Gating in Cerebral Networks

The correct functioning of the mammalian brain depends on the integrated activity of myriad neuronal and non-neuronal cells. Throughout, neuronal networks are under the control of neuromodulatory systems. One goal of current neuroscientific research is to elucidate how these systems operate, especially during normal conscious behaviours and processes. Mircea Steriade and Denis Paré describe the neuronal properties and networks that exist within and between the cortex and two important subcortical structures: the thalamus and the amygdala. The authors explore the changes in these properties, covering topics including morphology, electrophysiology, architecture and gating, and comparing regions and systems in both normal and diseased states. This book is aimed at graduates and postdoctoral researchers in neuroscience.

Mircea Steriade held the position of Professor and Head of the Laboratory of Neurophysiology at Laval University, Quebec, from 1968 to 2006.

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CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521851220

First published 2007

Printed in the United Kingdom at the University Press, Cambridge

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-85122-0 hardback

MS dedicates this book to Donca, Claude and Jacqueline.
DP dedicates this book to Noemi, Julian and Martha.

Sadly, when this book was in the final stages of production, Dr. Mircea Steriade passed away at the age of 81, after a long fight with cancer. Dr. Steriade began writing this book while undergoing chemotherapy, knowing that his was a terminal condition. Mircea Steriade was an extremely energetic man, passionate, uncompromising, forever driven by scientific discovery. He published more than 400 scientific papers during his career and was respected by supporters and competitors alike. I refer the reader to earlier obituaries [1,2] for biographical information.

I met Mircea Steriade in 1985 when I started as a PhD student in his laboratory. To a young graduate student, he was a formidable man who commanded respect. He had an unrivaled knowledge of the scientific literature and knew by heart the references of many classical papers. His culture was not limited to science however as he was an accomplished pianist, a student of history, and an avid reader of French literature. After my post-doctoral training in 1992, I returned to Steriade's Department at University Laval (Quebec City, Canada) as an Assistant Professor. We had adjacent offices and had lunch together every day. Thus, we grew very close and stayed in touch after I left Laval for Rutgers University in 2001. I am deeply indebted to him for he patiently taught me everything he knew about the science trade. More than a mentor however, he was a friend whose support and advice had a decisive influence in my life. Even after 50 years of research in neuroscience, he was still consumed by his work. He would often call me to share his excitement about the latest finding to come out of his laboratory. This is the image of Mircea I cherish most: passionate, enthusiastic, inquisitive, and forever young.

In correcting the proofs of this book, I was reminded of all the knowledge lost with the passing of Mircea Steriade. In writing this, I am reminded of the mentor who taught me so much and of the friend I miss.

Denis Paré

[1] Buzsáki, G., Paré, D. (2006) Mircea Steriade (1924–2006). *Nature Neuroscience* **9**: 713.

[2] Timofeev, I. (2006) Mircea Steriade (1924–2006). *Neuroscience* **142**: 917–920.

Contents

Preface

In neuroscience, the term gating can assume various meanings depending on the level of analysis. At the level of ionic channels, gating refers to the transition between two or more conformational states of channel proteins. At the neuronal or networks level, gating refers to changes in responsiveness and in inhibitory processes during different behavioral states. In both instances, the causative events and their functional consequences can vary widely. This book focuses on gating in the thalamocortical and amygdalocortical systems.

In the *thalamocortical system*, gating was often used to describe the blockade of signal transmission from the external world to the cerebral cortex during disconnected states, such as slow-wave sleep. In this monograph, we also discuss evidence that, despite absence of information from the external world, the behavioural state of slow-wave sleep is associated with the processing of internally generated signals and with synaptic plasticity. We also argue that these events may lead to the consolidation of memory traces acquired during the waking state as well as to a form of consciousness expressed by dreaming mentation. The opening of thalamic gates during brain-active states of waking and REM sleep changes the excitability of cortical neurons and leads to different forms of mentation.

In the *amygdalocortical system*, gating refers to how the transmission of sensory inputs is modulated according to their emotional significance. This process leads to alterations not only in behavioural responsiveness, but also in memory consolidation. In this system, gating can also be used to describe the facilitating effect of emotions on memory. We will therefore present evidence that, via the amygdala, emotional arousal can facilitate memory.

Besides these topics, this book compares the anatomical and physiological organization of two different brain networks: the thalamocortical and amygdalocortical systems. Whereas the thalamocortical system is the gateway for sensory inputs into consciousness, the amygdalocortical system receives highly processed sensory information from the neocortex and uses it to generate affects and modulate memory. Although both systems display unique properties, they are also similar in many ways. In particular, both systems illustrate how neuronal computations arise from complex interactions between the intrinsic properties of constitutive elements and the architecture of the network in which they are inserted. We will show how intrinsic neuronal properties are modulated, and sometimes overwhelmed, by background synaptic activities, which would explain some dissimilarities between data obtained in the intact brain and in some simplified preparations.

Acknowledgements

MS thanks the skilful and creative collaboration of his Ph.D. students and postdoctoral fellows during the past 37 years, since he established the Laboratory of Neurophysiology at Laval University. In particular, he is grateful to the work, during the past two decades, of D. Paré, R. Curró Dossi, D. Contreras, A. Nuñez, F. Amzica, I. Timofeev, D. Neckelmann, F. Grenier, P. Fuentealba, S. Crochet, Y. Cissé and D. Nita. P. Giguère was in charge of the technical development of laboratories. MS also thanks T. J. Sejnowski, M. Bazhenov, A. Destexhe and W. Lytton for their collaboration in combined experimental and computational studies. During all his work in Canada, MS's work was supported by grants from the Medical Research Council of Canada (now Canadian Institutes for Health Research), National Science and Engineering Research Council of Canada, Human Frontier Science Program, and National Institutes of Health of the USA.

DP acknowledges the essential contribution of his graduate and postdoctoral students. In particular, he wishes to underscore the creative involvement of J. Apergis-Schoute, E. Bauer, D. Collins, S. Duvarci, E. Lang, K. Likhtik, M. Martina, R. Paz, J.G. Pelletier, A. Pinto, A. Popescu, S. Royer and R. Samson. He also acknowledges the support of other friends, scientists or otherwise, who helped him during his career. They include S. Charpak, M. De Curtis, P. Giguère, J.F. Paré, G.J. Quirk, Y. Smith and J. Tepper. While in Canada, DP's research was supported by the Medical Research Council and the Natural Sciences and Engineering Research Council. Since in the US, his work is supported by the National Institutes of Health and the National Science Foundation.