Preface

Optical methods for functional imaging are indispensible tools for modern neuroscience due to their exceptional spatial and temporal sampling options and the large variety of possible functional read-outs ranging from voltage changes to metabolic states. As such, state-of-the-art optical imaging techniques have emerged as pivotal approaches for advancing our understanding of information processing in the mammalian neocortex, and many of the most imperative issues have now become technically accessible. The main goal of the present volume is to provide a collection of the most relevant optical methods currently used for investigating neocortical circuit dynamics. We believe that we were able to share our enthusiasm for this endeavor with a group of outstanding authors who have been instrumental in advancing optical methods in the past years and who at the same time are very successful users of those methods for interrogating the neocortex. We hope that the volume is useful for students as well as neuroscientists interested in applying optical approaches to answer their specific questions. The wealth of optical imaging methods that are currently applied in the neurosciences has forced us to limit the range to methods that (1) are applied in experiments in vivo, mainly in the rodent brain, and (2) measure the functional properties on the spatial scale of cortical circuits. We have divided the volume into three parts:

Part I is an introductory section that covers the physical fundamentals of optical imaging and introduces the molecular tools and imaging devices used for in vivo optical imaging. The first chapter outlines the methodological concepts of using light to address current questions in neuroscience. Next, two chapters treat the physical principles of imaging and the optical properties of brain tissue, respectively, followed by two further chapters that introduce functional indicators as well as light-controllable molecules. These five chapters thus provide a background for all the chapters in *Parts II and III*.

Part II covers the most relevant methods and their applications to investigate neuronal activity in the neocortex across a wide range of spatial and temporal scales. Several chapters present the advantages of two-photon microscopy to study neocortical dynamics, largely using in vivo calcium imaging from individual neurons and their dendrites or from large neuronal populations. Wide-field voltage-sensitive dye imaging is demonstrated as a complementary technique to reveal large-scale dynamics. In addition, the opportunities to probe causal relationship between cellular and circuit mechanisms and behavior with optogenetic tools are explained.

Part III focuses on optical imaging methods used to probe signals that do not directly reflect neuronal activity but provide information on the metabolic state of the cortex. The first two chapters address methods for imaging signals that originate from astrocytes and microglia. The remaining three chapters introduce techniques for measuring hemodynamics as well as oxygenation of blood and tissue.

Optical imaging is one of the most dynamic technological fields in neuroscience. Novel techniques, such as new optical probes or imaging instruments, are continually emerging and published in the most prestigious journals. In a way, this ever-changing field is thus very difficult to capture in a methods book, because the moment it is produced, the technological landscape may have changed again significantly. We nevertheless hope that our collection is useful even in the light of rapid changes, in part because some of the fundamental concepts remain unchanged.

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