

Preface

To see a World in a Grain of Sand
And a Heaven in a Wild Flower,
Hold Infinity in the palm of your hand
And Eternity in an hour.

WILLIAM BLAKE, *Auguries of Innocence*

Quantitative methods are bringing about a revolution in modern molecular and cellular biology. Groundbreaking technical advances are fueling a rapid expansion in our ability to observe, as seen in multidisciplinary studies that integrate theory, computation, experimental assays, and the control of microenvironments. Although a relatively small number of risk-takers and visionaries have led most of the advances, many of the ideas and methods are maturing and are ready to be adopted by a wider group of researchers. This book is intended to provide them with a solid foundation for starting work in this field.

These pages provide an introduction to the fundamentals of the emerging science of modern quantitative biology and what it is telling us about molecular and cellular behavior. The chapters, which span diverse topics and were contributed by recognized experts, are organized into three sections. Chapters 1–4 (Fundamental Concepts) cover bold ideas that inspire many questions and approaches of modern quantitative biology. There you'll find perspectives on evolution dynamics (Robert H. Austin), system design principles (Michael A. Savageau), chance and memory (Theodore J. Perkins, Andrea Y. Weiße, and Peter S. Swain), and information processing in biology (Ilya Nemenman). Chapters 5–10 (Methods) describe recently developed or improved techniques that are transforming biological research. You'll read about experimental methods for studying single-molecule biochemistry (Jeffrey A. Hanson and Haw Yang), small-angle scattering of biomolecules (Cy M. Jeffries and Jill Trehwella), subcellular localization of proteins (Jeffrey J. Saucerman and Jin Zhang), and single-cell behavior (Philippe Cluzel). You'll also find theoretical methods for synthetic biology (Ying-Ja Chen, Kevin Clancy, and Christopher A. Voigt) and modeling random variations among cells (Brian Munsky). Chapters 11–13 (Molecular and Cellular Systems) focus on specific biological systems where modern quantitative biology methods are making an impact. At the molecular level is protein kinase (Susan S. Taylor and Alexandr P. Kornev), at the regulatory system level is the genetic switch of phage lambda (John W. Little and Adam P. Arkin), and at the cellular level is *Escherichia coli* chemotaxis (Howard C. Berg). Chapters 1–10 also incorporate case studies of systems for which new concepts or methods are increasing our understanding.

The chapters stress focused studies of a single system, whether cell, protein, molecular network, or other system. Such studies already have revealed many marvels of biological behavior and have suggested general principles, such as evolutionary optimization of information processing and other measures of performance, that might apply much more broadly in biology. Quantitative biology often seeks to discover, in Blake's words, "a world in a grain of sand." It is this spirit that the book aims to capture.

The absence of a relevant topic shouldn't be seen as a sign of diminished importance or lack of relevance for the book. For example, recent advances in molecular dynamics simulations will accelerate the integration of biomolecular structural biology (a subject critical to early quantitative biology research and the development of the entire discipline of molecular biology) with modern quantitative biology. Recent important quantitative advances in developmental biology are also missing from this volume. The field is large, and there are many reasons a topic might not be included.

As an exception, some readers might wonder at the absence of *high-throughput* methods. After all, they are responsible for an explosive growth in the availability of genome sequence data, which is crucial to many quantitative methods. However, because much has already been written about high-throughput methods in systems biology, it is not necessary to cover the topic here.

This book also reflects the excitement among those in the quantitative biology community, a large number of whom have participated in the Annual q-bio Conference (<http://q-bio.org>). Similar to the long-established Cold Spring Harbor Symposia on Quantitative Biology, the q-bio Conference, now entering its sixth year, has been a lively forum for presenting many new ideas, methods, and findings as well as complete stories where new understanding is achieved through integration of modeling and experiments. The conference and the accompanying summer school are helping to create a community of researchers that is realizing the potential of advances in quantitative biology. In this book's pages, the q-bio community reaches out to a wider group and shows some of the amazing things that can now be done. In reading this book, you'll gain some understanding and I hope be excited (or even bothered!) by some of the perspectives. Perhaps you'll be inspired to ask a bold and provocative question yourself, bring a new tool into your lab, or subject a new system to quantitative scrutiny.

Lastly, I have no doubt that in time the impact of modern quantitative biology on medicine will be profound. For example, quantitative studies of protein kinase structure and function already have led to development of imatinib, an important cancer drug. Much of the quantitative biology community, however, is driven by the need to advance fundamental understanding as opposed to biomedical applications. Not everything described in this book will be equally important to human health, and it is too early to say where the most important contributions will come from. That is why I will be donating my royalties from this book to the Cystic Fibrosis Foundation. Thus, even if the work found in this volume doesn't directly help people live longer, healthier lives, the book sales will improve the future of young people who are living with this heart-breaking disease.

Additional material is available from the CRC Web site: <http://www.crcpress.com/product/isbn/9781439827222>

Michael E. Wall