

Advances in Neurobiology

Volume 21

Series Editor

Arne Schousboe

More information about this series at <http://www.springer.com/series/8787>

Albert Cheung-Hoi Yu • Lina Li
Editors

Systems Neuroscience

 Springer

Editors

Albert Cheung-Hoi Yu
Neuroscience Research Institute
Peking University
Beijing, China

Hai Kang Life Corporation Ltd.
China

Lina Li
Neuroscience Research Institute
Peking University
Beijing, China

Hai Kang Life Corporation Ltd.
China

ISSN 2190-5215

Advances in Neurobiology

ISBN 978-3-319-94591-0

<https://doi.org/10.1007/978-3-319-94593-4>

ISSN 2190-5223 (electronic)

ISBN 978-3-319-94593-4 (eBook)

Library of Congress Control Number: 2018951713

© Springer International Publishing AG, part of Springer Nature 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Systems neuroscience is essential for the understanding of higher cognitive functions such as language, memory, emotion, reasoning, pain, neural networks, and self-awareness and is also vital to the study of pathologies and diseases in brain systems. Brain is the most important and complex organ in the body. We believe that a full understanding of its mechanisms is only possible by addressing the properties of single cell types and how they interact with other groups of cells and function as a system through the lens of systems neuroscience.

Over the years, the definition of “Systems Neuroscience” has often been misinterpreted and confused by people who are not working in the field. For example, in an open content online encyclopedia, “Systems Neuroscience” has been misinterpreted as a subdiscipline of systems biology and neuroscience. Systems neuroscience and systems biology, in many aspects, are two entirely different disciplines. In particular, “Systems Neuroscience” is not the “Systems Biology” of neuroscience. Even throughout our invitation process for manuscripts, we have encountered a lot of difficulties due to the chaos in the interpretation of the subjects. With the recent advancement in the field of neuroscience and the initiation of “Brain Initiatives” in many countries, clarification of the terms systems neuroscience, neuroscience and systems biology, and their interconnections becomes urgent and necessary for all of us to have a better understanding of the field. It is particularly worth mentioning that compiling this book has been acclaimed as “an excellent initiative” by some experts in the field which is indeed encouraging!

This timely volume of *Systems Neuroscience* contains chapters from renowned scientists in this emerging field. Topics range from the basic study of systems neuroscience to its applications in disease therapy. The book covers, in more detail, how different neural circuits analyze sensory information, form perceptions of the external world, make decisions, and execute movements; how nerve cells behave when connected together to form the neural networks; and how the relationships between molecular and cellular approaches assist in understanding brain structure and function, high-level mental functions, brain pathologies, and therapy. Both traditional systems neuroscience approaches and systems biology analysis methods were included. A hierarchy of neurobiological complexity, therefore, arises from the

genome, transcriptome, proteome, peptidome, metabolome, cells, synapses, circuits, coding, plasticity, brain regions, whole brain, behavior, and other higher brain functions.

It took us 2 years to complete this book. We would like to sincerely thank all the authors for their great contribution, support, and patience, without which this work can never be completed. We would also like to acknowledge Matthew E. R. Butchbach, Tunahan Cakir, Jianguo Chen, Alexander C. Jackson, Veronika Koren, Ying Li, Grace Y. Sun, Miklos Vegh, Yuguo Yu, and Li Zhang, who enthusiastically contributed their knowledge and time in reviewing manuscripts for this special volume. Last but not least, we would like to thank our students Jiangshan Zhan, Tarokh Mollafarajzadeh, and Sara Rashidi for their assistance in the peer review process. We hope that this book would fill some gaps in knowledge and provide tantalizing samples of recent progress in research to promote the continuous development in the field of systems neuroscience and provide great insight in allowing effective integration of systems biology into neuroscience.

Beijing, China

Albert Cheung-Hoi Yu
Lina Li

Contents

1	Neuronal Bases of Systemic Organization of Behavior	1
	Yuri I. Alexandrov, Alexey A. Sozinov, Olga E. Svarnik, Alexander G. Gorkin, Evgeniya A. Kuzina, and Vladimir V. Gavrilov	
2	Neural Circuits Mediating Fear Learning and Extinction	35
	Roger Marek and Pankaj Sah	
3	The Hippocampal Ensemble Code for Spatial Navigation and Episodic Memory	49
	Susumu Takahashi	
4	Context-Dependent Adjustments in Executive Control of Goal-Directed Behaviour: Contribution of Frontal Brain Areas to Conflict-Induced Behavioural Adjustments in Primates	71
	Farshad A. Mansouri and Mark J. Buckley	
5	Synaptic Excitatory-Inhibitory Balance Underlying Efficient Neural Coding	85
	Shanglin Zhou and Yuguo Yu	
6	Mapping Molecular Datasets Back to the Brain Regions They are Extracted from: Remembering the Native Countries of Hypothalamic Expatriates and Refugees	101
	Arshad M. Khan, Alice H. Grant, Anais Martinez, Gully A. P. C. Burns, Brendan S. Thatcher, Vishwanath T. Anekonda, Benjamin W. Thompson, Zachary S. Roberts, Daniel H. Moralejo, and James E. Blevins	
7	Genome-Scale Brain Metabolic Networks as Scaffolds for the Systems Biology of Neurodegenerative Diseases: Mapping Metabolic Alterations	195
	Emrah Özcan and Tunahan Çakır	

8 Synaptic Plasticity and Synchrony in the Anterior Cingulate Cortex Circuitry: A Neural Network Approach to Causality of Chronic Visceral Pain and Associated Cognitive Deficits 219
Ying Li

9 Large De Novo Microdeletion in Epilepsy with Intellectual and Developmental Disabilities, with a Systems Biology Analysis 247
Kai Gao, Yujia Zhang, Ling Zhang, Weijing Kong, Han Xie, Jingmin Wang, Ye Wu, Xiru Wu, Xiaoyan Liu, Yuehua Zhang, Feng Zhang, Albert Cheung-Hoi Yu, and Yuwu Jiang

10 Using Systems Biology and Mathematical Modeling Approaches in the Discovery of Therapeutic Targets for Spinal Muscular Atrophy 267
Matthew E. R. Butchbach

11 Not Cure But Heal: Music and Medicine 283
Paulo E. Andrade and Joydeep Bhattacharya

Contributors

Yuri I. Alexandrov Department of Psychology, National Research University Higher School of Economics, Moscow, Russia

Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Paulo E. Andrade Department of Psychology, Goldsmiths, University of London, London, UK

Vishwanath T. Anekonda VA Puget Sound Health Care System, Office of Research and Development Medical Research Service, Department of Veterans Affairs Medical Center, Seattle, WA, USA

Joydeep Bhattacharya Department of Psychology, Goldsmiths, University of London, London, UK

James E. Blevins VA Puget Sound Health Care System, Office of Research and Development Medical Research Service, Department of Veterans Affairs Medical Center, Seattle, WA, USA

Division of Metabolism, Endocrinology, and Nutrition, Department of Medicine, University of Washington School of Medicine, Seattle, WA, USA

Mark J. Buckley Department of Experimental Psychology, Oxford University, Oxford, UK

Gully A. P. C. Burns Information Sciences Institute, Viterbi School of Engineering, University of Southern California, Marina del Rey, CA, USA

Matthew E. R. Butchbach Center for Applied Clinical Genomics, Nemours Biomedical Research, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE, USA

Center for Pediatric Research, Nemours Biomedical Research, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE, USA

Department of Pediatrics, Thomas Jefferson University, Philadelphia, PA, USA

Department of Biological Sciences, University of Delaware, Newark, DE, USA

Tunahan Çakır Department of Bioengineering, Gebze Technical University, Gebze, Kocaeli, Turkey

Kai Gao Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Vladimir V. Gavrilov Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Alexander G. Gorkin Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Alice H. Grant UTEP Systems Neuroscience Laboratory, University of Texas at El Paso, El Paso, TX, USA

Department of Biological Sciences, University of Texas at El Paso, El Paso, TX, USA

Graduate Program in Pathobiology, University of Texas at El Paso, El Paso, TX, USA

Yuwu Jiang Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Arshad M. Khan Sr UTEP Systems Neuroscience Laboratory, University of Texas at El Paso, El Paso, TX, USA

Department of Biological Sciences, University of Texas at El Paso, El Paso, TX, USA

Border Biomedical Research Center, University of Texas at El Paso, El Paso, TX, USA

Weijing Kong Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Evgeniya A. Kuzina Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Ying Li Department of Biomedical Sciences, City University of Hong Kong, Kowloon, Hong Kong

Centre for Biosystems, Neuroscience, and Nanotechnology, City University of Hong Kong, Kowloon, Hong Kong

School of Veterinary Medicine, City University of Hong Kong, Kowloon, Hong Kong

Xiaoyan Liu Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Farshad A. Mansouri Cognitive Neuroscience Laboratory, Department of Physiology, Monash Biomedicine Discovery Institute, Monash University, Clayton, VIC, Australia

Roger Marek Queensland Brain Institute, The University of Queensland, Brisbane, QLD, Australia

Anais Martinez UTEP Systems Neuroscience Laboratory, University of Texas at El Paso, El Paso, TX, USA

Department of Biological Sciences, University of Texas at El Paso, El Paso, TX, USA

Graduate Program in Pathobiology, University of Texas at El Paso, El Paso, TX, USA

Daniel H. Moralejo Division of Neonatology, Department of Pediatrics, University of Washington School of Medicine, Seattle, WA, USA

Emrah Özcan Department of Bioengineering, Gebze Technical University, Gebze, Kocaeli, Turkey

Zachary S. Roberts VA Puget Sound Health Care System, Office of Research and Development Medical Research Service, Department of Veterans Affairs Medical Center, Seattle, WA, USA

Pankaj Sah Queensland Brain Institute, The University of Queensland, Brisbane, QLD, Australia

Alexey A. Sozinov Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Faculty of Psychology, National Academic University of Humanities, Moscow, Russia

Olga E. Svarnik Shvyrkov's Lab, Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow, Russia

Susumu Takahashi Graduate School of Brain Science, Doshisha University, Kyoto, Japan

Brendan S. Thatcher VA Puget Sound Health Care System, Office of Research and Development Medical Research Service, Department of Veterans Affairs Medical Center, Seattle, WA, USA

Benjamin W. Thompson VA Puget Sound Health Care System, Office of Research and Development Medical Research Service, Department of Veterans Affairs Medical Center, Seattle, WA, USA

Jingmin Wang Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Xiru Wu Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Ye Wu Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Han Xie Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Albert Cheung-Hoi Yu Laboratory for Functional Study of Astrocytes, Department of Neurobiology, School of Basic Medical Sciences, Key Laboratory for Neuroscience, Ministry of Education, National Health and Family Planning Commission, Neuroscience Research Institute, Peking University, Beijing, China

Hai Kang Life Corporation Ltd., China

Yuguo Yu State Key Laboratory of Medical Neurobiology, School of Life Science and Human Phenome Institute, Institutes of Brain Science, Institute of Science and Technology for Brain-Inspired Intelligence, Fudan University, Shanghai, China

Feng Zhang Institute of Reproduction and Development, Obstetrics and Gynecology Hospital of Fudan University, Shanghai, China

Ling Zhang Institute of Reproduction and Development, Obstetrics and Gynecology Hospital of Fudan University, Shanghai, China

Yuehua Zhang Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Yujia Zhang Department of Pediatrics, Peking University First Hospital, Peking University Health Science Center, Beijing, China

Shanglin Zhou State Key Laboratory of Medical Neurobiology, School of Life Science and Human Phenome Institute, Institutes of Brain Science, Institute of Science and Technology for Brain-Inspired Intelligence, Fudan University, Shanghai, China