Preface

"You", your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells . . .

Francis H. C. Crick, *The Astonishing Hypothesis: The Scientific Search for the Soul*, New York, Scribner, 1994.

As the famous German scientist Max K.E.L. Planck (1858–1947), once said, "Knowledge precedes application." Later, the Austrian-British philosopher of science Karl R. Popper (1902–1994) believed that "before we can find the answers, we need the power to ask new questions, in other words, we need new technology." A key example of such a technological advance is the development of the new field of *optogenetics* by Karl Deisseroth, Edward Boyden, Ernst Bamberg Peter Hagemann, Georg Nagel and Gero Miesenböck. Gero Miesenböck defines optogenetics as "using genetic strategies for observing and controlling the function of neurons with light," whereas Deisseroth states that it is "the combination of genetic and optical methods to achieve gain or loss of function of well-defined events in specific cells of living tissue." The biochemistry of opsins helped to develop the new field of optogenetics and molecular engineering. Use of optogenetics as an important research tool continues to grow rapidly, and it is now used in more than 1,000 laboratories. Use of its associated technologies for delivering light deep into organisms as complex as freely moving mammals, for targeting light-sensitivity to cells of interest, and for assessing specific readouts, or effects, of this optical control are also expanding.

Although *optogenetics* was discovered little more than a decade ago, it has recently been applied to few representative neurological and cardiac diseases. The potential utility of these techniques to help us understand *"neuro-cognitive biology and genetics"* more broadly is just beginning. There is a growing interest in utilizing these techniques in academic research laboratories worldwide, to better understand their applications in neurobiology and neurology in order to develop new diagnostic tools and drug targets for neurological disorders. The emergence of these and other neuro-techniques led US President Barack Obama to prioritize brain research. In 2013, he announced the **B**rain **R**esearch through **A**dvancing

Innovative Neurotechnologies (BRAIN) Initiative, a collaborative, public-private research project for the development and application of innovative technologies that can create a dynamic understanding of brain function, and uncover the mysteries of brain disorders, such as Alzheimer's and Parkinson's diseases, depression and traumatic brain injury.

Optogenetics: From Neuronal Function to Mapping and Disease Biology is intended for those in the neuroscience, neurology, neural engineering, biotechnology, genetics, genomics, pharmaco-genomics and molecular medicine fields. There are a few books already available covering optogenetics. *(Miranda, E. (2010). Neural Engineering, BCI, Optogenetics, and Brain Implant. General Books, LLC; Surhone, L., Tennoe, M. and Henssonow, S. (2011). Optogenetics. Betascript Publishing Press; Scaglia, B. (2011). Optogenetics and Anxiety. Webster's Digital Services; Miesenböck, G. (2011). Optogenetics: Circuits, Genes, and Photons in Biological Systems. John Wiley & Sons; Knopfel, T. and Boyden, E. (2012). Optogenetics: Tools for Controlling and Monitoring Neuronal Activity. Elsevier Science Press; Hegemann, P. and Sigris, S. (2013). Optogenetics. Walter De Gruyter, Press; Ilango, A. and Lobo, M.K. (2014). Neural Circuits Underlying Emotion and Motivation: Insights from Optogenetics and Pharmacogenetics. Frontiers in Behavioral Neurosciences. Volume 8; and Yawo, H., Kandori, H. and Koizumi, A. (2015). Optogenetics: Light Sensing Proteins and their Application. Springer).*

For example, E. Miranda's *Neural Engineering, BCI, Optogenetics, and Brain Implant* highlighted the use of optogenetics for neural engineering and brain implant purposes, whereas L. Surhone, M. Tennoe and S. Henssonow's *Optogenetics* gave an overview of the field. Miesenböck (2011) covered the role of optogenetics in studying neural circuits, whereas Knopfel and Boyden (2012) emphasized the importance of optogenetic tools in the study of neural cell activity. Hegemann and Sigris (2013) and Ilango and Lobo (2014) summarized the use of opsin proteins in optogenetics and pharmacogenetics, respectively. A recent book by Yawo et al. (2015) focused on the light-sensing proteins. This present book differs, in that it is the first text completely devoted to combining optogenetics' use in model organisms, opsin biological tools and their applications in neurobiology and neurodegenerative diseases. Special emphasis is placed on the development of new-generation tools for in vivo imaging, and for the study of learning, neuro-psychiatric diseases and behavior. This book also focuses on the use of optogenetics in the context of vision re-storage, memory, plasticity and sleep.

The goal is for this book to serve as a reference for graduate students, postdoctoral researchers and instructors, and as an explanatory analysis for executives and scientists in molecular medicine, molecular engineering, biotechnology and pharmaceutical companies. Our hope is that this volume will serve as a prologue to the field for newcomers and as a reference for those already active in the field. We have carefully chosen the chapters, written by experts in the field from both academia and industry, and have divided the chapters into appropriate sections to support the theme expressed in the subtitle of this book: *From Neuronal Function to Mapping and Disease Biology*. Developing *"novel optogenetic tools"* is likely to become a prerequisite for *"deep-brain stimulations"* used for treating patients with epilepsy and other neurological disorders. The elegant and revolutionary optogenetic approaches that are covered in this book will undoubtedly have tremendous commercial promise for the development of innovative surgical procedures for human neurological diseases.

Many people have contributed to making our involvement in this project possible. We thank our teachers for their excellent teaching, guidance and mentorship, which have helped us to bring about this educational enterprise. We are extremely grateful to all of the contributors, without whose commitment this book would not have been possible. Many people have had a hand in the preparation of this book. Each chapter has been passed back and forth between the authors for criticism and revision; hence, each chapter represents a joint contribution. We thank our reviewers, who have made the hours spent putting this volume together worthwhile. We are indebted to the staff of Cambridge University Press, and, in particular, to Katrina Halliday for her generosity and efficiency throughout the editing of this book; she truly understands the urgency and need for this volume. We also extend our appreciation to Megan Waddington and Caroline Mowatt for their excellent cooperation during the development of this volume. We also want to thank Professor Georg Nagel of the University of Würzburg, Germany, (who is one of the discoverers of Channelrhodopsin, which paved the way for the field of optogenetics) for his thoughtfulness in writing a foreword to this book. Last, but not least, we thank Shyamala Appasani for her understanding and support during the development of this volume.

This book is the eighth in the series of *Gene Expression and Regulation*, and the fourth joint project of father and son. A portion of the royalties will be contributed to the Dr. Appasani Foundation (a non-profit organization devoted to bringing social change through the education of youth in developing nations) and The MINDS Foundation (**M**ental **I**llness and **N**eurological **D**isease**s**), which is committed to taking a grassroots approach to providing high-quality mental healthcare in rural India.

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