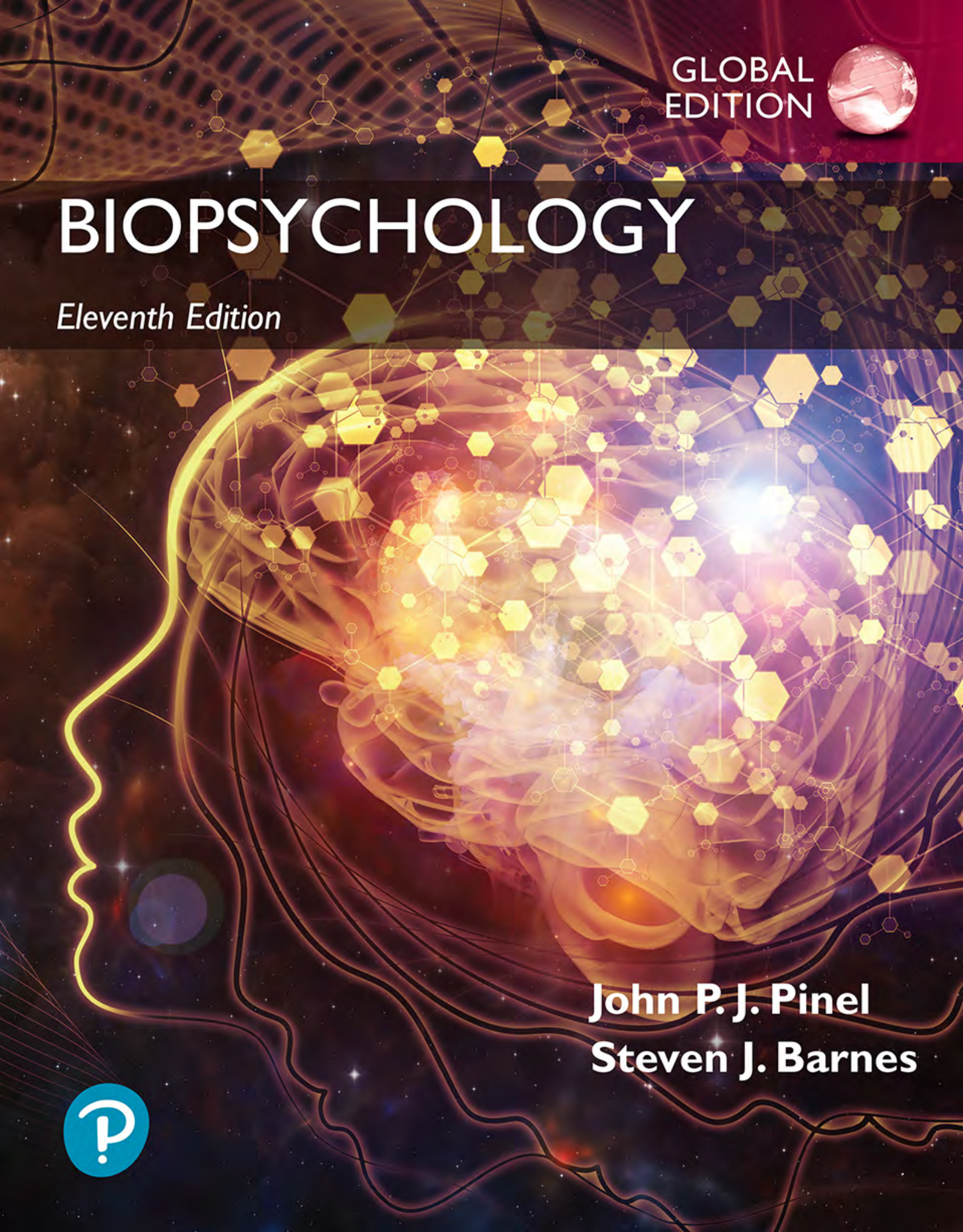
GLOBAL EDITION

BIOPSYCHOLOGY

Eleventh Edition



John P. J. Pinel
Steven J. Barnes

Biopsychology

ELEVENTH EDITION

GLOBAL EDITION

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University of British Columbia

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Brief Contents

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Preface

Welcome to the Eleventh Edition of *Biopsychology*! The Eleventh Edition of *Biopsychology* is a clear, engaging introduction to current biopsychological theory and research. It is intended for use as a primary course material in one- or two-semester courses in Biopsychology—variously titled Biopsychology, Physiological Psychology, Brain and Behavior, Psychobiology, Behavioral Neuroscience, or Behavioral Neurobiology.

The defining feature of *Biopsychology* is its unique combination of biopsychological science and personal, reader-oriented discourse. Instead of presenting the concepts of biopsychology in the usual fashion, the chapters address students directly and interweave the fundamentals of the field with clinical case studies, social issues, personal implications, useful metaphors, and memorable anecdotes.

Key Features in the Eleventh Edition

The following are features that have characterized recent editions of *Biopsychology* and have been maintained or expanded in this edition.

EMPHASIS ON BROAD THEMES The emphasis of *Biopsychology* is "the big picture." Four broad themes are present throughout the chapters and a Themes Revisited section at the end of each chapter briefly summarizes how each theme was developed in that chapter. The four major themes provide excellent topics for essay assignments and exam questions.

EFFECTIVE USE OF CASE STUDIES *Biopsychology* features many carefully selected case studies, which are highlighted in the chapters. These provocative cases stimulate interest, promote retention of the materials, and allow students to learn how biopsychological principles apply to the diagnosis and treatment of brain disorders.

REMARKABLE ILLUSTRATIONS The illustrations in *Biopsychology* are special. Each one was conceptualized and meticulously designed to clarify and reinforce the chapter content by uniquely qualified scientists. John Pinel and his artist/designer wife, Maggie Edwards, created many of the original illustrations from previous editions.

FOCUS ON BEHAVIOR In some biopsychological courseware, the coverage of neurophysiology, neurochemistry, and neuroanatomy subverts the coverage of behavioral research. *Biopsychology* gives top billing to behavior: It stresses that neuroscience is a team effort and that the unique contribution made by biopsychologists to this effort is their behavioral expertise.

EMPHASIS ON THE SCIENTIFIC METHOD *Biopsychology* emphasizes the scientific method. It portrays the scientific method as a means of answering questions that is as applicable in daily life as in the laboratory. And *Biopsychology* emphasizes that being a scientist is fun.

DISCUSSION OF PERSONAL AND SOCIAL IMPLICATIONS Several chapters of *Biopsychology*—-particularly those on eating, sleeping, sex, and drug addiction—carry strong personal and social messages. In these chapters, students are encouraged to consider the relevance of biopsychological research to their lives outside the classroom.

ENGAGING, INSPIRING VOICES Arguably the strongest pedagogical feature of *Biopsychology* is its personal tone. In the previous edition, Barnes and Pinel had addressed students directly and talked to them with warmth, enthusiasm, and good humor about recent advances in biopsychological science. This edition has not changed in this respect.

NEW! EMERGING THEMES For this edition, Barnes and Pinel have identified and highlighted two "emerging themes" throughout the chapters: Themes that they feel are quickly emerging from the biopsychology literature. The Themes Revisited section at the end of each chapter briefly summarizes how each emerging theme was developed in that chapter. The two emerging themes provide excellent topics for essay assignments and exam questions.

New, Expanded, or Updated Coverage in the Eleventh Edition

Biopsychology remains one of the most rapidly progressing scientific fields. Like previous editions, the Eleventh Edition of *Biopsychology* has meticulously incorporated recent developments in the field—it contains more than 950 citations of articles or books that did not appear in the preceding edition. These recent developments have dictated changes to many parts of the chapters. The following list presents some of the content changes to this edition, organized by chapter.

CHAPTER 1: BIOPSYCHOLOGY AS A NEUROSCIENCE

- Introduction of emerging themes appearing in the chapters
- Five new citations

CHAPTER 2: EVOLUTION, GENETICS, AND EXPERIENCE

- Updated schematic illustration of how biopsychologists think about the biology of behavior
- Updated coverage and new key terms related to the topic of gene expression
- Expanded coverage of the topic of transgenerational epigenetics
- Simplified coverage of the evolution of humankind
- Three new key terms: *activators*, *repressors*, *hominins*
- Twenty new citations

CHAPTER 3: ANATOMY OF THE NERVOUS SYSTEM

- Updated and expanded coverage of the functions of glial cells
- Updated anatomical description of the basal ganglia
- Sixteen new citations

CHAPTER 4: NEURAL CONDUCTION AND SYNAPTIC TRANSMISSION

- Improved explanation and coverage of the action potential
- Coverage of the mechanical transmission of membrane potentials
- Two new key terms: *graded potentials*, *voltage-gated ion channels*
- Sixteen new citations

CHAPTER 5: THE RESEARCH METHODS OF BIOPSYCHOLOGY

- Expanded coverage of magnetic-field-based brain-imaging techniques
- Improved explanations of how MRI and fMRI work
- New section on ultrasound-based imaging techniques, such as functional ultrasound imaging
- Introduction of two new transcranial stimulation techniques: transcranial electrical stimulation and transcranial ultrasound stimulation
- Expanded coverage of magnetoencephalography
- Updated coverage of intracellular unit recording
- Expanded and comprehensive coverage of genetic methods, including coverage of gene-editing techniques like the CRISPR/Cas9 method
- Updated coverage on the various ways that fluorescent proteins are used in research
- New case study: The case of the vegetative patient
- New section on the study of functional connectivity
- Nine new key terms: *functional ultrasound imaging*, *transcranial electrical stimulation*, *transcranial ultrasound stimulation*, *gene knockin techniques*, *gene editing techniques*, *CRISPR/Cas9 method*, *resting-state fMRI*, *functional connectivity*, *functional connectome*
- Forty-two new citations

CHAPTER 6: THE VISUAL SYSTEM

- Updated and expanded coverage of modern research on visual system receptive fields
- Updated and expanded coverage of how the concept of a visual system receptive field is changing
- Updated coverage of research on the ventral and dorsal visual streams
- Updated and expanded coverage of the brain pathology associated with prosopagnosia
- One new key term: *occipital face area*
- Thirty-two new citations

CHAPTER 7: SENSORY SYSTEMS, PERCEPTION, AND ATTENTION

- New chapter title
- New chapter introduction, including coverage of some interesting exteroceptive senses only found in particular nonhuman species.
- Updated coverage of the subcortical auditory pathways
- Updated coverage of the organization and functions of the primary auditory cortex
- Updated coverage of the effects of auditory cortex damage
- Introduction of the thermal grid illusion—including a new figure
- Updated coverage of neuropathic pain
- Updated coverage of taste receptors
- Updated coverage of primary gustatory cortex organization
- New module on Perception
- Three new Check It Out features related to perception
- Updated coverage of the neural mechanisms of attention
- Twelve new key terms: *sensation*, *perception*, *periodotopy*, *thermal grid illusion*, *percept*, *perceptual decision making*, *bistable figures*, *phantom percepts*, *Charles Bonnet syndrome*, *binding problem*, *attentional gaze*, *frontal eye field*
- Sixty-one new citations

CHAPTER 8: THE SENSORIMOTOR SYSTEM

- Updated coverage of the primary motor cortex
- Updated coverage of the role of the cerebellum in sensorimotor function
- Updated and expanded coverage of the role of the basal ganglia in sensorimotor function
- More concise coverage of the descending motor pathways
- Updated coverage of the neuroplasticity associated with sensorimotor learning
- New key term: *movement vigor*
- Thirty-seven new citations

CHAPTER 9: DEVELOPMENT OF THE NERVOUS SYSTEM

- Updated coverage of the case of Genie
- Extensive updates to the coverage of stem cells and neurodevelopment
- New figure on the role of glia in neurodevelopment
- Updated coverage of the mechanisms of migration and aggregation of neurons
- Updated coverage of the chemoaffinity hypothesis
- Updated coverage of synapse formation
- Extensive updates to the module on early cerebral development in humans
- New case study written by a self-advocate with autism spectrum disorder
- New case study about the autistic savant Stephen Wiltshire, known by some as the "human camera"
- Coverage of the role of transcription-related errors in individuals with ASD
- Updated coverage of face processing in autism spectrum disorder
- Updated coverage of Williams syndrome, including coverage of face processing differences
- Four new key terms: *subventricular zone*, *radial glial cells*, *radial-glia-mediated migration*, *prenatal period*
- Eighty-three new citations

CHAPTER 10: BRAIN DAMAGE AND NEUROPLASTICITY

- Updated coverage of the mechanisms of ischemic stroke
- New section on traumatic brain injuries
- Coverage of mild traumatic brain injuries
- Updated coverage of chronic traumatic encephalopathy
- Updated discussion of causal factors in epilepsy
- Updated naming of the different types of seizures based on the new diagnostic criteria from the International League Against Epilepsy
- Extensive updates to the section on Parkinson's disease
- Updated and expanded coverage of Huntington's disease
- Updated and expanded coverage of multiple sclerosis
- Extensive updates to the section on Alzheimer's disease—including a new figure
- Five new key terms: *traumatic brain injury (TBI)*, *closed-head TBI*, *subdural hematoma*, *mild TBI*, *alpha-synuclein*
- One hundred and forty-one new citations

CHAPTER 11: LEARNING, MEMORY, AND AMNESIA

- Updated coverage of H.M.
- Updated coverage of the amnesia of Korsakoff's syndrome
- New module: Amnesia after Traumatic Brain Injury: Evidence for Consolidation
- Updated coverage of the role of the hippocampus in consolidation
- Updated and improved coverage of the roles of grid cells
- Updated coverage of the relationship between place cells and grid cells
- New section: The hippocampus as a cognitive map
- Updated coverage of engram cells
- Coverage of the role of hippocampal-prefrontal connections in episodic memory
- Improved and updated coverage of long-term potentiation
- New section on nonsynaptic mechanisms of learning and memory
- Forty-eight new citations

CHAPTER 12: HUNGER, EATING, AND HEALTH

- New section: Evolution of Research on the Role of Hypothalamic Nuclei in Hunger and Satiety
- Updated and extended discussion of the role of hypothalamic circuits and gut peptides in hunger and eating
- Updated discussion of why some people gain weight, whereas others do not
- Updated coverage of leptin, insulin, and the arcuate melanocortin system
- Updated coverage of treatments for overeating
- New key term: *gut microbiome*
- Thirty new citations

CHAPTER 13: HORMONES AND SEX

- New module: Sexual development of brain and behavior
- Updated coverage of the aromatization hypothesis
- Extended and updated discussion of modern perspectives on sex differences in the brain
- Updated coverage of the role of gonadal hormones in female sexual behavior
- Extensive update to the module on sexual orientation and gender identity
- Four new key terms: *lesbian*, *transgender*, *gender identity*, *gender dysphoria*
- Forty-eight new citations

CHAPTER 14: SLEEP, DREAMING, AND CIRCADIAN RHYTHMS

- New module on dreaming
- Three new case studies directly related to the topic of dreaming
- Updated coverage of theories of dreaming
- Updated coverage of recuperation theories of sleep
- Updated coverage of the effects of sleep deprivation in humans
- Updated coverage of interventions for jet lag
- Updated coverage of the effect of shorter sleep times on health
- Two new figures
- One new key term: *lucid dreaming*
- One hundred and twenty-seven new citations

CHAPTER 15: DRUG USE, DRUG ADDICTION, AND THE BRAIN'S REWARD CIRCUITS

- Improved explanation of the relationship between drug withdrawal effects and conditioned compensatory responses
- Extensive update to coverage of nicotine
- Updated coverage of Korsakoff's syndrome
- Extensive update to coverage of marijuana
- Updated coverage of the history of cannabis use
- New discussion of the transgenerational epigenetic effects of drug taking
- Discussion of the current epidemic of opioid abuse
- Three new key terms: *smoking*, *vaping*, *drug craving*
- Eighty new citations

CHAPTER 16: LATERALIZATION, LANGUAGE, AND THE SPLIT BRAIN

- Updated coverage of sex differences in brain lateralization
- Updated coverage of anatomical asymmetries in the brain
- Updated coverage of the evolution of cerebral lateralization
- Updated coverage of the question of when cerebral lateralization evolved
- Twenty-seven new citations

CHAPTER 17: BIOPSYCHOLOGY OF EMOTION, STRESS, AND HEALTH

- Updated coverage of the facial feedback hypothesis
- Updated discussion of whether or not facial expressions are universal
- Thirty-two new citations

CHAPTER 18: BIOPSYCHOLOGY OF PSYCHIATRIC DISORDERS

- Major rewrite of this chapter
- Expanded coverage of all psychiatric disorders profiled in the chapter
- Coverage of the role of genetic, epigenetic, and neural factors for each psychiatric disorder
- Expanded and updated coverage of the discussion of the relative effectiveness of antidepressant medications
- Expanded coverage of theories of bipolar disorder
- Updated coverage of drug therapies for anxiety disorders
- Updated coverage of drug therapies for Tourette's disorder
- One hundred and seven new citations

Pedagogical Learning Aids

Biopsychology has several features expressly designed to help students learn and remember the material:

- **Scan Your Brain** study exercises appear within chapters at key transition points, where students can benefit most from pausing to consolidate material before continuing.
- **Check It Out** demonstrations apply biopsychological phenomena and concepts for students to experience themselves.
- **Themes Revisited** section at the end of each chapter summarizes the ways in which the book's four major themes, and its two emerging themes, relate to that chapter's subject matter.

- **Key Terms** appear in **boldface**, and other important terms of lesser significance appear in *italics*.
- **Appendixes** serve as convenient sources of additional information for students who want to expand their knowledge of selected biopsychology topics.

Ancillary Materials Available with *Biopsychology*

FOR INSTRUCTORS Pearson Education is pleased to offer the following supplements to qualified adopters.

***Test Bank* (9781292352008)** The test bank for the Eleventh Edition of *Biopsychology* comprises more than 2,000 multiple-choice questions, including questions about accompanying brain images. Each item has answer justification, learning objective correlation, difficulty rating, and skill type designation, so that instructors can easily select appropriate questions for their tests.

***Instructor's Manual* (9781292351988)** The instructor's manual contains helpful teaching tools, including at-a-glance grids, activities and demonstrations for the classroom, handouts, lecture notes, chapter outlines, and other valuable course organization material for new and experienced instructors.

***Video Embedded PowerPoint Slides* (9781292401973)** These slides, available in the Instructor's Resource Center, bring highlights of this edition of *Biopsychology* right into the classroom, drawing students into the lecture and providing engaging visuals, and include links to the videos referenced in each chapter.

***Standard Lecture PowerPoint Slides* (9781292351995)** These accessible slides have a more traditional format, with excerpts of the chapter material and artwork, and are available online at www.pearsonglobaleditions.com.

Acknowledgments

Seven people deserve special credit for helping us create this edition of *Biopsychology*: Maggie Edwards, Linnea Ritland, Chandra Jade, Olivia Sorley, Natasha Au, Zamina Mithani, and Kim Nipp. Maggie is an artist/designer/writer/personal trainer who is John's partner in life. She is responsible for the original designs of most of the illustrations that appear in the chapters. Linnea, Chandra, Olivia, Natasha, Zamina, and Kim are six remarkable alumni of the University of British Columbia; Linnea helped with the drawing, editing, and voiceovers for the Chalk It Up Animations; Chandra helped with the editing of some of the Chalk It Up Animations; Olivia helped with the drawing of some of the Chalk It Up Animations; Natasha and Zamina helped with collecting articles as part of the research that went into this edition; and Kim co-designed the cover of the text with Barnes.

Pearson Education did a remarkable job of producing the original *Biopsychology*. They shared the dream of a solution that meets the highest standards of pedagogy but is also personal, attractive, and enjoyable. Now they have stepped up to support the conversion of *Biopsychology* to electronic format. Special thanks also go to Kelli Strieby, Matthew Summers, and Lisa Mafrici at Pearson; Marita Bley for her development, editing, and coordination; and Annemarie Franklin at SPi Global for coordinating the production—an excruciatingly difficult and often thankless job.

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To the Student

We have tried to make *Biopsychology* different with content that includes clear, concise, and well-organized explanations of the key points but is still interesting to read—material from which you might suggest suitable sections to an interested friend or relative. To accomplish this goal, we thought about what kind of materials we would have liked when we were students, and we decided to avoid the stern formality and ponderous style of conventional science writing and to focus on ideas of relevance to your personal life.

We want *Biopsychology* to have a relaxed and personal style. In order to accomplish this, we imagined that we were chatting with you as we wrote and that we were telling you—usually over a glass of something—about the interesting things that go on in the field of biopsychology. Imagining these chats kept our writing from drifting back into conventional "textbookese," and it never let us forget that we were writing these materials for you.

As we write these words, we have finished work on this new edition, and now we are waiting with great excitement for *Biopsychology* to be released. There is more excitement around this edition than there has been since the first edition appeared in 1990—this time the excitement is about the release of *Biopsychology* in an online-only format and all the opportunities that it creates for effective teaching. We really hope that you will find this new format easy to use, interesting, and, most importantly, an effective learning tool.

We hope that *Biopsychology* teaches you much of relevance to your personal life and that reading it generates in you the same positive feelings that writing it did in us.

About the Authors

JOHN PINEL obtained his Ph.D. from McGill University in Montreal and worked briefly at the Massachusetts Institute of Technology before taking a faculty position at the University of British Columbia in Vancouver, where he is currently Professor Emeritus. Professor Pinel is an award-winning teacher and the author of more than 200 scientific papers. However, he feels that *Biopsychology* is his major career-related accomplishment: "It ties together everything I love about my job: students, teaching, writing, and research."

STEVEN BARNES obtained his Ph.D. from the University of British Columbia. He then worked as a postdoctoral fellow—first in the Department of Epileptology at the University of Bonn and then in the School of Interactive Arts and Technology at Simon Fraser University. He is currently an Associate Professor of Teaching, and Associate Head of Undergraduate Affairs, in the Department of Psychology at the University of British Columbia.

Steven is well-regarded for his work related to online learning technologies (e.g., the Tapestry Project; see tapestry-tool.com), student mental health and wellbeing, and bipolar disorder (BD). Steven co-directs the Collaborative RESearch Team to study psychosocial issues in BD (CREST.BD, see crestbd.ca), a BD research and knowledge exchange network, which received the 2018 Canadian Institutes for Health Research Gold Leaf Prize for Patient Engagement, Canada's most prestigious recognition for patient engagement in research across all health disciplines.

Steven is the recipient of multiple institutional awards for his teaching, including the prestigious Killam Teaching Prize and the 3M National Teaching Fellowship—the top national award given for teaching in any discipline in any postsecondary institution in Canada.

When he isn't teaching, writing, or doing research, he engages in the production of traditional pieces of visual art as well as interactive electronic artworks—some of which have been exhibited at prominent international venues. He sees his involvement in the creation of this new edition of *Biopsychology* as a complement to everything he loves to do: teaching, writing, visual and interactive art, and research.

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Chapter 1

Biopsychology as a Neuroscience

What Is Biopsychology, Anyway?

Image Source/Alamy Stock Photo

Chapter Overview and Learning Objectives

What Is Biopsychology?	**LO 1.1**	Define and discuss what is meant by *biopsychology*.
	LO 1.2	Discuss the origins of the field of biopsychology.
	LO 1.3	List the six fields of neuroscience that are particularly relevant to biopsychological inquiry.
What Types of Research Characterize the Biopsychological Approach?	**LO 1.4**	Compare the advantages and disadvantages of humans and nonhumans as subjects in biopsychological research.
	LO 1.5	Compare experiments, quasiexperimental studies, and case studies, emphasizing their utility in the study of causal effects.
	LO 1.6	Compare pure and applied research.
What Are the Divisions of Biopsychology?	**LO 1.7**	Describe the division of biopsychology known as physiological psychology.

LO 1.8 Describe the division of biopsychology known as psychopharmacology.

LO 1.9 Describe the division of biopsychology known as neuropsychology.

LO 1.10 Describe the division of biopsychology known as psychophysiology.

LO 1.11 Describe the division of biopsychology known as cognitive neuroscience.

LO 1.12 Describe the division of biopsychology known as comparative psychology.

How Do Biopsychologists Conduct Their Work?

LO 1.13 Explain how converging operations has contributed to the study of Korsakoff's syndrome.

LO 1.14 Explain scientific inference with reference to research on eye movements and the visual perception of motion.

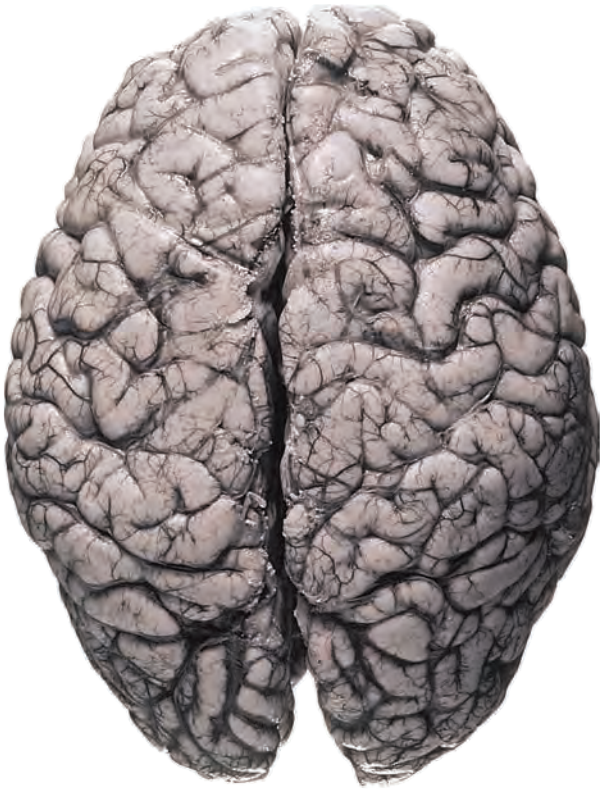
Thinking Critically about Biopsychological Claims

LO 1.15 Define critical thinking and evaluate biopsychological claims.

The appearance of the human brain is far from impressive (see Figure 1.1). The human brain is a squishy, wrinkled, walnut-shaped hunk of tissue weighing about 1.3 kilograms. It looks more like something you might find washed up on a beach than one of the wonders of the world—which it surely is. Despite its disagreeable appearance, the human brain is an amazingly intricate network of **neurons** (cells that receive and transmit electrochemical signals) and many other cell types. Contemplate for a moment the complexity of your own brain's neural circuits. Consider the 90 billion neurons in complex array (Walløe, Pakkenberg & Fabricius, 2014), the estimated 100 trillion connections among them, and the almost infinite number of paths that neural signals can follow through this morass (Zimmer, 2011). The complexity of the human brain is hardly surprising, considering what it can do. An organ capable of creating a *Mona Lisa*, an artificial limb, and a supersonic aircraft; of traveling to the moon and to the depths of the sea; and of experiencing the wonders of an alpine sunset, a newborn infant, and a reverse slam dunk *must* be complex. Paradoxically, **neuroscience** (the scientific 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 (see Gazzaniga, 2010)?

Neuroscience comprises several related disciplines. The primary purpose of this chapter is to introduce you to one of them: biopsychology. Each of this chapter's five modules characterizes the neuroscience of biopsychology in a different way. However, before you proceed to the body of this chapter, we would like to tell you about the case of Jimmie G. (Sacks, 1985), which will give you a taste of the interesting things that lie ahead.

Figure 1.1 The human brain: Appearances can be deceiving!



UHB Trust/The Image Bank/Getty Images

The Case of Jimmie G., the Man Frozen in Time

Jimmie G. was a friendly 49-year-old. He liked to chat about his school days and his time in the navy, both of which he could describe in remarkable detail. Jimmie was an intelligent man with superior abilities in math and science. So why was he a patient in a neurological ward?

When Jimmie talked about his past, there were hints of his problem. When he talked about his school days, he used the past tense; but when he recounted his early experiences in the navy, he switched to the present tense. More worrisome was that he never talked about anything that happened to him after his time in the navy.

Jimmie was tested by eminent neurologist Oliver Sacks, and a few simple questions revealed a curious fact: Jimmie believed he was 19. When asked to describe what he saw in a mirror, Jimmie became so frantic and confused that Dr. Sacks immediately took the mirror out of the room.

Returning a few minutes later, Dr. Sacks was greeted by a once-again cheerful Jimmie, who acted as if he had never seen Sacks before. Indeed, even when Sacks suggested they had met recently, Jimmie was certain they had not.

Then Dr. Sacks asked where Jimmie thought he was. Jimmie replied that all the beds and patients made him think that the place was a hospital. But he couldn't understand why he would be in a hospital. He was afraid that he might have been admitted because he was sick but didn't know it.

Further testing confirmed what Dr. Sacks feared. Although Jimmie had good sensory, motor, and cognitive abilities, he had one terrible problem: He forgot everything that was said or shown to him within a few seconds. Basically, Jimmie could not remember anything that had happened to him since his early 20s, and he was not going to remember anything that happened to him for the rest of his life. Dr. Sacks was stunned by the implications of Jimmie's condition.

Jimmie's situation was heart-wrenching. Unable to form new lasting memories, he was, in effect, a man frozen in time, a man without a recent past and no prospects for a future, stuck in a continuous present, lacking any context or meaning.

Remember Jimmie G.; you will encounter him again later in this chapter.

Four Major Themes of This Text

You will learn many new facts in this text—new findings, concepts, terms, and the like. But more importantly, many years from now, long after you have forgotten most of those facts, you will still be carrying with you productive new ways of thinking. We have selected four of these for special emphasis: Thinking Creatively, Clinical Implications, the Evolutionary Perspective, and Neuroplasticity.

THINKING CREATIVELY ABOUT BIOPSYCHOLOGY. We are all fed a steady diet of biopsychological information, misinformation, and opinion—by television, newspapers, the Internet, friends, relatives, teachers, and so on. As a result, you likely already hold strong views about many of the topics you will encounter in this text. Because these preconceptions are shared by many biopsychological researchers, they have often impeded scientific progress, and some of the most important advances in biopsychological science have been made by researchers who have managed to overcome the restrictive effects of conventional thinking and have taken creative new approaches. Indeed, **thinking creatively** (thinking in productive, unconventional ways) is the cornerstone of any science. In this text, we describe research that involves thinking "outside the box," we try to be creative in our analysis of the research we are presenting, or we encourage you to base your thinking on the evidence rather than on widely accepted views.

CLINICAL IMPLICATIONS. Clinical (pertaining to illness or treatment) considerations are woven through the fabric of biopsychology. There are two aspects to the clinical implications theme: (1) much of what biopsychologists learn about the functioning of a healthy brain comes from studying dysfunctional brains; and (2) many of the discoveries of biopsychologists have relevance for the treatment of brain dysfunction. One of our major focuses is on the interplay between brain dysfunction and biopsychological research.

THE EVOLUTIONARY PERSPECTIVE. Although the events that led to the evolution of the human species can never be determined with certainty, thinking of the environmental pressures that likely led to the evolution of our brains and behavior often leads to important biopsychological insights. This approach is called the **evolutionary perspective**. An important component of the evolutionary perspective is the comparative approach (trying to understand biological phenomena by comparing them in different species). Throughout this text, you will find that we humans have learned much about ourselves by studying species that are related to us through evolution. Indeed, the evolutionary approach has proven to be one of the cornerstones of modern biopsychological inquiry.

NEUROPLASTICITY. Until the early 1990s, most neuroscientists thought of the brain as a three-dimensional array of neural elements "wired" together in a massive network of circuits. The complexity of this "wiring diagram" of the brain was staggering, but it failed to capture one of the brain's most important features. In the past four decades, research has clearly demonstrated that the adult brain is not a static network of neurons: It is a plastic (changeable) organ

that continuously grows and changes in response to an individual's environment and experiences. The discovery of **neuroplasticity** is arguably the single most influential discovery in modern neuroscience. As you will learn, it is a major component of many areas of biopsychological research.

You have probably heard of neuroplasticity. It is a hot topic in the popular media, where it is upheld as a panacea: A means of improving brain function or recovering from brain dysfunction. However, contrary to popular belief, the plasticity of the human brain is not always beneficial. For example, it also contributes to various forms of brain dysfunction (e.g., Tomaszcyk et al., 2014). Later on, you will see examples of both the positive and the negative sides of neuroplasticity.

Emerging Themes of This Text

As you read through this text you will start to see other themes in addition to the ones we outlined for you in the previous section. Many of them you will spot on your own. Here we highlight two "emerging" themes: themes that could become major themes in future editions of this text.

THINKING ABOUT EPIGENETICS. Most people believe their genes (see Chapter 2) control the characteristics they are born with, the person they become, and the qualities of their children and grandchildren. In this text, you will learn that genes are only a small part of what determines who you are. Instead, you are the product of ongoing interactions between your genes and your experiences—such interactions are at the core of a field of study known as **epigenetics**. But epigenetics isn't just about you: We now know that the experiences you have during your lifetime can be passed on to future generations. This is a fundamentally different way of thinking about who we are and how we are tied to both our ancestors and descendants. Epigenetics is currently having a major influence on biopsychological research.

CONSCIOUSNESS. As you will see, this text also examines different aspects of **consciousness** (the perception or awareness of some aspect of one's self or the world) from a biopsychological perspective. Indeed, one major goal of biopsychological research is to establish a better understanding of the neural correlates of consciousness (see Ward, 2013; Blackmore, 2018). To give you a taste of this emerging theme, you will soon appreciate that (1) we are not consciously aware of much of the information we receive from our environments, (2) there are many different states of consciousness, and (3) there can be dramatic alterations in consciousness as a result of brain dysfunction.

What Is Biopsychology?

This module introduces you to the discipline of biopsychology. We begin by exploring the definition and origins of biopsychology. Next, we examine how biopsychology is related to the various other disciplines of neuroscience.

Defining Biopsychology

LO 1.1 **Define and discuss what is meant by *biopsychology*.**

Biopsychology is the scientific study of the biology of behavior (see Dewsbury, 1991). Some refer to this field as *psychobiology*, *behavioral biology*, or *behavioral neuroscience*; but we prefer the term *biopsychology* because it denotes a biological approach to the study of psychology rather than a psychological approach to the study of biology: Psychology commands center stage in this text. *Psychology* is the scientific study of behavior—the scientific study of all overt activities of the organism as well as all the internal processes that are presumed to underlie them (e.g., learning, memory, motivation, perception, emotion).

What Are the Origins of Biopsychology?

LO 1.2 **Discuss the origins of the field of biopsychology.**

The study of the biology of behavior has a long history, but biopsychology did not develop into a major neuroscientific discipline until the 20th century. Although it is not possible to specify the exact date of biopsychology's birth, the publication of *The Organization of Behavior* in 1949 by Donald Hebb played a key role in its emergence (see Brown & Milner, 2003). In his book, Hebb developed the first comprehensive theory of how complex psychological phenomena, such as perceptions, emotions, thoughts, and memories, might be produced by brain activity. Hebb's theory did much to discredit the view that psychological functioning is too complex to have its roots in the physiology and chemistry of the brain. Hebb based his theory on experiments involving both human and nonhuman animals, on clinical case studies, and on logical arguments developed from his own insightful observations of daily life. This eclectic approach has become a hallmark of biopsychological inquiry.

In comparison to physics, chemistry, and biology, biopsychology is an infant—a healthy, rapidly growing infant, but an infant nonetheless. In this text, you will reap the benefits of biopsychology's youth. Because biopsychology does not have a long history, you will be able to move quickly to the excitement of modern research.

How Is Biopsychology Related to the Other Disciplines of Neuroscience?

LO 1.3 List the six fields of neuroscience that are particularly relevant to biopsychological inquiry.

Neuroscience is a team effort, and biopsychologists are important members of the team (see Albright, Kandel, & Posner, 2000; Kandel & Squire, 2000). Biopsychology can be further characterized by its relation to other neuroscientific disciplines.

Biopsychologists are neuroscientists who bring to their research a knowledge of behavior and of the methods of behavioral research. It is their behavioral orientation and expertise that make their contribution to neuroscience unique (see Cacioppo & Decety, 2009). You will be able to better appreciate the importance of this contribution if you consider that the ultimate purpose of the nervous system is to produce and control behavior (see Grillner & Dickinson, 2002). Think about it.

Biopsychology is an integrative discipline. Biopsychologists draw together knowledge from the other neuroscientific disciplines and apply it to the study of behavior. The following are a few of the disciplines of neuroscience that are particularly relevant to biopsychology:

- **Neuroanatomy**. The study of the structure of the nervous system (see Chapter 3).
- **Neurochemistry**. The study of the chemical bases of neural activity (see Chapters 4 and 15).
- **Neuroendocrinology**. The study of interactions between the nervous system and the endocrine system (see Chapters 13 and 17).
- **Neuropathology**. The study of nervous system dysfunction (see Chapters 10 and 18).
- **Neuropharmacology**. The study of the effects of drugs on neural activity (see Chapters 4, 15, and 18).
- **Neurophysiology**. The study of the functions and activities of the nervous system (see Chapter 4).

What Types of Research Characterize the Biopsychological Approach?

Biopsychology is broad and diverse. Biopsychologists study many different phenomena, and they approach their research in many different ways. This module discusses three major dimensions along which biopsychological research may vary: It can involve either human or nonhuman subjects, it can take the form of either formal experiments or nonexperimental studies, and it can be either pure or applied.

Human and Nonhuman Subjects

LO 1.4 Compare the advantages and disadvantages of humans and nonhumans as subjects in biopsychological research.

Both human and nonhuman animals are the subjects of biopsychological research. Of the nonhumans, mice and rats are the most common subjects; however, cats, dogs, and nonhuman primates are also commonly studied.

Humans have several advantages over other animals as experimental subjects of biopsychological research: They can follow instructions, they can report their subjective experiences, and their cages are easier to clean. Of course, we are joking about the cages, but the joke does serve to draw attention to one advantage humans have over other species of experimental subjects: Humans are often cheaper. Because only the highest standards of animal care are acceptable, the cost of maintaining an animal laboratory can be prohibitive for all but the most well-funded researchers.

Of course, the greatest advantage humans have as subjects in a field aimed at understanding the intricacies of human brain function is that they have human brains. In fact, you might wonder why biopsychologists would bother studying nonhuman subjects at all. The answer lies in the evolutionary continuity of the brain. The brains of humans are similar in fundamental ways to the brains of other mammals—they differ mainly in their overall size and the extent of their cortical development. In other words, the differences between the brains of humans and those of related species are more quantitative than qualitative, and thus many of the principles of human brain function can be clarified by the study of nonhumans (see Hofman, 2014; Katzner & Weigelt, 2013; Krubitzer & Stolzenberg, 2014).

One major difference between human and nonhuman subjects is that humans volunteer to be subjects. To emphasize this point, human subjects are more commonly referred to as *participants* or *volunteers*.

Nonhuman animals have three advantages over humans as subjects in biopsychological research. The first is that the brains and behavior of nonhuman subjects are simpler than those of human participants. Hence, the study of nonhuman species is often more likely to reveal fundamental brain–behavior interactions. The second advantage is that insights frequently arise from the **comparative approach**, the study of biological processes by comparing different species. For example, comparing the behavior of species that do not have a cerebral cortex with the behavior of species that do can provide valuable clues about cortical function. The third advantage is that it is possible to

conduct research on laboratory animals that, for ethical reasons, is not possible with human participants. This is not to say that the study of nonhuman animals is not governed by a strict code of ethics (see Blakemore et al., 2012)—it is. However, there are fewer ethical constraints on the study of laboratory species than on the study of humans.

In our experience, most biopsychologists display considerable concern for their subjects, whether they are of their own species or not; however, ethical issues are not left to the discretion of the individual researcher. All biopsychological research, whether it involves human participants or nonhuman subjects, is regulated by independent committees according to strict ethical guidelines: "Researchers cannot escape the logic that if the animals we observe are reasonable models of our own most intricate actions, then they must be respected as we would respect our own sensibilities" (Ulrich, 1991, p. 197).

If you are concerned about the ethics of biopsychological research on nonhuman animals, you aren't alone. Both of us wrestle with various aspects of it. For example, a recurring concern we both have is whether the potential benefits of a research study outweigh the stress induced in the nonhuman subjects.

When people are asked for their opinion on nonhuman animal research, most fall into one of two camps: (1) Those in support of animal research—if and only if both the suffering of animals is minimized and the potential benefits to humankind cannot be obtained by other methods, or (2) those that are opposed to animal research—because it causes undue stress that is not outweighed by the potential benefits to humankind.

Journal Prompt 1.1

What are your initial feelings about biopsychological research on nonhuman animals? If you are sympathetic to one of the two aforementioned camps, explain your reasoning.

Because biopsychological research using nonhuman subjects is controversial, it first has to be approved by a panel of individuals from a variety of backgrounds and with different world views. These *nonhuman animal ethics committees* are tasked with very difficult decisions. Accordingly, it is usually the case that these committees will ask the researchers proposing a particular study to provide additional information or further justification before they approve their research.

Nonhuman animal ethics committees emphasize consideration of the so-called "three R's": Reduction, Refinement, and Replacement. Reduction refers to efforts to reduce the numbers of animals used in research. Refinement refers to refining research studies or the way animals are cared for, so as to reduce suffering. Providing animals with better living conditions is one example of refinement. Finally, replacement refers to the replacing of studies using animal subjects with alternate techniques, such as experimenting on cell cultures or using computer models.

One of the earliest examples of replacement is the now ubiquitous crash-test dummy in the auto industry. Prior to the advent of the crash test dummy, live pigs were sometimes used as passengers in automobile crash tests. This example of replacement makes an important point about how notions of what is ethically acceptable in animal experimentation are in constant flux: Now that dummies are a viable alternative, nobody would be in favor of using pigs for crash tests. The recent development of complex computer models of nonhuman and human brains (see Frackowiak & Markram, 2015) might change the very nature of biopsychological research in your lifetime.

Experiments and Nonexperiments

LO 1.5 Compare experiments, quasiexperimental studies, and case studies, emphasizing their utility in the study of causal effects.

Biopsychological research involves both experiments and nonexperimental studies. Two common types of nonexperimental studies are quasiexperimental studies and case studies.

EXPERIMENTS. The experiment is the method used by scientists to study causation, that is, to find out what causes what. As such, it has been almost single-handedly responsible for the knowledge that is the basis for our modern way of life. It is paradoxical that a method capable of such complex feats is so simple. To conduct an experiment involving living subjects, the experimenter first designs two or more conditions under which the subjects will be tested. Usually, a different group of subjects is tested under each condition (**between-subjects design**), but sometimes it is possible to test the same group of subjects under each condition (**within-subjects design**). The experimenter assigns the subjects to conditions, administers the treatments, and measures the outcome in such a way that there is only one relevant difference between the conditions being compared. This difference between the conditions is called the **independent variable**. The variable measured by the experimenter to assess the effect of the independent variable is called the **dependent variable**. If the experiment is done correctly, any differences in the dependent variable between the conditions must have been caused by the independent variable.

Why is it critical that there be no differences between conditions other than the independent variable? The reason is that when there is more than one difference that could affect the dependent variable, it is difficult to determine whether it was the independent variable or the unintended difference—called a **confounded variable**—that led to the observed effects on the dependent variable. Although the experimental method is conceptually simple, eliminating all confounded