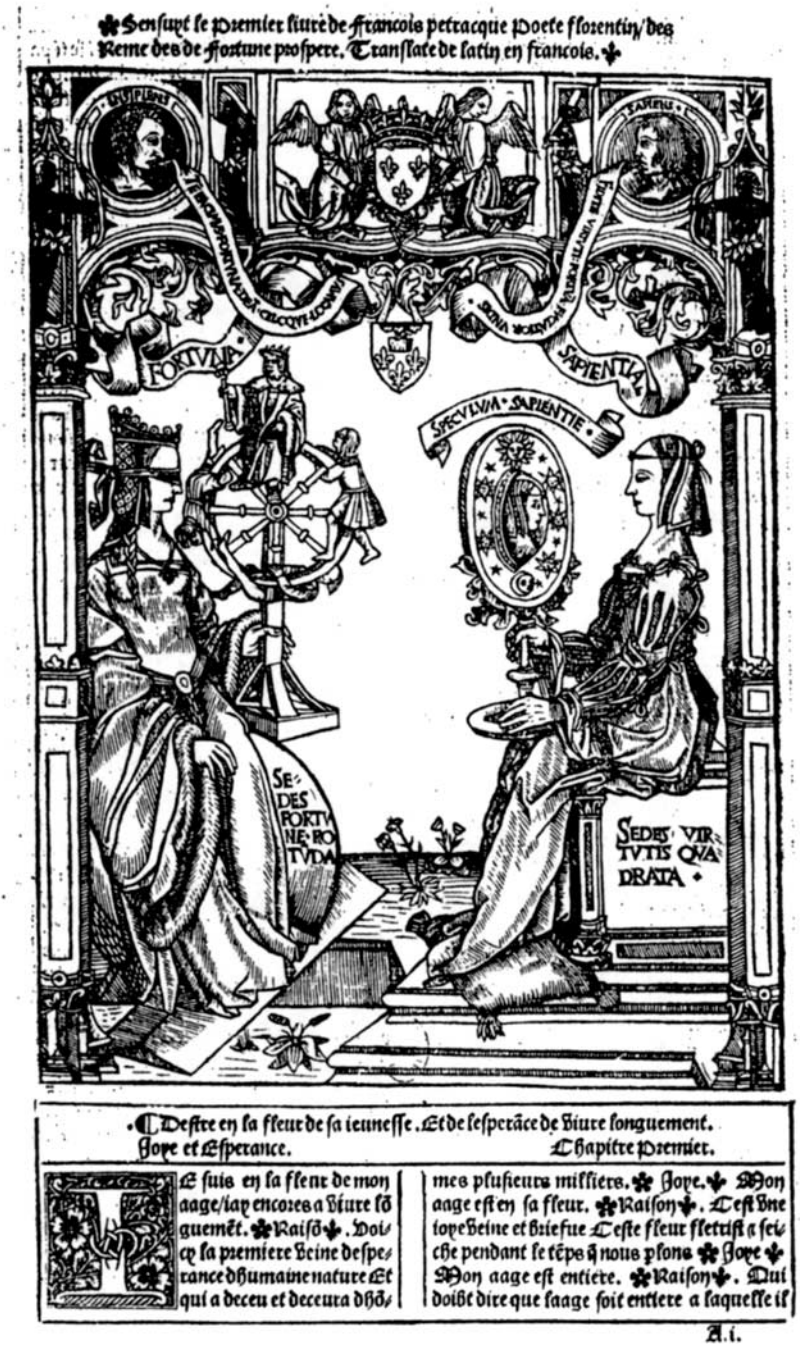
We envision a broad audience comprising both scholars from many fields and interested laymen, and have therefore kept technical material to a minimum. The handful of equations that do appear do not do double duty as explanations.

This is a book by several hands, but it is by no means an anthology. We tell a continuous story, with characters who appear and reappear, episodes that overlap and intersect, and common themes that repeat like a refrain. The plot line zigzags from one discipline to another – Fortuna did not honor these boundaries – and the reader will, for example, meet R. A. Fisher in the chapter on psychology as well as in those on experimental methodology and biology, and encounter debates over the implications of statistics for freedom of the will in physics as well as in sociology. A collaboration was essential because the scope and interdisciplinary nature of the topic required a range of knowledge that exceeds the competence of any single author. Some chapters were drafted by one of us, others by two or even three. But the entire manuscript was planned and then revised in light of criticism and discussion by all members of the group. That its contents reflect a diversity of interests will, we hope, be counted among its strengths rather than its weaknesses. We have not identified chapters by their original authors, but rather present the book as we conceived (and conceive) it: a collaborative work, with a narrative that stretches from beginning to end. Dutiful subjects of the empire of chance, we used a lottery to order our names on the title page.

As all scholars know, such a wholehearted collaboration requires special conditions. All six of us were members of the year-long research project on "The Probabilistic Revolution" at the Center for Interdisciplinary Studies in Bielefeld, Federal Republic of Germany. Essays

written by participants in this project now fill two thick volumes (Krüger, Daston, and Heidelberger, eds., 1987; Krüger, Gigerenzer, and Morgan, eds., 1987) that demonstrate the importance of the topic across a wide range of fields, nations, and centuries. Our subset of six hoped to condense and connect the elements contained in these essays into a single narrative, one that viewed the growth of probabilistic and statistical ideas from a unified perspective. We also hoped to perpetuate the intense collegiality of the Bielefeld year with a project that would build upon our preliminary consensus, and one that would demand still greater collaborative efforts. In addition to our many discussions with our Bielefeld colleagues, we have drawn heavily on the collections mentioned above, as well as from recent books by Ian Hacking (1975; forthcoming), Donald MacKenzie (1981), Stephen Stigler (1986), Theodore Porter (1986), Gerd Gigerenzer and David Murray (1987), and Lorraine Daston (1988). We include also the results of much original research on crucial topics not addressed in the existing scholarly literature.

Fortuna's wheel governed not only the fates of men, but also her own. Few biographies contain as many ironic twists, turnabouts, and improbabilities as that of probability itself. Our story confounds expectation at many turns: we find physics borrowing from sociology; words that flip-flop meanings into their opposites; strange pairings of probability with determinism, or mechanism with chance. Philosophy scorned Fortuna as "changeable," and change, both subtle and dramatic, episodic and enduring, is the leitmotif of this study. Yet whereas the vicissitudes of fortune, as Gibbon says, "bury empires and cities in a common grave," we see no sign that Fortuna's empire will suffer a turn of the wheel.



Fortuna (left) and Sapientia (right) are depicted here in traditional opposition. The slow breakdown of this opposition is the topic of this book. Source: Petrarch, *Remède de l'un et l'autre fortune prospère et adverse* (Paris, 1524); courtesy of the Bibliothèque Nationale, Paris.