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Editors

Hippocampal Microcircuits

A Computational Modeler's Resource Book

Springer

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Preface

Microcircuits are functional modules that act as elementary processing units bridging the gap between single-cell activity and large-scale network activity in the brain. Microcircuits can be found in all parts of mammalian nervous systems and involve many different neuronal types embedded within multiple feedforward and feedback loops. Synaptic connections may be excitatory and inhibitory and target-specific spatial domains of a neuron. In addition to fast signalling, neurons and their microcircuit environment are subject to neuromodulatory signals. Thus, fast synaptic transmission and neuromodulation in neuronal microcircuits combine to produce complex dynamics of neural activity and information processing at the network level.

The hippocampus has an indispensable role in spatial navigation and memory processes and is amongst the most intensively studied regions of mammalian brain. Hippocampal microcircuits exhibit a wide variety of population patterns, including oscillations at theta (4–7 Hz) and gamma frequencies (30–100 Hz), under different behavioural conditions. The complex dynamics conceivably reflects specific information processing states of the networks. Recent years have witnessed a dramatic accumulation of knowledge about the anatomical, physiological and molecular characteristics as well as the connectivity and synaptic properties of the various cell types in hippocampal microcircuits. However, much research is needed to decipher the precise function of the detailed microcircuits.

This book provides an overview of our current knowledge of hippocampal biology. Most data are presented in tabular or pictorial form so that the salient features and key parameters are readily accessible to the reader. It also provides a snapshot of the state-of-the-art approaches to investigate hippocampal microcircuits. The central aim of the volume is to provide a unique resource of data and methodology to anyone interested in developing microcircuit-level computational models of the hippocampus.

The book is divided into two thematic areas: (1) experimental background and (2) computational analysis. In the first thematic area, experimental neuroscientists describe the salient properties of the various cell types found in the hippocampus as well as their connectivity patterns and the characteristics of the different synapses. In addition, behaviour-related ensemble activity patterns of morphologically identified neurons in anaesthetized and freely moving animals provide insights on the function

of the hippocampal areas. In the second thematic area, computational neuroscientists present models of the hippocampal microcircuits at various levels of detail from single-cell to large-scale networks, developed on the basis of experimental data. Models of computation performed by single neurons, both principal cells as well as interneurons, and synapses with implemented plasticity rules are presented. Networks models of rhythm generation, spatial navigation and associative memory are discussed. Finally, a chapter is dedicated to describing simulation environments of single neurons and networks currently used by computational neuroscientists in developing their models.

Aside from offering up-to-date experimental information on the hippocampal microcircuits, our edited volume provides examples of systematic methodologies for modelling microcircuits necessary to all computational neuroscientists interested in bridging the gap between the single cell, the network and the behavioural levels. Importantly, we also identify outstanding questions and areas in need of further clarification that will guide future research in both biological and computational fields.

This volume will be an invaluable resource not only to computational neuroscientists, but also to experimental neuroscientists, electrical engineers, physicists, mathematicians and all researchers interested in microcircuits of the hippocampus. Graduate-level students and trainees in all of these fields will find this book an insightful and readily accessible source of information.

Finally, there are many people who we would like to thank for making this book possible. This includes all the contributing authors who did a great job. We would like to thank Joseph Burns, our former Springer senior editor, without whose support in the initial stages, this book would not have been possible. Last, but not least, we would like to thank Ann H. Avouris, our current Springer senior editor, and members of the production team, who were a consistent source of help and support. We dedicate this work to our families.

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