Preface

This is the second edition of a step-by-step tutorial for professionals, researchers and students working in the area of neuroscience in general, and computational neuroscience in particular. It can also be used as an interactive self-study guide to understanding biological neuronal and network structure for those working in the area of artificial neural networks and the cognitive sciences. The tutorials are based upon the GENESIS neural simulation system, which is now being used for teaching and research in at least 26 countries. The following chapters consist of a combination of edited contributions from researchers in computational neuroscience and current users of the system, as well as several chapters that we have written ourselves.

This book, and the tutorial simulations on which it is based, grew out of a simulation laboratory accompanying the annual Methods in Computational Neuroscience course taught at the Marine Biological Laboratory in Woods Hole, MA from 1988 to 1992. Since that time, the tutorials have been further developed and refined while being used in courses taught at Caltech and several other institutions, including the Crete course in Computational Neuroscience. For this second edition, we have made many revisions and additions based on comments, suggestions and corrections from members of the GENESIS Users Group, BABEL, and from students and teachers who have used this book.

The release of GENESIS version 2.1, with its many new features, has resulted in the addition of two new chapters and the addition of new material to existing chapters. With the availability of the GENESIS chemical kinetics modeling library and its graphical interface (*Kinetikit*), we expect to see GENESIS being increasingly used to relate cellular and network properities to biochemical signaling pathways (Chapter 10). The increasing sophistication, realism and size of large network models and the use of computationally intensive automatic parameter fitting methods have led to the development of a new parallel version of GENESIS (PGENESIS) which allows GENESIS to run on parallel computers and networks of workstations (Chapter 21). Other new additions include a section describing ways to implement synaptic modification (learning), a section describing uses of a new type of GENESIS ionic channel (the two-dimensional tabulated channel) which allows modeling of a wide variety of voltage and ionic concentration-dependent channels, a description of improvements in the procedure for implementing fast "implicit" numerical methods in GENESIS simulations, and descriptions of many new GENESIS commands and simulation components.

This new edition is accompanied by a CD-ROM containing the complete GENESIS 2.1 distribution with *Kinetikit*, PGENESIS and hypertext reference manuals. It also includes numerous tutorial simulations and example simulation scripts, including all of those used in the book, plus a collection of GENESIS models taken from the BABEL archives. Please see Appendix A for further details.

Part I of the book teaches concepts in neuroscience and neural modeling by means of interactive computer tutorials. These allow the student to perform realistic simulations and experiments on model neural systems. The simulations are user-friendly with on-line help and may be used without any prior knowledge of the GENESIS simulator or computer programming. The tutorials in Part II teach the use and programming of the GENESIS simulator for the construction of one's own simulations. Each tutorial is accompanied by a number of suggested exercises, "experiments," or projects which may be either assigned as homework or used for self-study.

Although they form a sequence, these tutorials were designed so that they may be used independently, as supplemental material for existing courses. This presentation, as well as the variety of suggested exercises and optional projects, makes it possible to explore topics at various levels of depth. For example, a survey course without much time to devote to a simulation laboratory might use only one or two simulations selected from the first few chapters, which treat the Hodgkin-Huxley model, passive propagation in dendrites, and the temporal summation of synaptic potentials in a multi-compartmental neuron model. A more advanced course, or one that emphasizes the use of computer simulation as a tool for the understanding of the nervous system, would place more emphasis on the later chapters that deal with the role of ionic conductances in burst firing of neurons, central pattern generator circuits, cortical networks and modeling of biochemical signaling pathways. A course that can devote time to student simulation projects can use the tutorials in Part II to quickly get students to the point of creating their own simulations. In the introductory chapter (Table 1.1), we list the correspondence between the Part I chapters and those in several popular neuroscience textbooks. Later, in Sec. 3.2, we give an overview of the tutorials used in this book.

We have found that even experienced researchers who are familiar with the concepts presented in the introductory chapters have been able to learn something from the accompanying simulations, and have been able to use the more advanced simulations as a starting point for original research simulations. As interest in the field of computational neuroscience continues to expand, and as increasing numbers of neuroscientists recognize the necessary connection between modeling and experimental neurobiology, we hope and anticipate that this book will promote access to the power of realistic simulations of neural structures.

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Part I

Neurobiological Tutorials with GENESIS