FROM MOLECULES TO NETWORKS
From Molecules to Networks, Second Edition
by John H. Byrne and James L. Roberts

Resources for Professors:

- All figures from the book available as PowerPoint slides
- Links to web sites carefully chosen to supplement the content of the textbook

Companion Web Site:
http://elsevierdirect.com/companions/9780123741325

Tools for All Your Teaching Needs

textbooks.elsevier.com

Academic Press

To adopt this book for course use, visit http://textbooks.elsevier.com.
# Table of Contents

List of Contributors vii  
Preface to the Second Edition ix  
Preface to the First Edition x  

1. Cellular Components of Nervous Tissue 1  
   PATRICK R. HOF, ESTHER A. NIMCHINSKY,  
   GRAHAME KIDD, LUZ CLAUDIO, AND BRUCE D. TRAPP  

2. Subcellular Organization of the Nervous System: Organelles and Their Functions 19  
   SCOTT BRADY, DAVID R. COLMAN, AND PETER BROPHY  

3. Energy Metabolism in the Brain 49  
   GERALD A. DIENEL  

4. Electrotonic Properties of Axons and Dendrites 111  
   JOHN H. BYRNE AND GORDON M. SHEPHERD  

5. Membrane Potential and Action Potential 133  
   DAVID A. MCCORMICK  

6. Molecular Properties of Ion Channels 159  
   DAVID MATTHEW YOUNG, YUH NUNG JAN, AND LILY YEH JAN  

7. Dynamical Properties of Excitable Membranes 181  
   DOUGLAS A. BAXTER AND JOHN H. BYRNE  

8. Release of Neurotransmitters 217  
   ROBERT S. ZUCKER, DIMITRI M. KULLMANN, AND THOMAS L. SCHWARZ  

9. Pharmacology and Biochemistry of Synaptic Transmission: Classical Transmitters 267  
   ARIEL Y. DEUTCH AND ROBERT H. ROTH  

10. Nonclassic Signaling in the Brain 301  
    ARIEL Y. DEUTCH, ANDREA GIUFFRIDA, AND JAMES L. ROBERTS  

11. Neurotransmitter Receptors 321  
    M. NEAL WAXHAM  

12. Intracellular Signaling 359  
    HOWARD SCHULMAN  

13. Regulation of Neuronal Gene Expression and Protein Synthesis 391  
    JAMES L. ROBERTS AND JAMES R. LUNDBLAD  

14. Modeling and Analysis of Intracellular Signaling Pathways 413  
    PAUL D. SMOLEN, DOUGLAS A. BAXTER, AND JOHN H. BYRNE  

15. Connexin- and Pannexin-Based Channels in the Nervous System: Gap Junctions and More 445  
    JUAN C. SÁEZ AND BRUCE J. NICHOLSON  

16. Postsynaptic Potentials and Synaptic Integration 469  
    JOHN H. BYRNE
17. Complex Information Processing in Dendrites 489
   JOHN H. BYRNE AND GORDON M. SHEPHERD

18. Information Processing in Neural Networks 513
   JAMES J. KNIERIM

19. Learning and Memory: Basic Mechanisms 539
   JOHN H. BYRNE, KEVIN S. LADBAR, JOSEPH E. LE DOUX,
   GLENN E. SCHAFE, J. DAVID SWEATT, AND RICHARD F. THOMPSON

20. Molecular and Cellular Mechanisms of Neurodegenerative Disease 609
   MARK R. COOKSON, RANDY STRONG, P. JOHN HART,
   AND JAMES L. ROBERTS

Index 631
Contributors

Douglas A. Baxter  (181, 413) Department of Neurobiology and Anatomy, The University of Texas Medical School at Houston, Houston, TX
Scott Brady  (19) Department of Anatomy and Cell Biology, University of Illinois at Chicago, Chicago, IL
Peter Brophy  (19) Department of Preclinical Veterinary Sciences, University of Edinburgh, Edinburgh, Scotland, UK
John H. Byrne  (111, 181, 413, 469, 489, 539) Department of Neurobiology and Anatomy, The University of Texas Medical School at Houston, Houston, TX
Luz Claudio  (1) Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York, NY
David R. Colman  (19) Director’s Office, Montreal Neurological Institute, Montreal, QC, Canada
Mark R. Cookson  (609) Neurogenetics Laboratory, NIH, National Institute of Aging, Bethesda, MD
Ariel Y. Deutch  (267, 301) Department of Psychiatry, Vanderbilt Medical Center, Vanderbilt University, Nashville, TN
Gerald A. Dienel  (49) Department of Neurology, University of Arkansas for Medical Sciences, Little Rock, AR
Andrea Giuffrida  (301) Department of Pharmacology, The University of Texas Health Science Center at San Antonio, San Antonio, TX
P. John Hart  (609) Department of Biochemistry, The University of Texas Health Science Center, San Antonio, TX
Patrick R. Hof  (1) Department of Neuroscience, Mount Sinai School of Medicine, New York, NY
Lily Yeh Jan  (159) University of California, San Francisco, San Francisco, CA
Yuh Nung Jan  (159) University of California, San Francisco, San Francisco, CA
Grahame Kidd  (1) Department of Neurosciences, Cleveland Clinic Lerner Research Institute, Cleveland, OH
James J. Knierim  (513) Department of Neurobiology and Anatomy, The University of Texas Medical School at Houston, Houston, TX
Dimitri M. Kullmann  (217) Department of Clinical Neurology, Institute of Neurology, Queen’s Square, University College London, London, England, UK
Kevin S. LaBar  (539) Center for Cognitive Neuroscience, Duke University, Durham, NC
Joseph E. LeDoux  (539) Center for Neural Science, New York University, New York, NY
James R. Lundblad  (391) Division of Endocrinology, Diabetes, and Clinical Nutrition, School of Medicine, Oregon Health Sciences University, Portland, OR
David A. McCormick  (133) Department of Neurobiology, Yale University School of Medicine, New Haven, CT
Bruce J. Nicholson  (445) Department of Biochemistry, The University of Texas Health Science Center at San Antonio, San Antonio, TX
Esther A. Nimchinsky  (1) Department of Radiology, Mount Sinai School of Medicine, New York, NY
James L. Roberts  (301, 391, 609) Department of Pharmacology, The University of Texas Health Science Center at San Antonio, San Antonio, TX
Robert H. Roth  (267) Department of Psychiatry, Yale University School of Medicine, New Haven, CT
Juan C. Saez  (445) Departamento de Ciencias Fisiologicas, Pontificia Universidad Catolica de Chile, Santiago, Chile
Glenn E. Schafe  (539) Department of Psychology, Yale University, New Haven, CT
Howard Schulman  (359) PPD Biomarker Discovery Sciences, LLC, Menlo Park, CA
Thomas L. Schwarz  (217) Department of Neurology, Children’s Hospital, Harvard University, Boston, MA
Gordon M. Shepherd  (111, 489) Department of Neurobiology, Yale University School of Medicine, New Haven, CT
Paul D. Smolen  (413) Department of Neurobiology and Anatomy, The University of Texas Medical School at Houston, Houston, TX

Randy Strong  (609) Department of Pharmacology, The University of Texas Health Science Center, San Antonio, TX

J. David Sweatt  (539) Department of Neurobiology, University of Alabama at Birmingham, Birmingham, AL

Richard F. Thompson  (539) Neuroscience Research Institute, University of Southern California, Los Angeles, CA

Bruce D. Trapp  (1) Department of Neuroscience, Cleveland Clinic Foundation, Cleveland, OH

M. Neal Waxham  (321) Department of Neurobiology and Anatomy, The University of Texas Medical School at Houston, Houston, TX

David Matthew Young  (159) University of California, San Francisco, San Francisco, CA

Robert S. Zucker  (217) Neurobiology Division, Department of Molecular and Cell Biology, University of California, Berkeley, Berkeley, CA
The second edition contains substantial improvements over the first edition. All chapters have been updated to include recent developments in the field, and major revisions have been done on the chapters on Energy Metabolism in the Brain, Molecular Properties of Ion Channels, Gap Junctions, and Learning and Memory. In addition, this edition features two new chapters, Information Processing in Neural Networks and Molecular and Cellular Mechanisms of Neurodegenerative Disease. Although the first edition covered biochemical and gene networks in significant detail, little was included on neural networks. It is the neural networks in the brain that collect and process information about the external world and about the internal state of the body and generate motor commands. Therefore, an understanding of these networks is essential to understanding the brain and also helps to put the cellular and molecular processes in perspective. However, discussing all of the brain systems is beyond the scope of a textbook on cellular and molecular neuroscience. Rather, our goal is to describe the principles of operation of neural networks and the key circuit motifs that are common to many networks. The second new chapter reports on the progress in the last 20 years on elucidating the cellular and molecular mechanisms underlying brain disorders. This chapter focuses specifically on amyotrophic lateral sclerosis (ALS), Parkinson disease, and Alzheimer’s disease, and the progress that has been made and the strategies that have been used to study and treat the disorders. The fact that all three diseases are associated with neuronal loss, albeit in different brain regions and with different neurotransmitter groups, suggests that there may be common aspects to the degenerative process.

We are once again extremely grateful to Johannes Menzel at Elsevier for his unfading support and encouragement throughout the project. Thanks also to Clare Caruana, Meg Day, Kristi Gomez, Kirsten Funk, Megan Wickline, and members of the production staff. Special thanks to Lorenzo Morales, the graphic artist on the project, who did an outstanding job of creating many of the illustrations in the second edition and restyling all the illustrations for consistency among chapters. He also designed the cover illustration.

John H. Byrne
James L. Roberts
Preface to the First Edition

The past twenty years have witnessed an exponential increase in the understanding of the nervous system at all levels of analyses. Perhaps the most striking developments have been in the understanding of the cell and molecular biology of the neuron. The field has moved from treating the neuron as a simple black box that added up impinging synaptic input to fire an action potential to one in which the function of nerve cells involves a host of biochemical and biophysical processes that act synergistically to process, transmit and store information. In this book, we have attempted to provide a comprehensive summary of current knowledge of the morphological, biochemical, and biophysical properties of nerve cells. The book is intended for graduate students, advanced undergraduate students, and professionals. The chapters are highly referenced so that readers can pursue topics of interest in greater detail. We have also included material on mathematical modeling approaches to analyze the complex synergistic processes underlying the operation and regulation of nerve cells. These modeling approaches are becoming increasingly important to facilitate the understanding of membrane excitability, synaptic transmission, as well gene and protein networks. The final chapter in the book illustrates the ways in which the great strides in understanding the biochemical and biophysical properties of nerve cells have led to fundamental insights into an important aspect of cognition, memory.

We are extremely grateful to the many authors who have contributed to the book, and the support and encouragement during the two past years of Jasna Markovac and Johannes Menzel of Academic Press. We would also like to thank Evangelos Antzoulatos, Evyatar Av-Ron, Diasinou Fioravanti, Yoshihisa Kubota, Rong-Yu Liu, Fred Lorenzetii, Riccardo Mozziachiodi, Gregg Phares, Travis Rodkey, and Fredy Reyes for help with editing the chapters.

John H. Byrne
James L. Roberts