INTRODUCTION

The United States Congress designated the 1990s as the Decade of the Brain, but some suggest that the twenty-first century will be the century of the brain, when the last great frontier in biology—an understanding of the most complex biological system, the human brain—will be breached. Already the considerable advances made in neuroscience over the past 50-100 years are being called upon to explain many things about human behavior. Interdisciplinary programs are appearing in our colleges and universities asking what various disciplines and fields can learn from neuroscience and vice versa. At Harvard, I have been associated with the Mind, Brain and Behavior program since its inception in 1993, and I codirected it for a year. It attracts faculty from the Harvard Medical, Law, Divinity, and Business Schools as well as the School of Education and the Faculty of Arts and Sciences. Fields as diverse as philosophy, music, English, linguistics, anthropology, and history of science are represented, as well as the expected fields of biology, psychology, and computer science.

Many examples can be offered to illustrate the impact of neuroscience on other disciplines; I offer two here. First, studies of how we learn and remember things have demonstrated convincingly that memories are largely reconstructive and creative. False memories are not uncommon. These findings have fundamentally changed the way the law views eyewitness testimony. Contrary to the long-held belief that an eyewitness can faithfully record and remember an event, we now realize that what we remember or even perceive of an event depends on many factors—previous experiences, biases, attention, imagination, and so forth. Different eyewitnesses can give very different reports, though in each case describing what each observer firmly believes he or she saw.

A second example is the placebo effect—long thought to be without physiological basis. If a sugar pill is administered to someone experiencing pain, that person reports a lessening of the pain if told the placebo will help. We now know that the pain reduction is caused by the release of endogenous opiate-like substances in the brain. No drug trial today is carried out without a control cohort receiving a similar, but presumably inactive, agent. But placebo effects can greatly influence the outcome of such trials. How then do we decide what is efficacious and what is not? This question has enormous implications for medical therapies.

How far does the influence of neuroscience extend? Have studies on the developing brain, for example, told us much about how we should raise or educate our children? Some say yes, but others respond with a resounding no. The stakes are high—public programs such as Head Start, costing millions, if not billions, of dollars, are linked to notions supposedly neurobiologically based, but often the neurobiological evidence cited in support of one position or another is weak, controversial, or overinterpreted. The view that the young brain is more modifiable than the adult brain—which is certainly true—led to the notion that the first three years are the essential ones for raising a healthy, happy, and competent child. This extreme view, and the evidence on which it is based, has recently been critically examined in John Bruer's book *The Myth of the First Three Years.* As Bruer clearly documents, the first three years are important for brain development, but so are subsequent years. Nothing closes down completely after just three years—indeed, the brain continues to mature until the ages of 18-20, as we shall see.

What about the adult brain? How hard-wired is it? Once it is injured, is recovery possible or are we stuck with just what was there before the injury? Recent studies suggest that the adult brain is much more plastic than was long believed, but how much plasticity can there be? What about the influence of genes on behavior? How do genes and behavior relate? This contentious subject has generated volumes—with highly polarized views. The list of books written about it is long and includes provocative titles such as *The Mismeasure of Man*, *Not in Our Genes*, and most recently *The Blank Slate*.

And finally, the aging brain. Does the brain eventually fail in all of us, or is this a pessimistic view? Is it likely that maximal life span can be extended to 150-180 years? What about the age-related neurodegenerative diseases such as Alzheimer's and Parkinson's diseases? Are there reasonable approaches that might be taken to deal with these frightening and devastating conditions?

The purpose of this book is to lay out many of the neurobiological facts we have about the developing, adult, and aging brain. Clearly, the neurobiology is at a primitive stage compared to the richness of psychological observations that have been made on children, adults, and aging people. Nevertheless, not only have modern neurobiological studies given us some firm facts with which to ponder many of the issues laid out above, but neuroscience studies have also given us models—ways to think neurobiologically about the issues. The models in their details might not turn out to be right, but they suggest that we can get at many of the underlying phenomena and understand them.

Ultimately, we seek to understand the human brain, but our ability to study it neurobiologically is limited for the most part to noninvasive imaging or recording techniques. Occasionally we can get a piece of human brain to analyze, but this is the exception. On the other hand, we can study the brains of animals, and often the animal brain data are directly relevant to an aspect of human brain function or, at the very least, they give us a way to think about how the human brain might work. Throughout this book, I give examples of animal brain studies and what I believe they are telling us.

The book is not written for the expert, but for those non-experts and nonscientists interested in the issues and how they are being approached. I have tried to portray the neurobiology fairly and accurately, but in a simplified way. The book is divided into three parts: I, The Developing Brain; II, The Adult Brain; and III, The Aging Brain. Three chapters comprise the section on the developing brain, two the section on the adult brain, and just one on the aging brain. This division reflects to a considerable degree the amount of research and focus on these three aspects of human brain biology. The emphasis might be shifting somewhat as our population ages and the devastation of the age-related neurodegenerative diseases looms greater. Nevertheless, the challenge of understanding how the brain develops and how that understanding might help in raising the next generations to the best of our and their abilities is key to the future of humankind.

Initial work on the book took place during a delightful stay at the Rockefeller Study and Conference Center in Bellagio, Italy. Much of the book was written during an equally delightful stay at the International Institute for Advanced Study in Kyoto, Japan. Lisa Haber-Thomson and Carla Blackmar expertly drew the figures, and Stephanie Levinson provided the crucial secretarial help needed to bring the project to fruition. Jerome Kagan, Mark Konishi, Brian Perkins, and Richard Sidman read parts or all of the manuscript and provided many useful corrections, comments, and suggestions. And last but not least, Jeffrey Robbins enthusiastically encouraged the book, edited it, and improved it immeasurably.