

Preface

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Since the first publication of two full-length manuscripts on head direction cells by Jeffrey S. Taube, Robert U. Muller, and James B. Ranck Jr in 1990, there has been a rapidly accelerating growth in knowledge about and interest in these fascinating neurons. Like the place-selective hippocampal neurons, head direction cells serve as a particularly remarkable model of high-level cognitive processing at the level of single neurons. Found in about ten different brain areas, these cells fire action potentials only when the animal orients its head in a specific direction in space. Since different neurons are selective for different directions, those active at any given moment can provide an accurate spatial reference signal. These responses are strongly influenced by distal landmarks in the local environment (and thus are independent of the earth's magnetic field). However, they do not depend on these cues being viewed from a particular perspective or distance, and they persist in darkness or without any landmark cues. This stimulus invariance and robustness suggest that these responses can contribute information vital for spatial orientation behaviors such as navigation and can participate in brain representations of the head in space.

But how does the brain go about creating and maintaining these representations? When environmental cues are displaced, what are the neural mechanisms that permit the responses of the population of neurons to coherently follow them? What rules guide the anchoring of the cell responses to sensory inputs? How are the responses of the diverse brain structures in this network united? And how do head direction cells influence orientation behavior and navigation choices? This book will address such questions, and present the state of the art as well as directions for further research on issues that remain on the frontiers of our knowledge.

While this book is primarily intended for students and researchers in the cognitive sciences, neurosciences, computational sciences, and robotics, we hope that it may also prove useful to clinicians, philosophers, and all others who share our curiosity and passion to understand not only how spatial cognition works but, more generally, how the brain works.

Much of the work presented here is based upon presentations at a conference held at an estate in the Var region of France on September 14–18, 2002, under the sponsorship of the Treilles Foundation. This book, however, has been organized to provide a coherent, comprehensive, and didactic presentation of the topic in a manner accessible to nonspecialists, but comprehensive enough to serve as a reference for specialists as well. As much as possible, the actual researchers who made the scientific discoveries have been asked to explain their work, permitting a variety of viewpoints on several key issues.

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