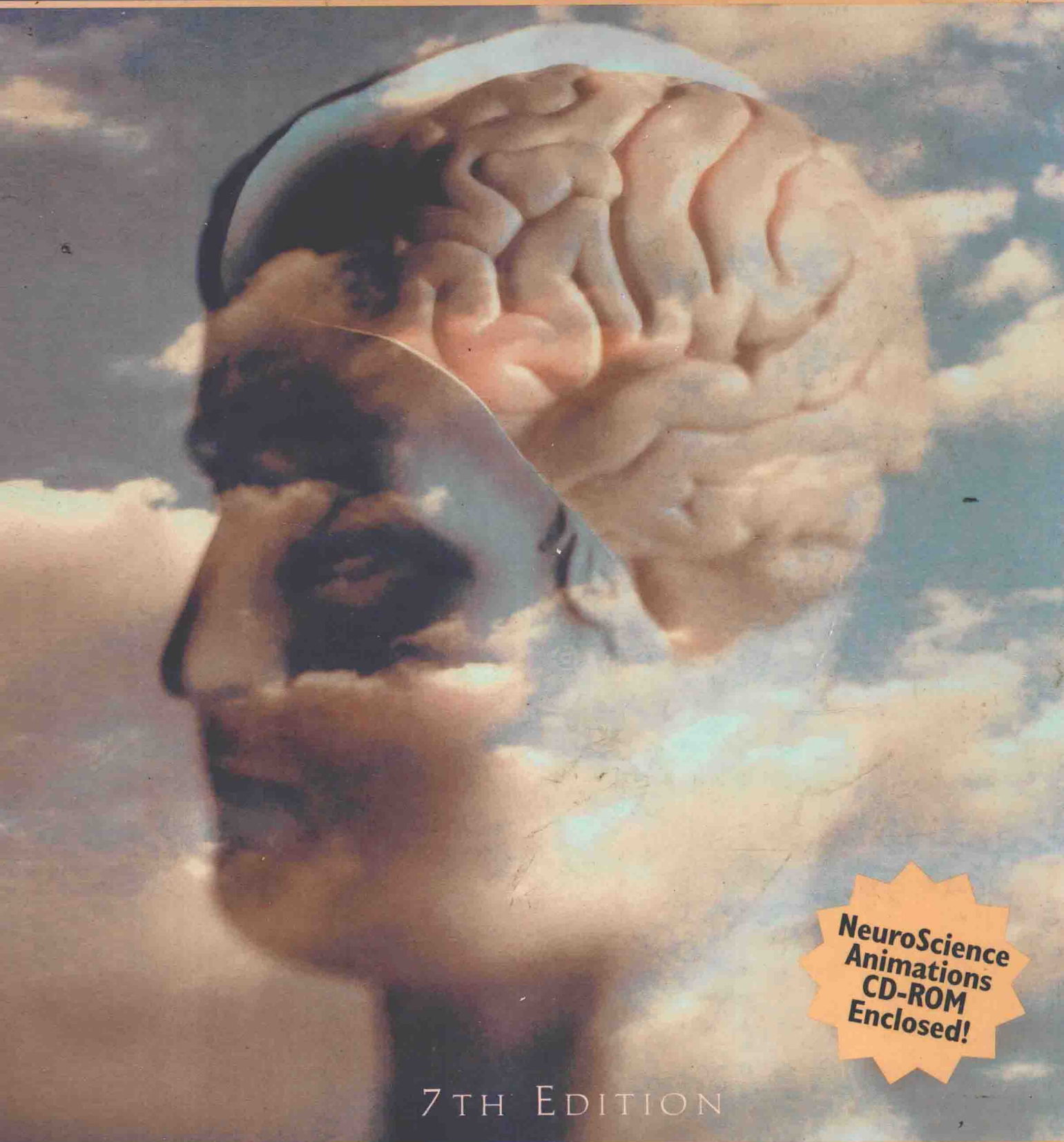


# PHYSIOLOGY OF BEHAVIOR



**NeuroScience  
Animations  
CD-ROM  
Enclosed!**

7TH EDITION

# NEIL R. CARLSON

SEVENTH EDITION

# Physiology of Behavior

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# Preface

I wrote the first edition of *Physiology of Behavior* about a quarter of a century ago. The interesting work coming out of my colleagues' laboratories—a result of their creativity and hard work—has given me something new to say with each edition. Because there was so much for me to learn, I enjoyed writing this edition just as much as the first one. That is what makes writing new editions interesting—learning something new and then trying to find a way to convey the information to the reader.

In the preface to each of the previous editions, I mentioned some of the new research methods that had recently been developed. Investigators are continuing to develop new methods—for example, new staining techniques for specific substances, new imaging methods, new recording methods, and the means for analyzing the release of neurotransmitters and neuromodulators in restricted regions of the brains of freely moving animals. The research reported in this edition reflects the enormous advances made in research methods: targeted mutations against an enormous variety of genes, insertion of genes that put fluorescent dyes on protein products, single-photon scanning laser microscopy that permits observation of biochemical and structural changes in living neurons—and the list continues. Nowadays, as soon as a new method is developed in one laboratory, it is adopted by other laboratories and applied to a wide range of problems. And more and more, researchers are combining techniques that converge upon the solution to a problem. In the past, individuals tended to apply their particular research method to a problem; now they are more likely to use many methods, sometimes in collaboration with other laboratories.

You will notice that the art in this book continues to evolve. Jay Alexander and I have worked together to redraw much of the anatomical art. Jay, an artist who also works as a technician in the Psychology Department at the University of Massachusetts, supplied the artistic talent. I think the result of our collaboration is a set of clear, consistent, and attractive illustrations.

The first part of the book is concerned with foundations: the history of the field, the structure and functions of neurons, neuroanatomy, psychopharmacology, and re-

search methods. The second part is concerned with inputs and outputs: the sensory systems and the motor system. The third part deals with classes of species-typical behavior: sleep, reproduction, emotional behavior, and ingestion. The chapter on reproductive behavior includes maternal behavior as well as mating. The chapter on emotion includes a discussion of emotional reactions, communication of emotions, feelings of emotions, and aggression. Ingestive behavior is covered in two chapters—one on drinking and one on eating.

The fourth part of the book deals with learning. The first learning chapter discusses research on synaptic plasticity and the neural mechanisms that are responsible for perceptual learning and stimulus-response learning (including classical and operant conditioning). The second learning chapter discusses human amnesia and the role of the hippocampal formation in relational learning. The final part of the book deals with verbal communication and mental and behavioral disorders. The latter topic is now covered in three chapters; the first discusses schizophrenia and the affective disorders; the second discusses the anxiety disorders, autism, and stress; and the third discusses drug abuse.

The following list includes some of the information that is new to this edition:

- An expanded discussion of the evolution of our species.
- A new section on evolution of the human brain.
- A discussion of new research on neural circuits involved in facial recognition.
- Discovery of mirror neurons in primate cortex and their possible role in the evolution of language.
- Discovery of a region of visual association cortex that detects optic flow.
- Discovery of new nociceptors.
- Discovery of ligands for human odor receptors.
- Discussion of the potential use of transplantation of glomus cells from the carotid body to treat Parkinson's disease.
- Discovery of the role of histamine in sleep and arousal.

- Discovery of the cause of canine narcolepsy: the gene for the orexin receptor.
- Discovery of a new photoreceptor responsible for synchronization of circadian rhythms.
- New research on the role of leptin in reproduction.
- Discovery of pheromone binding protein in the vomeronasal organ.
- Discussion of the role of the prefrontal cortex in emotion and decision making.
- Role of the basal ganglia in disgust.
- New research on alcohol, serotonin, and aggression.
- Discovery that peptides are critically involved in hunger and satiety:  $\alpha$  MSH, orexin, CART, and MCH.
- Synergy between CCK and leptin.
- Role of uncoupling proteins in obesity.
- New research on biochemical and structural changes during long-term potentiation.
- An expanded discussion of the role of the prefrontal cortex in working memory.
- Recent functional imaging studies on the anatomy of memory.
- Role of the limbic cortex of the medial temporal lobe in stimulus-stimulus associations.
- More functional imaging studies on the anatomy of language.
- The PCP hypothesis of schizophrenia.
- Recent research on schizophrenia as a degenerative disorder.
- Discovery of the antidepressant effect of a drug that blocks substance-P receptors.
- New research on thalidomide and autism.

Besides updating my discussion of research, I have updated my writing. Writing is a difficult, time-consuming endeavor, and I find that I am still learning how to do it well. I have said this in the preface of every edition of this book, and it is still true. I have worked with copyeditors who have ruthlessly marked up my manuscript, showing me how to do it better the next time. I keep thinking, "This time there will be nothing for the copyeditor to do," but I am always proved wrong: Each page contains notes showing me how to improve my prose. But I do think that each time the writing is better organized, smoother, and more coherent.

Good writing means including all steps of a logical discourse. My teaching experience has taught me that an entire lecture can be wasted if the students do not understand

all of the "obvious" conclusions of a particular experiment before the next one is described. Unfortunately, puzzled students sometimes write notes feverishly, in an attempt to get the facts down so they can study them—and understand them—later. A roomful of busy, attentive students tends to reinforce the lecturer's behavior. I am sure all my colleagues have been dismayed by a question from a student that reveals a lack of understanding of details long since passed, accompanied by quizzical looks from other students that confirm that they have the same question. Painful experiences such as these have taught me to examine the logical steps between the discussion of one experiment and the next and to make sure they are explicitly stated. A textbook writer must address the students who will read the book, not simply colleagues who are already acquainted with much of what he or she will say.

Because research on the physiology of behavior is an interdisciplinary effort, a textbook must provide the student with the background necessary for understanding a variety of approaches. I have been careful to provide enough biological background early in the book that students without a background in physiology can understand what is said later, while students with such a background can benefit from details that are familiar to them.

I designed this text for serious students who are willing to work. In return for their effort, I have endeavored to provide a solid foundation for further study. Those students who will not take subsequent courses in this or related fields should receive the satisfaction of a much better understanding of their own behavior. Also, they will have a greater appreciation for the forthcoming advances in medical practices related to disorders that affect a person's perception, mood, or behavior. I hope that students who read this book carefully will henceforth perceive human behavior in a new light.

## Supplements for Students

I have prepared a revised CD-ROM, containing the *Neuroscience Animations* and the *Computerized Study Guide*. The animations demonstrate some of the most important principles of neuroscience through movement and interaction. They include modules on neurophysiology (*Neural Communication*, *The Action Potential*, *Synapses*, *Postsynaptic Potentials*, and *Psychopharmacology*), neuroanatomy, psychopharmacology, audition, memory and verbal communications. The disk also includes the *Neuroanatomy Primer*, which contains several modules designed to help you learn about the structure and functions of the nervous system. The interactive *Computerized Study Guide* contains a set of *Self Tests* that include multiple-choice questions and an



online review of terms and definitions. The questions and list of terms and definitions present questions and keep track of your progress, presenting missed items until you have answered all of them correctly. The computerized study guide also includes *Interactive Illustrations* from the book that will help you learn terms and concepts. This CD-ROM is included *free* with the purchase of a new book.

A *Study Guide*, which my wife and I wrote, is also available. This workbook provides a framework for guiding study behavior. It promotes a thorough understanding of the principles of physiological psychology through active participation in the learning process. The study guide contains a set of *Concept Cards*. An important part of learning about physiological psychology is acquiring a new vocabulary, and the concept cards will help with this task. Terms are printed on one side of these cards, and definitions are printed on the other.

The publisher of this book, Allyn & Bacon, hosts a companion Web site for this text: [www.abacon.com/carlsonpob](http://www.abacon.com/carlsonpob). This site contains additional multiple-choice test questions for you, organized by chapter. This forum allows you to further practice exam taking. The Web site also provides hot links to other relevant sites of interest and research updates, provided by Paul Wellman, Professor of Psychology at Texas A&M.

## Supplements for Instructors

Several supplements are available for instructors who adopt *Physiology of Behavior*. An *Instructor's Manual* was written by Paul Wellman. This manual contains material intended to enhance class discussion and to provide assistance and advice in using the media supplements that accompany the text. It contains chapter-by-chapter changes in the seventh edition and will closely reference the corresponding PowerPoint presentation.

Paul Wellman has prepared a set of *PowerPoint Presentations* specifically for the seventh edition of the book. Available on CD-ROM, the presentations contain 15–20 text slides per chapter that provide a framework for lecture outlines and include selected images from the book.

Professor Wellman has also prepared a *Test Bank*. The test bank, available in print and also in Windows and Macintosh formats, contains a minimum of 80 multiple-choice questions per chapter.

The Digital Image Archive, version 2.0, will be available to adopters of this book. Containing 256 full-color images, this CD-ROM will allow you to use the best of the art from the book in classroom demonstrations.

A new video from the Films for the Humanities & Sciences called *Biological Psychology* is also available to

adopters of the text. This 80-minute video covers topics such as the transmission of genetic information, neuroanatomy, the visual system, and dreaming. Please contact your local Allyn & Bacon sales representative for this and any other of the supplements for instructors.

## Acknowledgments

Although I must accept the blame for any shortcomings of the book, I want to thank the many colleagues who helped me by responding to my requests for reprints of their work, suggesting topics that I should cover, sending photographs that have been reproduced in this book, and pointing out deficiencies in the previous edition. I particularly want to thank Edna Cohen of the Hebrew University of Jerusalem, who, while translating the sixth edition of this book into Hebrew, found errors and unclear statements that I have tried not to repeat in this edition.

Before I began work on the book, my publisher sent a questionnaire to colleagues who were familiar with the previous edition. Their responses to this questionnaire helped me to decide what changes to make in the revision. I thank:

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aging the book's production. She got everything done on time, despite an extremely tight schedule. Few people realize what a difficult, demanding, and time-consuming job a production editor has with a project such as this, with hundreds of illustrations and an author who tends to procrastinate, but I do, and I thank her for all she has done. Barbara Willette served as copyeditor. Her attention to detail surprised me again and again; she found inconsistencies in my terminology, awkwardness in my prose, and disjunctions in my logical discourse and gave me a chance to fix them before anyone else saw them in print.

I must also thank my wife Mary for her support. Writing is a lonely pursuit, because one must be alone with one's thoughts for many hours of the day. I thank her for giving me the time to read, reflect, and write without feeling that I was neglecting her too much. I also thank her for the superb job she did preparing the study guide.

I was delighted to hear from many students and colleagues who read previous editions of my book, and I hope that the dialogue will continue. Please write to me and tell me what you like and dislike about the book. My address is Department of Psychology, Tobin Hall, University of Massachusetts, Amherst, Massachusetts 01003. My e-mail is [nrc@psych.umass.edu](mailto:nrc@psych.umass.edu). When I write, I like to imagine that I am talking with you, the reader. If you write to me, we can make the conversation a two-way exchange.

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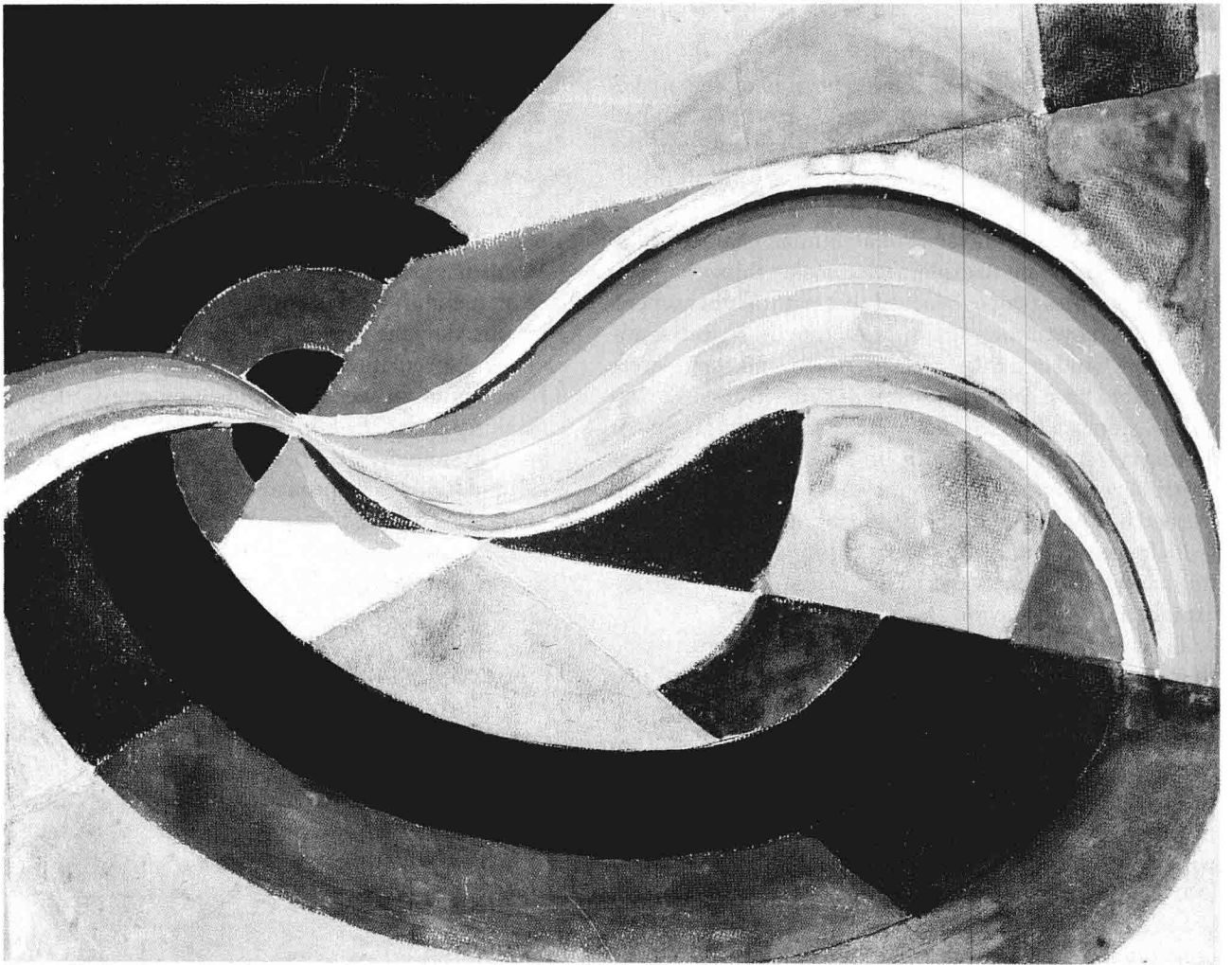
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# Introduction



*Helice* by Robert Delaunay.

### Understanding Human Consciousness: A Physiological Approach

Blindsight

Split Brains

Interim Summary

### The Nature of Physiological Psychology

The Goals of Research

Biological Roots of Physiological  
Psychology

Interim Summary

### Natural Selection and Evolution

Functionalism and the Inheritance of Traits

Evolution of the Human Species

Evolution of Large Brains

Interim Summary

### Ethical Issues in Research with Animals

### Careers in Neuroscience

Interim Summary

### Strategies for Learning

The last frontier in this world—and perhaps the greatest one—lies within us. The human nervous system makes possible all that we can do, all that we can know, and all that we can experience. Its complexity is immense, and the task of studying it and understanding it dwarfs all previous explorations our species has undertaken.

One of the most universal of all human characteristics is curiosity. We want to explain what makes things happen. In ancient times people believed that natural phenomena were caused by animating spirits. All moving objects—animals, the wind and tides, the sun, moon, and stars—were assumed to have spirits that caused them to move. For example, stones fell when they were dropped because their animating spirits wanted to be reunited with Mother Earth. As our ancestors became more sophisticated and learned more about nature, they abandoned this approach (which we call *animism*) in favor of physical explanations for inanimate moving objects. But they still used spirits to explain human behavior.

From the earliest historical times, people have believed they possessed something intangible that animated them—a mind, or a soul, or a spirit. This belief stems from the fact that each of us is aware of his or her own existence. When we think or act, we feel as though something inside us is thinking or deciding to act. But what is the nature of the human mind? We have physical bodies, with muscles that move it and sensory organs such as eyes and ears that perceive information about the world around us. Within our bodies the nervous system plays a central role, receiving information from the sensory organs and controlling the movements of the muscles. But what role does the mind play? Does it *control* the nervous system? Is it a *part of* the nervous system? Is it physical and tangible, like the rest of the body, or is it a spirit that will always remain hidden?

This puzzle has historically been called the *mind-body question*. Philosophers have been trying to answer it for many centuries, and more recently scientists have taken up the task. Basically, people have followed two different approaches: dualism and monism. **Dualism** is a belief in the dual nature of reality. Mind and body are separate; the body is made of ordinary matter, but the mind is not. **Monism** is a belief that everything in the universe consists of matter and energy and that the mind is a phenomenon produced by the workings of the nervous system.

Mere speculation about the nature of the mind is futile. If we could answer the mind-body question simply by thinking about it, philosophers would have done so long ago. Physiological psychologists take an empirical, practical, and monistic approach to the study of human nature. Most of us believe that once we understand the workings of the human body—and, in particular, the workings of the nervous system—the mind-body problem will have been solved. We will be able to explain how we perceive, how we think, how we remember, and how we act. We will even be able to explain the nature of our own self-awareness. Of course, we are far from understanding the workings of the nervous system, so only time will tell whether this belief is justified. In any event there is no way to study nonphysical phenomena in the laboratory. All that we can detect with our sense organs and our laboratory instruments are manifestations of the physical world: matter and energy.

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**dualism** The belief that the body is physical but the mind (or soul) is not.

**monism** (*mahn ism*) The belief that the world consists only of matter and energy and the mind is part of it.

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