Chapter 1
Introduction

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1.1 Computational Neuroscience

The last several years have seen a dramatic increase in the number of neurobiologists building or using computer-based models as a regular part of their efforts to understand how different neural systems function (Eeckman and Bower 1993, Bower 1992). As experimental data continue to be amassed, it is increasingly clear that detailed physiological and anatomical data alone are not enough to infer how neural circuits work. Experimentalists appear to be recognizing the need for the quantitative approach to exploring the functional consequences of particular neuronal features that is provided by modeling. This combination of modeling and experimental work has led to the creation of the new discipline of computational neuroscience (Eeckman and Bower 1993).

More than the use of models *per se*, we believe that computational neuroscience is most distinguished from classical neurobiology by an explicit focus on how the nervous system computes. Thus, instead of obtaining experimental information about the structure of the nervous system for its own sake, a computational approach involves collecting that information most relevant at the moment for the advancement of functional understanding. In our hands, models, especially those based on the detailed physiology and anatomy of the brain region in question, capture what is known about this region while also directing further experimental investigations. These same models can then provide an interpretation for the data that were obtained. Thus, the interaction between experiments and computer modeling is increasingly iterative and interdependent.

This approach to the interaction between computer models and experimental investi-

gations obviously goes far beyond the traditional notion that experiments are simply for "testing" theoretical ideas. Furthermore, we believe that it requires that models not primarily be designed to cast novel ideas in more or less biological detail. Instead, modeling becomes a mechanism for generating new ideas based on the anatomy and physiology of the circuits themselves (Bower 1995). This issue is discussed in more detail in Chapter 11. However, a major objective of this tutorial guide to the use of the GENESIS simulator, and of GENESIS itself, is to provide future computational neurobiologists with the tools to construct models of this sort.

1.2 Using This Book

This book is divided into two parts that are intended to serve two different purposes. Part I describes the use of eight interactive tutorials which introduce modeling at different scales, ranging from parts of neurons to large neuronal networks. Depending on the audience, these tutorials can serve several purposes. The tutorial chapters are written so that they can be used by students of neurobiology, as well as by engineers, physicists, computer scientists, and others who are interested in increasing their knowledge of the nervous system. Each chapter begins by presenting the necessary theoretical background for the topic and then uses the tutorial simulations to further explore the implications of the theory. The book is designed to be used either for self-study, or for use in a course as a supplement to an introductory neuroscience text at the level of *Neurobiology* (Shepherd 1994), *From Neuron to Brain* (Nicholls, Martin and Wallace 1992) or *Principles of Neural Science* (Kandel, Schwartz and Jessell 1991). For a course that stresses a more quantitative approach at the single cell level, *Foundations of Cellular Neurophysiology* (Johnston and Wu 1995) would be an appropriate companion to *The Book of GENESIS*. Table 1.1 lists the chapters in these texts that correspond to the tutorials in Part I. Later, in Sec. 3.2, we present an overview of these tutorials.

In addition to exploring basic neurobiological principles, these chapters also introduce general concepts relevant to the process of modeling itself. Although no knowledge of computer programming is needed to use the tutorials, one may nevertheless learn a great deal about computer modeling from these simulations. For example, we consider the effect of numerical integration time steps on the results of simulations. We gain some understanding of why slight changes in some parameters can greatly affect the results, whereas changes in others have little effect. A recurring theme is the question, "When can I get by with a simple model, and when must I capture all the details in my model?" When constructing a model, we rarely have all the experimental information that we would like. Several of these chapters address the issue of using modeling as a means of bridging the gap between experiment and theory.

Part II of the book is intended as an introduction to the use of GENESIS as a modeling

BoG	*Shepherd*	*Nicholls et al.*	*Kandel et al.*	*Johnston and Wu*
4	4, 5	4	5,6,8	3,6
5	—	5	7	4
6	7	7	10,11	13
7	25	4,13	—	7
8	20	15	—	—
9	11,25,30	17	34,50	14
10	8	8	12	—

Table 1.1 Chapters in some commonly used neuroscience texts that relate to chapters in Part I of *The Book of GENESIS* (BoG). The texts listed are *Neurobiology* (Shepherd 1994), *From Neuron to Brain* (Nicholls et al. 1992), *Principles of Neural Science* (Kandel et al. 1991) and *Foundations of Cellular Neurophysiology* (Johnston and Wu 1995).

system. After an introduction to our "modeling philosophy," we begin a series of chapters that teach the use of the GENESIS simulation language for the construction of your own simulations. These generally follow the same sequence of topics as in Part I. Each chapter allows you to modify and build upon the simulations created in the previous one, as you progress from simpler to more complex models. The modular nature of GENESIS simulations encourages this approach to the development of simulations. Thus, you will be able to modify the tutorial simulations from Part I and use them as a starting point for your own original simulations. As some of these are based upon recent research simulations, this can drastically reduce the time required to produce a sophisticated neural simulation.

Finally, there are the appendices and indices. Appendix A describes the procedure for obtaining and installing the GENESIS simulator and the tutorials, and Appendix B gives listings of the various GENESIS simulation scripts that are used in Part II. In addition to the usual subject index, we have provided alphabetized indices for the GENESIS script language commands and basic simulation components (GENESIS objects) that are used in Part II.

One more comment on the general tone of this book. We have intentionally designed the tutorials and the text to provide a heavy emphasis on the actual "hands-on" use of the simulations described. Thus, it is written as a manual or "work-book," rather than as a textbook to be read passively. Our emphasis on hands-on demonstrations reflects our conviction that this form of learning is more valuable than a standard lecture or reading format (Alper 1994).