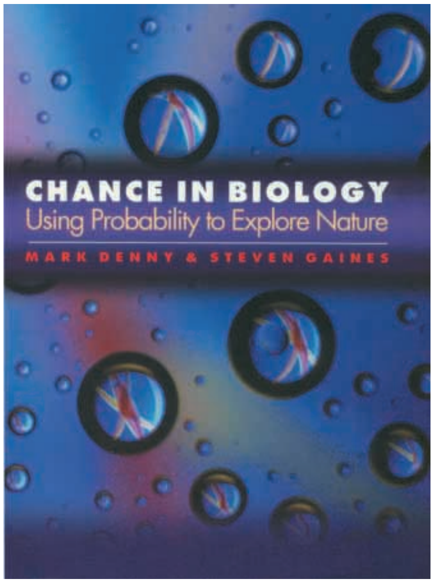
Book Review

HERE'S YOUR CHANCE



Chance in Biology: Using Probability to Explore Nature

By M. Denny and S. Gaines

Princeton University Press (2002)
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£19.95 / $29.95.

As a teacher of introductory biology, I try very hard to instill in my students the fact that quantitative reasoning is an integral tool for life sciences. Thus I am constantly on the lookout for potential books that simultaneously are of interest to students of biology, exemplify the importance of mathematical skills for understanding biological phenomena, and are accessible at an introductory level. Although few, if any, books meet these criteria, *Chance in Biology*, by Mark Denny and Steven Gaines, is a strong contender on at least two fronts, and while it may be too sophisticated for first-year college students without much experience in biology or mathematics it can serve admirably in various contexts for more advanced undergraduates, graduate students and faculty alike.

As befits a book exploring the uses of probability theory for understanding biology, the brief opening chapter sets the stage by highlighting various roles that chance and disorder play in living systems. A case study is made of the molecular structure and material properties of spider silk (Denny is after all a biomechanist). The lesson learned is not only that random processes are ubiquitous in life, but also that a deeper understanding of stochasticity itself can lead to predictive models and experiments that elucidate biological phenomena. As Denny and Gaines point out, rather than lamenting life's disorder, why not use probability theory to take advantage of it.

Like other areas of math, or any other discipline for that matter, probability theory has its own language. Chapters 2, 3 and 4 serve as a dictionary, and also provide a set of tools and guidelines for operating within the conceptual framework of statistics and chance. We learn about Venn diagrams and are given a formal definition of probability and probability distributions. An intriguing section on Bayes' formula and AIDS examines how an understanding of conditional probabilities, the probability of some event given knowledge about another event, can be used to investigate the likelihood of HIV infection given a positive HIV test. Chapter 3 continues with the topic of probability distributions, focusing on distributions in which the number of possible outcomes is discrete (i.e. some integer value) and any one outcome has some associated probability. Here we are introduced to the binomial and geometric probability distributions and the formulations for the major players in statistics; the idealized average or expectation of a variable (μ_x), its variance (σ^2_x) and closely related standard deviation (σ_x).

Chapter 4 turns to continuous probability distributions, where the number of potential outcomes is infinite and uncountable and introduces the 'workhorse of statistics': the normal probability density function and its associated normal or Gaussian distributions. As Denny and Gaines point out, this family of distributions is a centerpiece for biostatistics because so many of the variables studied by biologists are at least approximately normally distributed.

Now armed with an understanding of the essential elements of probability theory, we can begin to explore its utility with respect to biology. Chapters 5 and 6 are devoted to the statistics of 'random walks', processes consisting of multiple discrete, randomly determined steps. Countless physical and biological phenomena fit the bill and Denny and Gaines use chapter 5 mainly to delve into the world of molecular diffusion. We follow a molecule of sugar through a glass of iced tea, and engage in a hypothetical race between a diffusing cloud of particles and contestants ranging in size from *E. coli* to anchovies. The thrust of this section is to illustrate the importance of diffusion as a transport process at small scales and its futility at larger scales.

While many of us are vaguely familiar with the notion of random walks in the context of Brownian motion and diffusion, we may be less acquainted with other applications. Chapter 6 outlines more diverse biological topics to which the mathematics underlying random walks can be applied. The chapter begins by developing a quantitative framework for exploring how long it takes random motion to navigate a bounded space by following the itinerant lifecourse of phytoplankton in a turbulent lagoon before ending in the belly of a clam, and concludes with a discussion of three-dimensional random motion in the context of protein configuration and the elastic properties of biological materials.

Chapter 7 explores how to glean information about the extremes of a population, such as freak waves or the likelihood of rupturing your eardrum at a loud cocktail party. From here we learn that the distribution of extremes generally fits one of three asymptotic functions known as Gumbel curves. These, in turn, are used to investigate topics ranging from human longevity, lethal temperatures for barnacles, and streaks in baseball (e.g. consecutive wins or losses, number of homeruns in a season etc.). Amazingly, the authors calculate that Mark McGwire's 70 homeruns in 1998 was an event expected to occur approximately every 14,000 years; I wonder how long we might have expected to wait for Barry Bond's even more astonishing feat of 73 homeruns in 2001.

Chapter 8 serves as a wonderful introduction to the physics of 'noise'. It explores noise in the context of how sensory systems have evolved to cope with its ubiquitous nature. We are given a thorough discussion of how rod cells fare in dim light, and why the cell bodies of neurons shouldn't get too small (consider the consequences of a neuron that fires in response to the opening of a single sodium channel). As this chapter exemplifies, the subject matter of this book is incredibly diverse, but in surveying this diversity the authors have demonstrated one of their points: stochastic processes underlie much of life.

In summary, this is a fantastic book. Indeed, one would be hard-pressed to find a more readable and lucid introduction to probability theory. The fact that it is written by biologists for biologists is also important. Rather than simply describing an array of quantitative tools, the book provides a singular but broad context for using such tools in biology. As the authors admit up front, this is a mathematics textbook. However, whenever mathematics is invoked, the authors move step by step through their formulations, and often provide a written interpretation of the critical points. Moreover, the incorporation of problems at the end of each chapter (as well as answers and explanations in the book's final chapter!) was a stroke of brilliance, allowing readers to practice what they learn along the way.

As to the book's audience, although I can't help but conclude that this text would be somewhat overwhelming for an introductory biology course, the book would serve perfectly as the centerpiece for an interdisciplinary course exploring the intersection of math and biology and would readily fit into the supplementary reading of a biostatistics course. It is a book that will be equally useful to the biologist trying to emphasize quantitative reasoning in his or her discipline as to the mathematician, physicist or statistician seeking to engage the many biology students searching for a context for the mathematical tools and concepts they are learning. In short, *Chance in Biology* examines the ubiquitous nature of random processes in biological systems and illustrates the importance of probability theory to the study of such processes.

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