Preface

Good books by active scientists offer serious treatments of sophisticated topics in biology, evolution, physics, and mathematics. Since I was a teenager, such books have been a major inspiration to me. In *The Entangled Brain*, I wanted to do the same—hopefully!—and write about my favorite topic, which has been the object of my research during the past three decades. Many good, and even excellent, general-audience books about neuroscience focus on a certain aspect of the mind-brain—say, addiction, cognition, memory, and so on. This makes sense, as there is probably too much to cover and the topic is better suited for a college textbook, for example. But I wanted to write about the brain broadly construed, not a narrower subject such as "emotion" or "reward."

That's what I tried to do here. But this is a relatively short book, not a 1,000-page tome. So, it had to be selective and leave a lot out. That also meant that it had to be more idiosyncratic, reflecting my view of the brain and not necessarily providing a more extensive exposition with pros and cons of many concepts and ideas. This decision entailed following what I consider a way of thinking about the brain that, while not rare, is also *not* mainstream among neuroscientists.

A central thesis of the book is that biology does not work like physics, and even less so like engineering. Biological systems are not easily reducible to separate units that, when put together, give us the whole back. Unfortunately, in my view, even brain scientists (many of them, at least) don't fully appreciate this idea. Their descriptions of the brain are full of labels for brain regions, indicating that they perform function *X* (here's "fear") or *Y* (here's "reward"), as if the separate pieces functioned quasi-autonomously. This thinking reflects a mapping between structure (anatomy) and function

(behavior) that goes back more than a century. For example, in the early twentieth century, Korbinian Brodmann, an early neuroanatomist, subdivided the human brain into roughly 50 specific anatomical units that were thought to map to relatively distinct functions. To this day, Brodmann's map and its refinements are routinely used by researchers. Indeed, one of the central approaches of neuroscience has been a divide-and-conquer strategy that tries to break up the entire organ into subcomponents that can be, purportedly, properly understood. They then can be put back together in the hope that the overall functionality will reflect the summed individual parts. I believe this strategy is problematic; in fact, it is inadequate to understand systems like the brain (and genetics by the way) in which the interactions among the parts create mechanisms and processes than cannot be derived by looking at parts in isolation.

In *The Entangled Brain*, I wanted to avoid what I find in many general-audience books—namely, descriptions that simplify the brain to such an extreme as to appear, at times, caricatures. For example, in the context of emotion and motivation, an often-heard narrative is that primitive, subcortical regions like the amygdala (presumably "responsible for fear") and the striatum (presumably "responsible for reward") produce automatic behaviors that are next-to-impossible to subvert—hence, anxiety disorders and addiction. At the same time, the prefrontal cortex, the "newer and more rational" part of the brain, allows us to exert control over the subcortical bits and correct behaviors when appropriate (no cake-eating if one is on a diet, as an example). The treatment in the pages that follow adheres to a way of thinking that eschews these first-order explanations. The resulting story is not so simple, but I believe readers are more than ready to face the complexity. We don't have to put functions inside little boxes in the brain and tell neat stories. Reality is immensely more complex.

The view formulated here is that parts of the brain work in a coordinated fashion, such that functions are carried out by large-scale distributed circuits, also called large-scale *networks*. In other words, collections of gray matter parts exchange signals with one another and, by doing so, bring about behaviors. The circuits are distributed, not local, involving disparate parts in the cortex and the subcortex, for example. And they are "large scale" because they don't only involve a pair, or possibly a few regions, but many components working simultaneously. That is the sense in which *the brain is entangled*, as summarized by the book's title. The overall goal of the

book is to introduce the central nervous system to readers in a sophisticated yet engaging manner—I hope! The text exposes readers to some of the complexities surrounding our understanding of the brain, without submitting the reader to a tsunami of technicalities.

Many lay readers (and some neuroscientists) implicitly assume that the human brain is rather unique with its prominent cortex (a word that means "bark" in Latin, like the exterior covering of the trunk and branches of a tree). However, in the past several decades, neuroanatomists have uncovered striking similarities in the overall "plan" of the brain of all vertebrates (fish, amphibians, reptiles, birds, and mammals). It is therefore both helpful and important to understand the central nervous system of humans from this so-called *comparative* lens. I cover this evolutionary link in chapter 9.

The concept of *complex systems* permeates *The Entangled Brain*. Complex systems are comprised of many relatively simple interacting parts and exhibit *emergent* behaviors: properties absent at the level of the individual parts but observed for the system as a whole. Starting in the 1940s with intellectual movements such as cybernetics and systems biology, complex systems theory has spread into most fields of knowledge where the interactions between elements (including feedback loops) challenge our ability to decipher how a given system works. Today, many fields including neuroscience, ecology, and the study of evolution apply insights from this domain of knowledge.

The pages ahead introduce the reader to the brain at the systems level. The book does not aim to be comprehensive. Neuroscience is such a sprawling field of research that this is not really possible. Whereas the text does not spell out a "novel" view of the brain per se, it closely reflects a line of thinking that I have outlined, and continue to develop, in a series of peer-reviewed conceptual papers, as well as published papers on "cognitive-emotional interactions" from a comparative viewpoint (that is, when all vertebrates are considered). In particular, one notion that is the outcome of my research over the past 30 years—and that undergirds the entire text—is that perception, cognition, action, emotion, and cognition are closely interrelated in the brain. You can't point to the brain and say, "This is where *X* happens."

Many books are the product of long years of work, on and off. Early drafts of this book date to the end of 2016. The text took much of its present form

during a couple delightful months in Turin, Italy, where on a short sabbatical stay I taught a course based on the material. I am grateful to the University of Turin for hosting me, in particular my friend Marco Tamietto for his amazing hospitality. I am also grateful to the University of Maryland, College Park, for the sabbatical support. I'm thankful to the students at the University of Turin for the feedback on my lectures and draft chapters—*grazie mille*. Marco Viola also provided excellent feedback on chapter 4 (What Do Brain Areas Do?). I'm also thankful for the feedback that I received from the students in my class at the University of Maryland, when I taught a follow-up version of the original course at Turin. I am indebted to Loreta Medina and Ester Desfilis for sharing their enormous knowledge of vertebrate neuroanatomy over the past years; their guidance has helped shape my (evolving!) view of the organization of the brain. I wish to thank Sydni Roberts, Kelly Morrow, Govinda Surampudi, and especially Trang Nguyen for their help with the figures in this book; Trang also helped a lot with the index. Feedback of colleagues on Twitter was also key in finalizing the book's title.

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The Entangled Brain

How Perception, Cognition, and Emotion Are Woven Together

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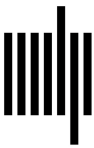

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