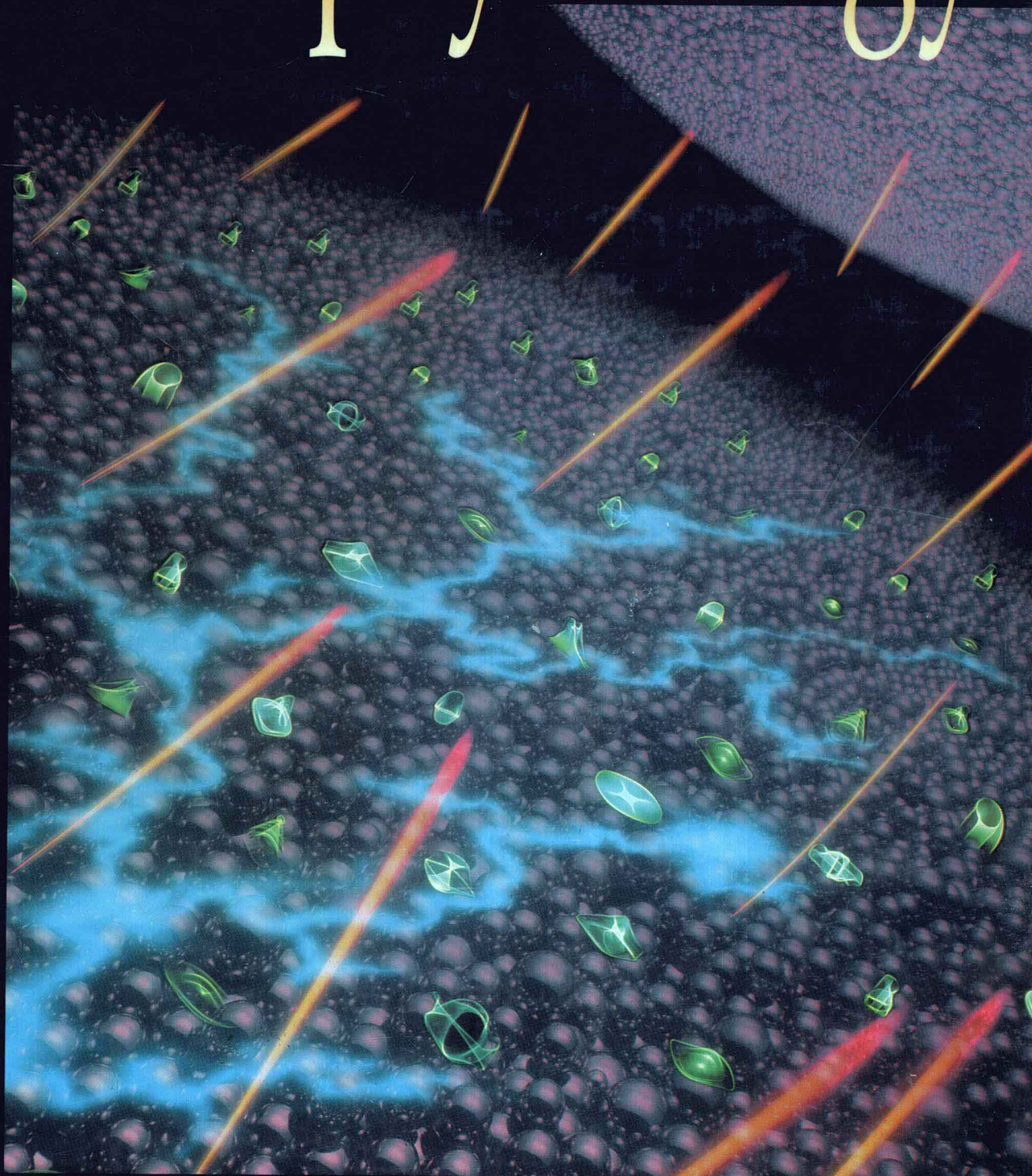
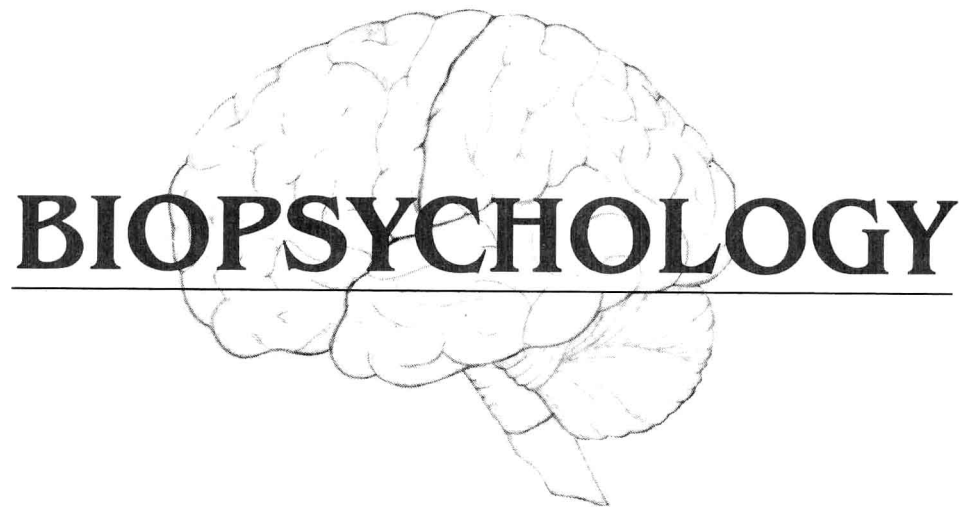


# Biopsychology



JOHN P. J. PINEL



**John P. J. Pinel**

THE UNIVERSITY OF BRITISH COLUMBIA

**ALLYN AND BACON**

BOSTON LONDON SYDNEY TORONTO

*To the memory of Donald Olding Hebb (1904–1985)  
for his contributions to biopsychology*

AND

*To Maggie and Greg for their  
love and support*



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A Division of Simon & Schuster  
160 Gould Street  
Needham Heights, Massachusetts 02194

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Cover designer: Lynda Fishbourne*

**Library of Congress Cataloging-in-Publication Data**

Pinel, John P. J.  
Biopsychology.

Includes bibliographical references.

1. Psychobiology. I. Title.

QP360.P463 1990 152 89-18091  
ISBN 0-205-12052-0

Printed in the United States of America

10 9 8 7 6 5 4 3 2

91 92 93 94



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# Preface

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**T**his book is intended for use as a primary text in one- or two-semester undergraduate courses in biopsychology (variously titled Biopsychology, Physiological Psychology, Brain and Behavior, Psychobiology, Behavioral Neuroscience, Behavioral Neurobiology, etc.). Because most of the students who enter undergraduate biopsychology courses have had little previous exposure to neuroscientific topics, I have attempted to tailor *Biopsychology* to the needs of the beginning student. *Biopsychology* is a book that focuses on fundamentals rather than details; a book that clearly and carefully develops each topic from primary principles; and a book that never forgets that scientific material is more easily digested with a dash of humor, a sprinkling of enthusiasm, and a dollop of personal implication. The following are some of the general approaches and good intentions that guided its preparation.

## Increasing the Emphasis on Behavior

In many biopsychology textbooks the coverage of neurophysiology, neurochemistry, and neuroanatomy subverts the coverage of behavioral research. This prejudice is often most obvious in the obligatory chapter on research methods, where the various neuroanatomical, neurophysiological, and neurochemical research methods are typically described at great length while behavioral technology receives short shrift. In contrast, *Biopsychology* gives behavior top billing: It stresses that neuroscience is a team effort and that the unique contribution made by biopsychologists to this team is their behavioral expertise. Half the research methods chapter (chapter 4) is dedicated to methods for studying behavior, and half is dedicated to methods for studying the nervous system.

## Increasing the Coverage of Human Research

*Biopsychology* provides more than the customary coverage of case studies and experiments involving brain-damaged and healthy human subjects. However, despite this increased attention to human research, controlled experiments in laboratory species provide the backbone for most of the chapters. A point of view that pervades *Biopsychology* is that diversity is a major strength of biopsychological research and that major advances have often resulted from the convergence of research involving human and nonhuman subjects.

## Helping Students Learn

The diversity of information to which the beginning biopsychology student must be introduced makes the task of both the teacher and the student difficult. Accordingly, I have incorporated in *Biopsychology* features expressly designed to help students learn the material. Five are particularly noteworthy.

- First are the lists of key terms and definitions that appear at the end of each chapter; these are expressly designed to help students prepare for examinations. My students tell me that they are very helpful.
- Second are the study exercises that punctuate the text. Rather than appearing at the end of each chapter, these exercises occur at key transition points, where students can benefit greatly by pausing to consolidate their understanding of preceding fundamentals before proceeding to new material.
- Third are the food-for-thought discussion questions at the end of each chapter.
- Fourth are the many demonstrations, anecdotes, analogies, and case studies that I have used to illus-

trate important principles and generate interest in them.

- Fifth are the illustrations.

### Improving the Illustrations

Because biopsychology is such a highly visual discipline, particular attention was paid to the design of the illustrations in this book. Each was carefully designed and annotated to clarify central ideas raised in the body of the text. One of the major strengths of the illustrations is that they are produced in full color. In this respect, *Biopsychology* represents a first: It is the first biopsychology textbook to be produced in full color from cover to cover. The decision to produce *Biopsychology* in full color was motivated by pedagogical, rather than cosmetic, objectives. There were three of them.

- First, I wanted to be able to illustrate at appropriate points in the text the color-coded brain scans and selective neural staining and labelling procedures that play such a central role in current biopsychological research.
- Second, I wanted to use color to simplify what is the most difficult task faced by many beginning biopsychology students—learning the three-dimensional structure of the brain from a series of two-dimensional drawings. It is remarkable how much a neuroanatomical drawing can be clarified by color labelling its key structures.
- Third, I wanted to be able to lead each student through the section of the text on color vision by illustrating the key phenomena under investigation.

### Generating an Appreciation for the Scientific Method

Woven through the fabric of many chapters are important messages about the scientific method. The following are four recurring themes: (1) The scientific method is a method of answering questions that is as applicable to daily life as it is to the biopsychology laboratory. (2) The scientific method is fun—it is virtually the same method that detectives use to solve unwitnessed crimes or that treasure hunters use to infer the location of sunken galleons. (3) Widely accepted scientific theories are current best guesses rather than statements of absolute fact. (4) Even theories that ultimately prove to be wrong can contribute greatly to the progress of science.

### Making Biopsychology Personal

One sure way to interest students in biopsychology and to improve their level of performance is to

relate what they are learning to their own lives. Several chapters in *Biopsychology*—particularly those on eating, sleeping, sex, and drug abuse—carry strong personal messages. Many of the food-for-thought questions at the end of each chapter are designed to encourage students to consider the implications of biopsychological research for life in the real world. Some of these questions are excellent topics for classroom discussion.

### How to Use the Text

An important feature of *Biopsychology* from a course-design perspective is that each chapter is written so that it is as independent as possible from other chapters. When a technical term is encountered that has been explained earlier in the text, it is briefly redefined, and the reader is referred to the relevant previous chapter. Thus, it is quite feasible to omit certain chapters or to vary their sequence. Further flexibility in course design is provided by the appendices. These appendices summarize detailed information that is appropriate for some kinds of students and courses, but not for others. For example, there are appendices illustrating the projections of the cranial nerves, the location of each hypothalamic nucleus, and the hormonal correlates of the human female menstrual cycle. By putting these details in appendices, each instructor can decide whether to assign them or not. There is a table in the Instructor's Manual that suggests sample syllabi for courses with five different profiles.

### Ancillary Materials Available with Biopsychology

The ancillary materials available with *Biopsychology* differ from those available with comparable texts in several ways; the most obvious is that they have been prepared entirely by me, the author of the text. I understand why authors do not often choose to write the ancillary material for texts that they have just finished writing, but my commitment to teaching did not allow me to take this route. I believe that students and instructors deserve ancillary material that is written with the same tone, orientation, and care as the text.

### Study Guide

Each chapter of the study guide includes three sections. Section I is composed of the so-called “jeopardy study items”—named after the popular television quiz show. The jeopardy study items are arranged in two columns on the page with questions on the left and answers on the right. Some-

times there is nothing in the space to the right of a question and the student's task is to write in the correct answer (with reference to the text). Sometimes there is nothing in the space to the left of an answer and the student's task is to write in the correct question (again with reference to the text). When the jeopardy study items are completed, the student has a list of questions and answers that summarize all of the main points in the chapter, and they are conveniently arranged for bidirectional studying—students can study with one half of each page covered and then the other.

Section II of each study guide chapter is composed of essay study questions. Spaces are provided for the student to write outlines of the correct answers to each question (with reference to the text). These essay study questions encourage students to consider broader issues in their studying.

Section III of each study guide chapter is a practice examination, which is designed to be written after most, but not all, of the studying has been completed. It is recommended that students write the practice examination at least twenty-four hours before the scheduled time of their formal examination so that the results of the practice examination can be used to guide the last stages of their studying. The practice final examination is composed of multiple-choice questions, fill-in-the-blanks questions, short-answer questions, true-and-false questions, and diagram questions. The correct answers appear at the end of each study guide chapter.

### Test Bank

Provided to the instructor of each class using *Biopsychology* is an extensive multiple-choice test bank. From the student's perspective, one of the most important parts of any textbook is the test bank—the clarity, difficulty, and focus of the test bank have a substantial effect on the degree to which those students who have learned the material well will be rewarded for their efforts. My intention in preparing the multiple-choice test bank was to supply enough good test items—1327 by last count—of varied focus and difficulty that every instructor can tailor examinations to the specific needs of her or his class without having to invest a substantial amount of time in test construction.

### Instructor's Manual

The instructor's manual for *Biopsychology* provides the instructor with two things: a set of lecture notes that complement the text and a set of over-

head transparency masters to accompany each lecture. There are notes for two one-hour lectures to accompany each chapter of the text, and there are two or three overhead masters to go along with each lecture.

Each page of the instructor's manual is divided in two columns: a left column which covers two-thirds of the page, and a right column, which covers one-third. The lecture notes are printed in the left column and the right column is left blank for each instructor to make her or his own insertions.

I expect that the lecture notes in the instructor's manual will be used in three different ways. Some instructors might use them as sources for preparing their own lectures in a separate book; other instructors might add their own personal touches in the right-hand columns and lecture directly from the manual; and still others might find that they can lecture effectively directly from the manual notes with few additions—at least on those few occasions when they are caught short of preparation time.

### Acknowledgments

Many people have contributed to the successful completion of this book. Particularly instrumental in my decision to begin writing were Bill Barke, Philip Curson, Boris Gorzalka, Fred Regan, and Jerry Kraus. During the writing phase, many colleagues and students provided me with information and feedback, and put up with my predictable cycles of enthusiasm and despair as I neared the completion of one chapter and then became mired in middle of the next. These supporters include, in no particular order, Maggie Edwards, Rod Cooper, Michael Mana, Jon Druhan, Jim Pfaus, Tim Harpur, Scott Mendelson, Boris Gorzalka, Tess O'Brien, Eric Eich, Bob Hare, Don Wilkie, Janet Werker, Jack Kelly, Cathy Rankin, Dave Mumby, Wolfgang Linden, Tony Phillips, Roy Wise, Steve Woods, Peter Graf, Dave Albert, Kwon Kim, Christine Beck, Emma Wood, Mel Goodale, Craig Jones, Harvey Weingarten, Henry Koopmans, Ralph Mistlberger, Steve Petersen, Beverley Charlish, Dennis Paul, Jim Blackburn, Robert Bolles, Geoff Carr, Jill Becker, and Stanley Coren. Although I have never met them, the following instructors deserve special thanks for reviewing early drafts of the manuscript and exposing its weaknesses to me. Being able to see my efforts through their critical eyes, led to significant improvements in all of the chapters.

John F. Axelson  
College of the Holy Cross

Neil Rowland  
University of Florida

Anthony R. Caggiula  
*University of Pittsburgh*  
Sally Haralson  
*California State University  
at Long Beach*  
Charles Kutscher  
*Syracuse University*  
Joan B. Lauer  
*Purdue University at  
Indianapolis*  
George V. Rebec  
*Indiana University*

Virginia F. Saunders  
*San Francisco State  
University*  
Cheryl Sisk  
*Michigan State University*  
Paul J. Wellman  
*Texas A & M University*  
Jeffrey Wilson  
*Indiana University–Purdue  
University at Fort Wayne*  
Thomas B. Wishart  
*University of Saskatchewan*

The amount of graphic, typographic, and clerical work that went into the preparation of this book was prodigious. Six people carried this burden for me, and thus allowed me to focus on writing. Michael Mana, Lucille Hoover, and Christine Beck located and photocopied all of the cited articles, plus many more—a stack over seven feet tall. Christine Beck prepared the reference list, and she

helped prepare the glossaries at the end of each chapter. Maggie Edwards produced first versions of many dozens of original drawings and graphs, and she also obtained permission for me to reprint those obtained from other sources. Liz McCrick transformed my scrawl into typed copy, which she had to revise again and again and again (sorry Liz).

I would like to express my gratitude to the members of the Allyn and Bacon publishing team for their exceptional efforts in bringing this project to fruition. I am in awe of their ability to transform my typed pages into the striking volume that you have in front of you. My thanks go to Bill Barke, Diane McOscar, Alicia Reilly, Laura Frankenthaler, Judy Hauck, Elaine Ober, Anne Marie Fleming, Deborah Schneck, and Kathy Smith who were largely responsible for the editing, design, and production of this book.

Finally, I would like to thank you, the reader. It is you, and only you, who make my efforts and the efforts of all those acknowledged above worthwhile.

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# To the Student

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In the 1960s, I was, in the parlance of the times, “turned on” by an undergraduate course in biopsychology. I could not imagine anything more interesting than a field of science dedicated to studying the relation between psychological functioning and the brain. This initial fascination has been nourished by twenty-five years as a student, teacher, and researcher of biopsychology. *Biopsychology* is my effort to share this fascination with you.

I have tried to make *Biopsychology* a different kind of textbook, a textbook that includes clear, concise, well-organized explanations of the key points but is still interesting to read—a book from which you might suggest a suitable chapter to an interested friend or relative. To accomplish this goal, I thought a bit about what kind of textbook I would have liked when I was a student, and I de-

cided immediately to avoid the stern formality and ponderousness of conventional textbook writing. What I wanted was a more relaxed and personal style. To accomplish this, I imagined that you and I were chatting as I wrote and that I was telling you—usually over a glass of something—about the interesting things that go on in the field of biopsychology. Imagining these chats kept my writing from drifting back into conventional “textbookese,” and it never let me forget who I was writing this book for. I hope that *Biopsychology* teaches you much, and I hope that reading it manages to generate for you the same personal feeling that writing it did for me. If you are so inclined, please write; I welcome your comments and suggestions. You can write to me at the Department of Psychology, University of British Columbia, Vancouver, B.C., Canada V6T 1Y7.



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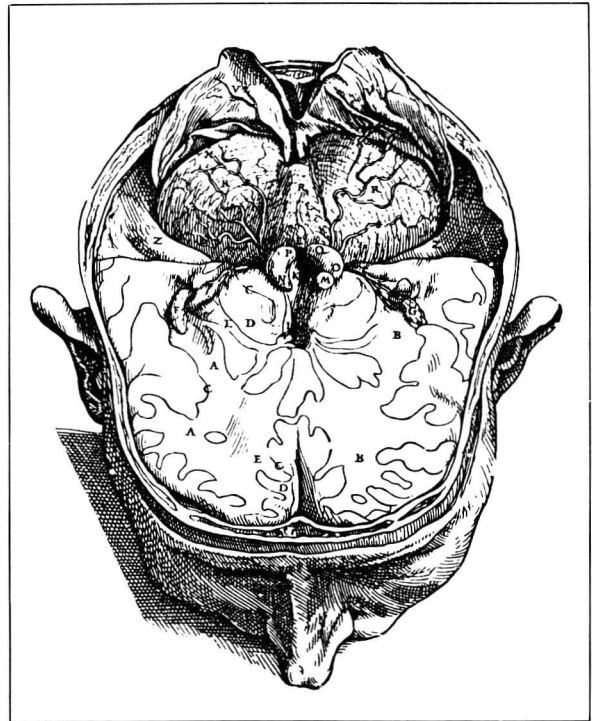
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## Biopsychology as a Neuroscience

The appearance of the human brain is far from impressive (see Figure 1.1). It is a squishy, wrinkled, walnut-shaped hunk of tissue weighing little more than 1.5 kilograms—about 3 pounds. It looks like something that you might find washed up on a beach rather than like one of the wonders of the world—which it surely is. Despite its unprepossessing external appearance, the human brain is a wonderfully complex cellular network comprising an estimated 100 billion highly specialized cells called **neurons**, which receive and transmit complex electrochemical signals. Contemplate for a moment the complexity of the brain's neural circuits. Consider the 100 billion neurons in complex array, each receiving direct input from dozens of neurons and passing on its output to dozens more; consider the estimated 100 trillion connections between them; and consider the infinite number of paths that a neural signal could follow through this morass.

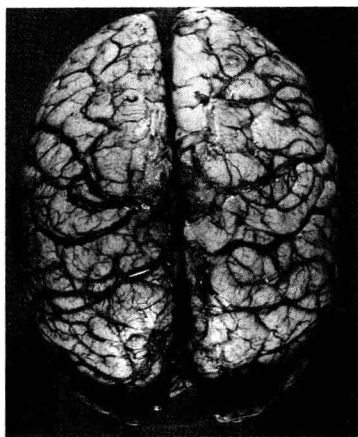
Although the complexity of the human brain is truly amazing, it would be even more amazing if the human brain were not so complex. It is inconceivable that an organ capable of creating a Mona Lisa, an artificial heart, and a supersonic aircraft; of traveling to the moon and to the depths of the sea; and of experiencing the wonder of an alpine sunset, a newborn infant, and a reverse slam dunk would itself not be complex. Paradoxically, **neuroscience** (the study of the nervous system) may prove to be the brain's



ultimate challenge: Does the brain have the capacity to understand something as complex as itself?

There is only one way for scientists to study something as complex as the brain. It is to study it bit by bit, from this perspective and that in the hope that it may eventually be possible to combine specific pieces of information into





**FIGURE 1.1** A human brain viewed from above.  
(Courtesy of Kenneth Berry, Head, Neuropathology,  
Vancouver General Hospital.)

a broader understanding. For example, some neuroscientists study the physiological basis of memory by analyzing the transmission of neural signals between two particular neurons in the abdominal ganglion of the *Aplysia*, a large marine mollusk; others study it by assessing the memory deficits of human patients with brain damage; and still others study it by assessing effects of drugs on the ability of rats to remember mazes. Although it is unlikely that any single research approach will ever reveal how memories are stored in the brain, there is reason for optimism if you consider that neuroscien-

tists are currently studying the neural basis of memory in hundreds of different ways. It is out of the convergence of different approaches that important answers are likely to come.

Given the diversity of neuroscientific research, it is safe to say that no two neuroscientists take exactly the same approach to their subject matter. It is possible, however, to group approaches with certain features in common into various neuroscientific subdisciplines. As its title indicates, this book is about one such subdiscipline: biopsychology. The primary purpose of this first chapter is to introduce you to biopsychology. To accomplish this, it deals with the following six questions:

- 1.1 What Is Biopsychology?**
- 1.2 What Is the Relation Between Biopsychology and the Other Disciplines of Neuroscience?**
- 1.3 What Types of Research Characterize the Biopsychological Approach?**
- 1.4 What Are the Four Divisions of Biopsychology?**
- 1.5 How Do Biopsychologists Use Observational Methods to Study the Unobservable?**
- 1.6 What Is Bad Science, and How Do You Spot It?**

## **1.1 What Is Biopsychology?**

**Biopsychology** is the branch of neuroscience concerned with how the brain and the rest of the nervous system (including the endocrine system) control behavior. Of course, one could, as some have done, refer to this field as “psychobiology” or “behavioral biology” or “behavioral neuroscience,” but I prefer the term *biopsychology* because it puts the emphasis on psychology (behavior), which is the emphasis that distinguishes biopsychology from the other subdisciplines of neuroscience. “Biopsychology” denotes a biological approach to the study of psychology; the alternatives denote a psychological approach to the study of biology. Psychology commands center stage in this text. Psychology can be defined as the study of behavior, if the term *behavior* is used in its broadest sense to refer to all overt activities of the organism as well as the psychological processes that are presumed to underlie them (e.g., learning, memory, motivation, perception, and emotion).