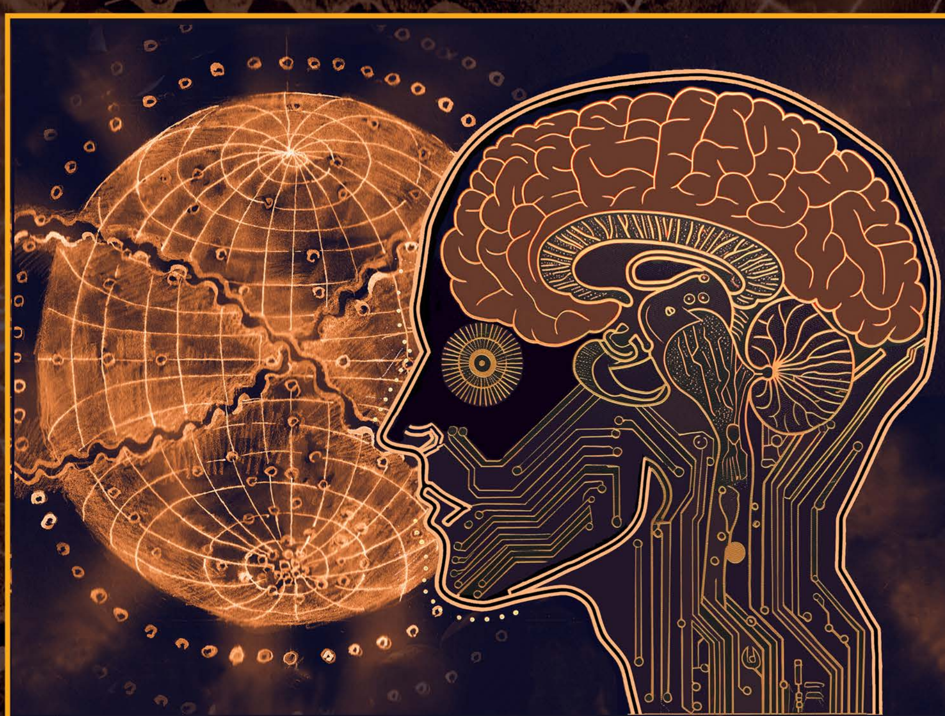
THEORETICAL NEUROSCIENCE

Understanding Cognition



XIAO-JING WANG

CRC Press
Taylor & Francis Group

Larry Abbott, William Bloor Professor of Theoretical Neuroscience, Columbia University; co-author with Peter Dayan of the textbook "*Theoretical Neuroscience*"
"In this textbook, Xiao-Jing Wang takes the reader on a remarkable journey from cellular and synaptic biophysics to memory, decision making, psychiatry and large-scale brain structure. His insights on how to apply theoretical methods to higher cognitive functions will be valuable to anyone thinking about thinking."

Jean-Pierre Changeux, Institute Pasteur, Paris; author of "*Neuronal Man: the Biology of Mind*"
"X-J Wang book illuminates how in the past decades a new field has emerged from the theoretical modeling of a wide diversity of neural processes which has successfully contributed to our understanding of brain functions up to Cognition. The book progresses from the most elementary building blocks of the brain, neurons, synapses and their molecular components up to global executive functions and the new field of computational psychiatry. The immense knowledge recently acquired and beautifully presented in the book is a must for anybody concerned by the higher functions of the brain: a bible for the students, a grandiose panorama for the educated scientists."

Anne Churchland, Professor of Neurobiology, University of California, Los Angeles
"This compelling book explains foundational concepts in theory and modeling in a way that marries rigor with intuition. It furnishes readers with powerful theory and modeling tools that are critically needed to tackle problems in modern neuroscience. Wang's explanations of network dynamics, normalization and attractor models for cognition are certain to inspire experimentalists and theorists alike."

Robert Desimone, Director of the McGovern Institute for Brain Research, Doris and Donald Berkey Professor of Neuroscience, MIT
"In Theoretical Neuroscience: Understanding Cognition*, Xiao-Xing Wang explains that while the brain is not a computer, all of its elements, from synapses to circuits, obey computational principles that underlie our cognitive functions. As a leader in the computational field, he gives an insider's account of these principles at both a mathematical and conceptual level. This should be required reading for any student of modern neuroscience."*

Stanislas Dehaene, Chair of Experimental Cognitive Psychology, Collège de France, Paris
"In the 20th century, Molecular Biology decoded the intricate mechanisms of DNA and RNA, the "logic of life" celebrated by Nobel Prize Laureate François Jacob. Understanding the logic of neural circuits of cognition is an equivalent goal for 21st century in Neuroscience. This important book represents a fundamental step forward : it provides a synthesis of elemental circuit building blocks of core cognitive functions, how their operation can be mathematically modeled, and how their composition may account for a variety of cognitive processes and behavioral tasks."

Brent Doiron, Heinrich Kluver Professor of Neurobiology, Director of the Grossman Center for Quantitative Biology and Human Behavior, University of Chicago
"Understanding the brain needs an appreciation of its components and activity over a wide range of spatial and temporal scales: from synapses to whole brain circuits, from rapid sensory and motor responses to lifetime memory. In this book Xiao-Jing Wang beautifully shows how theoretical and mathematical thinking can provide the needed abstraction to not only describe the brain at each scale, but synthesize these across scales into a compelling and deep understanding of neural function. At whatever stage you are in your neuroscience journey, from novice to expert, this is now required reading."

John Duncan, University of Cambridge and the Medical Research Council; author of "*How Intelligence Happens*"
"Nobody understands better than Xiao-Jing Wang how the events of the mind are built from the dynamic activity of neural populations, and in this book, he explains the state of the art from top to bottom. With extraordinary depth and scope, the story moves from the fundamentals of the neuron to the highest levels of human intelligence. Anybody aiming to understand the union of mind and brain can start right here."

Ann Graybiel, Institute Professor, MIT
"Xiao-Jing Wang has written a remarkable book, melding together viewpoints of a physicist/mathematician and those of a neuroscientist to produce a unique account of how the brain and its vast number of networks could operate to produce behavior. Wang has undertaken the job of bridging these two worlds, and the result is a grand success. This volume will be invaluable not only to academics, but also to all who have an interest in how the brain does its work. Xiao-Jing Wang has created a book to read and re-read, culminating in an introduction to brain-wide modeling to address the unsolved mysteries of the normal brain and the need for computational psychiatry to alleviate mental illness."

John Krystal, Chair of the Department of Psychiatry, Robert L. McNeil, Jr. Professor of Translational Research, Yale University School of Medicine
"This book is a remarkable opus from Dr. X-J Wang, a pioneering computational neuroscientist who's work continues to surprise and inspire me. This book is logically organized. It builds from a model neuron, to networks, to cognition/behavior, and it integrates all of this in considering issues of "computational psychiatry", i.e., behavioral pathology. Wirtten with clarity and an accessible style, this wonderful book is useful for people entering the field of computational neuroscience. It is also a wonderful resource for clinical investigators hoping to learn about the formalism of computational models."

Eve Marder, University Professor, Brandeis University; Former President of the Society for Neuroscience
"Theoretical Neuroscience: Understanding Cognition *by X-J. Wang is a remarkable book. It reads easily, and puts much of the field of quantitative and computational neuroscience into frameworks that allow the reader to see the etiology and genesis of the particular methods and findings being discussed. The book is comprehensive and moves seamlessly from the details of the biophysics of single neurons and synapses to some of the most complex puzzles in the neuroscience of cognition. This book will be useful for trainees and for established investigators as its breadth and depth will be helpful for everyone as they wish to gain access to the conceptual frameworks of large areas of neuroscience and their quantitative analyses."*

William Newsome, Harman Family Provostial Professor of Neurobiology, the inaugural Director of Wu Tsai Neuroscience Institute, Stanford University, Co-chair of the US Brain Initiative
"In a rapidly advancing field, Xiao-Jing Wang provides a beautiful and timely account of where we have been, where we are now, and where we are likely heading. From biophysical models of single neurons, through network models of neural circuits, to macro-level models of communication between brain areas, Wang sure-handedly guides the reader with clear, incisive exposition of each topic. For dessert, we are treated to Wang's forward-looking views on computational psychiatry and future interactions between artificial intelligence and natural intelligence. This book is a must-read for anyone intrigued with the nexus between neuroscience, cognitive science, and computational theory."

Mu-ming Poo, Scientific Director of Institute of Neuroscience, Chinese Academy of Sciences; Paul Licht Distinguished Professor in Biology Emeritus, University of California, Berkeley
"This monumental treatise by Xiao-Jing Wang, one of the leading computational neuroscientists in the world, offers a thorough survey and critical synthesis of both experimental and theoretical works on various cognitive processes in the brain. A valuable book for consultation by researchers and students of neuroscience."

Matthew Rushworth, Chair of Psychology Department, Oxford University, Britain
"Xiao-Jing Wang has been a leader in theoretical neuroscience for many years. The approaches and models that he has devised have inspired the field. Even more importantly, however, Xiao-Jing Wang has had an impact on cognitive science and neuroscience more generally that has changed how scientists working with brain and behavioural data think about the issues that they are investigating. Theoretical Neuroscience: Understanding Cognition *provides an accessible but comprehensive guide not just to how this happened but also to the very latest ideas emerging at the field's frontier."*

Doris Tsao, University of California at Berkeley
"If a genie were to grant me a wish, I might ask for a guided tour of the brain—starting in the microscopic world of neurons and synapses, traveling through the vast landscapes of large-scale cortical interactions underlying higher cognitive functions, and culminating in our modern era of AI. A tour with a master at my side who could cut through the dense jungle of thousands of scientific papers and explain the key findings with clarity, putting them in a precise conceptual and mathematical framework. Xiao-Jing Wang's remarkable book is exactly that wish come true. This book is an invaluable guide for young researchers and anyone who wants to truly understand what is known about the brain."

Theoretical Neuroscience

This textbook is an introduction to Systems and Theoretical/Computational Neuroscience, with a particular emphasis on cognition. It consists of three parts: Part I covers fundamental concepts and mathematical models in computational neuroscience, along with cutting-edge topics. Part II explores the building blocks of cognition, including working memory (how the brain maintains and manipulates information "online" without external input), decision making (how choices are made among multiple options under conditions of uncertainty and risk) and behavioral flexibility (how we direct attention and control actions). Part III is dedicated to frontier research, covering models of large-scale multi-regional brain systems, Computational Psychiatry and the interface with Artificial Intelligence. The author highlights the perspective of neural circuits as dynamical systems, and emphasizes a cross-level mechanistic understanding of the brain and mind, from genes and cell types to collective neural populations and behavior. Overall, this textbook provides an opportunity for readers to become well versed in this highly interdisciplinary field of the twenty-first century.

Xiao-Jing Wang is Distinguished Global Professor of Neural Science at New York University, where he is also affiliated with the Courant Institute of Mathematical Sciences and Department of Physics. Before joining New York University, he was Professor at Yale University. His honors include a Guggenheim Fellowship, the Swartz Prize for Theoretical and Computational Neuroscience and the Goldman-Rakic Prize for Outstanding Achievement in Cognitive Neuroscience.

Theoretical Neuroscience

Understanding Cognition

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